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HVAC pipes in wooden elements

CONCEPT, THERMAL LOSSES AND NOISE IN SMARTTES SOLUTIONS

SINTEF

SINTEF Research

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HVAC pipes in wooden elements

Concept, thermal losses and noise in SmartTES solutions

Preface

Results presented in this project report have been carried out within WP-1, Multifunctional TES of the project "*smartTES – Innovation in timber construction for the modernisation of the building envelope"*. See www.tesenergyfacade.com for more information about the main project.

Trondheim, 19th of March 2014

Anders Homb

SINTEF Building and Infrastructure

Abstract

The work presented in this report gives the contribution from SINTEF Building and Infrastructure concerning integration of HVAC pipes in SmartTES elements. The focus has been on evaluation of mounting possibilities and calculation of thermal losses, moisture conditions and noise.

Content

Introduction

The optimal performance of an air tight, energy efficient building requires controlled (mechanical) ventilation in order to avoid damages caused by humidity and to obtain good indoor climate. Modern air condition aggregates are equipped with efficient heat recovery units, thus supporting a low energy standard. The construction system of SmartTES Elements offers the space for the integration of technical devices and ducts for heating, ventilation and air conditioning. The scope of the task is to develop a SmartTES element with integrated HVAC devices by development of concept solutions and technical properties, for instance optimization of systems and/or development of solutions for the integration of ducts and technical devices into the building envelope.

The work presented in this report gives the contribution from SINTEF Building and Infrastructure in the SmartTES project concerning HVAC integration with focus on evaluation of mounting possibilities, calculation of thermal losses, moisture conditions and noise.

1.   Concepts

Installation of a HVAC system in an existing building may be solved in different ways. It will of course depend very much on the type of building and if one or more vertical shafts are available in the existing building. Due to natural decay, a great number of multiple dwelling units in Europe from the 1950's to 1980's have reached a point where renovation within the next decade is necessary. School buildings and residential buildings are building types with a huge need of modernization. For these buildings, small to medium vertical shafts normally exists, available for at least the outlet air of a modernized HVAC system. The SmartTES element offer space for installation of for instance the inlet air. Further evaluation and work presented in this report is based on a new HVAC system with inlet pipes in the SmartTES elements and outlet air in an existing shaft. An exception is the individual installation concept.

1.1   Individual installations

The individual installation concept is based on one installation per flat (residential building). A principal drawing of installations in three flats is presented in figure 1.1.

Fig. 1.1
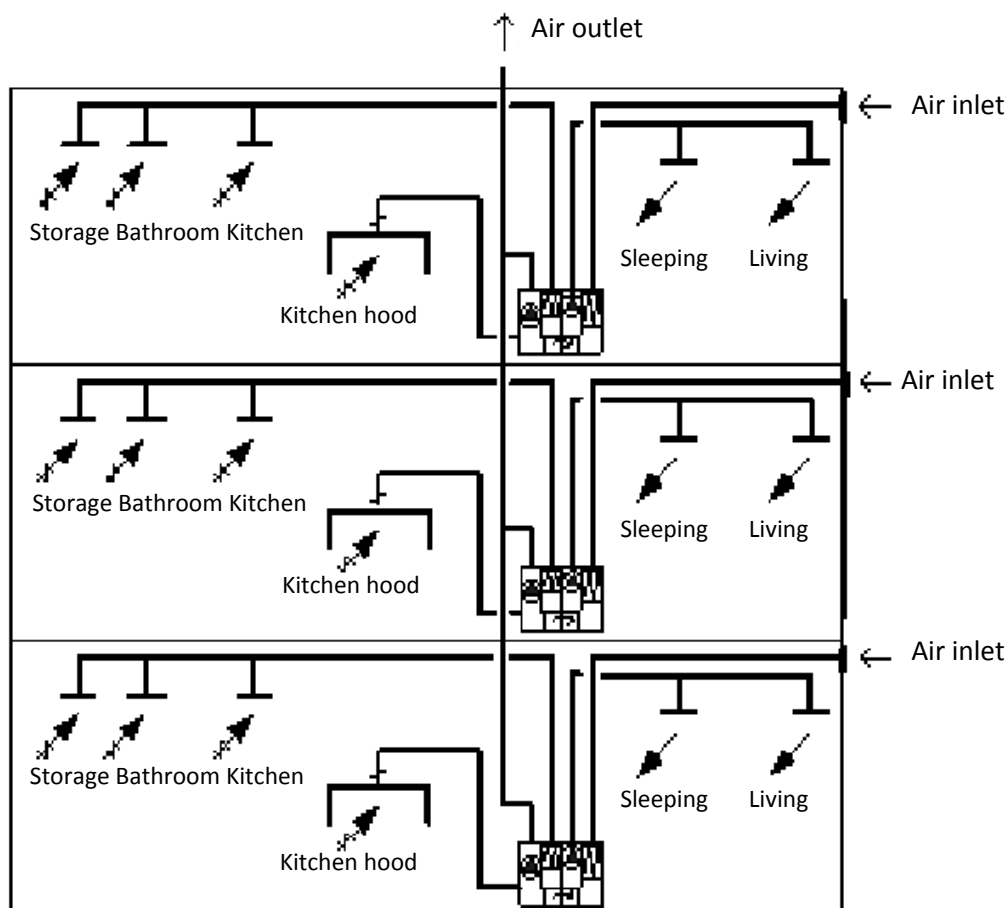Principal drawing of a concept with individual installation of HVAC units and pipes, see report Schild (2012)

In this case, an individual aggregate has to be positioned in the flat. It needs space itself and of course necessary possibilities of inlet and outlet pipes from that position. Anther disadvantage of this concept is that the local unit may give noise and vibration disturbances in the flat. But it is

possible to make a specification ahead of an order with respect to noise and vibration properties. In some cases it is also difficult to have space for an air inlet duct through the exterior wall. The SmartTES element can of course be used in such cases for a vertical air inlet or outlet. For other cases the SmartTES element will be free from prefabricated HVAC installations. Another possible disadvantage of this concept is the need for access to the unit for maintenance, and who will be responsible for the maintenance?

Individual installations also have advantages, for instance individual regulation of flow and temperature, and the air supply will not be affected by neighboring flats. Smaller shaft area is also an advantage compared with central unit systems. Most often it is possible to have an air inlet through the exterior wall. Energy efficient products are available, and it is possible to compare specifications of different products.

1.2 One installation per staircase

The concept with one installation per staircase is based on one central unit per vertical shaft, relevant for both school buildings and residential buildings. A principal drawing of an installation is presented in figure 1.2.
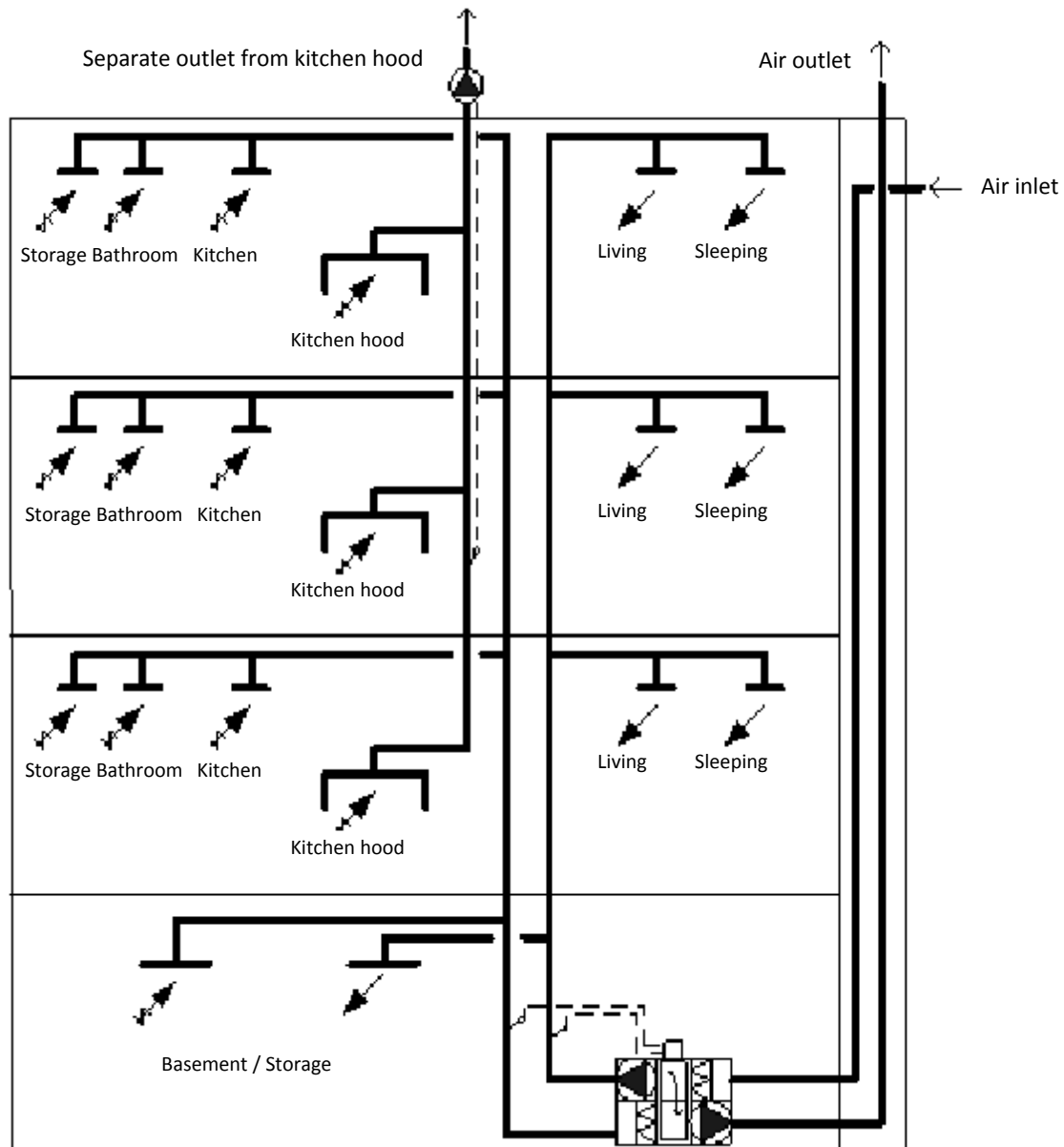
Fig. 1.2
Principal drawing of a concept with one installation per staircase or building, see Schild (2012)

In the figure, the central unit is positioned in the basement, but a position in the attic or on the roof is probably more common. The basement solution makes it possible to choose favorable positions for the inlet air, and it is often easy to get entrance to the system for maintenance. Another advantage of this concept is the possibility of common and more professional organizing of the maintenance. It is also possible to ventilate common areas with air extract to for instance garages. Energy efficient products are available, and it is possible to compare specifications of different products.

Disadvantages to this concept are the need for shaft for the pipes, and in some cases the need for space for the central units. If an existing shaft can be used for the outlet air, the SmartTES element offers sufficient space for the air inlet pipes. Noise disturbances in the flats from the main unit may be a problem in addition to possible noise transfer between the flats, i.e. inlet/outlet device connec-

ted to the common main pipe. See chapter 5 for more information and tools regarding these challenges. A common main pipe may also cause transfer of odor/smell between the flats. This concept also represents challenges regarding the necessity of central regulation of flow and temperature.

1.3   Central unit per building

The concept with one installation per block or building is based on several shafts coupled to one central unit. This solution is also relevant for many school buildings and residential buildings. A principal drawing of an installation will be equal to one installation per staircase, see therefore figure 1.2.

In the figure, the central unit is positioned in the basement, but a position at the attic or roof is probably more common. The advantages of this concept are much the same as the concept with one unit per vertical shaft, see chapter 1.2. But in this case it will be even fewer installations to maintain.

The disadvantages of this concept are also much the same as for the concept with one vertical unit per vertical shaft, see chapter 1.2. In addition, this solution will give more severe consequences for the ventilated areas in case of long time stop of the unit.

1.4   Example and evaluation

SINTEF Building and Infrastructure has contributed to several projects regarding upgrading of HVAC system in existing buildings, for example three projects with individual installations and two projects with common units for one building or one vertical shaft. But so far, the SmartTES element concept has not been used for installation of new pipes in Norway. Figure 1.3 shows a plan (one floor) of five flats in a building with outlet air pipes colored red.
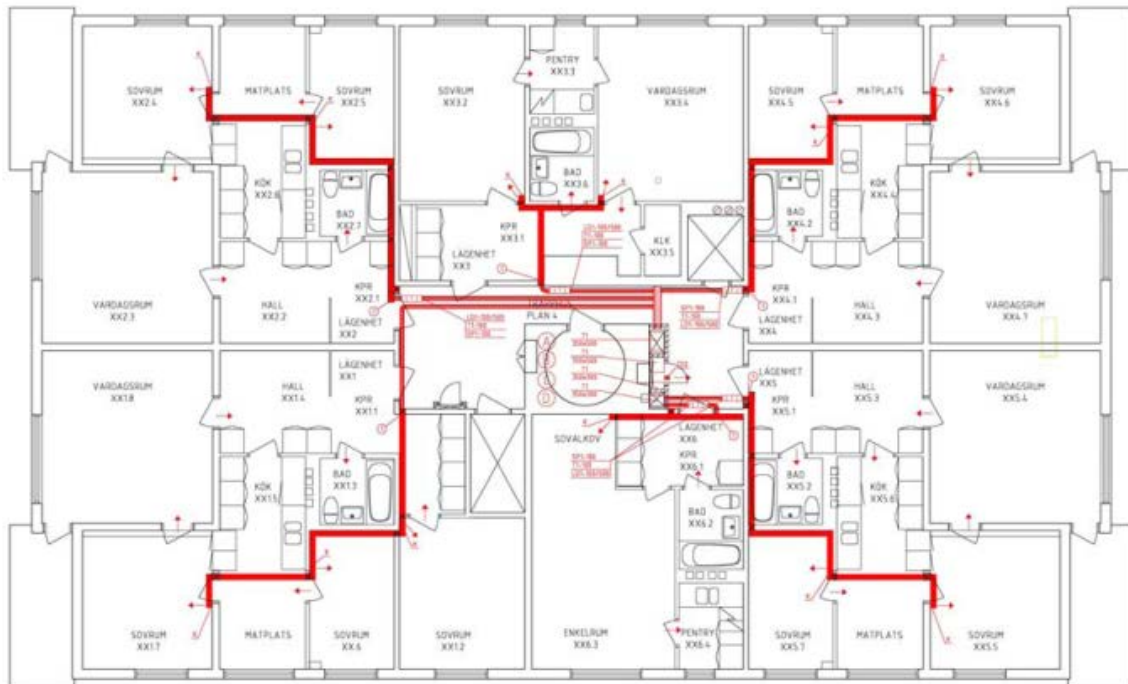

Fig. 1.3
Floor plan of five apartments. Upgrade of a building with one central unit and outlet pipes coloured red, see Schild (2012)

In table 1.1, we present an evaluation of the different concepts with respect to type of installation and some essential properties. This is a brief summary of analysis from the previous chapters.

Table 1.1
Evaluation of the presented concepts for HVAC upgrade of residential buildings and school buildings

Property	Individual installation	One unit per vertical shaft or per building
Air inlet position	Challenging	Preferable
Inlet transfer ducts	From SmartTES façade directly to flat	Inside new SmartTES Elements or through old garbage chute [2]
Duct positions in the flat/section	Challenging	Challenging
Air extract [1]	Use existing	Use existing
Kitchen air extract	Normally available	Recycling device or challenging
Noise	Focus on unit, position and duct damping	Focus on central unit and transmission between flats

1) Assuming that a shaft is available for the air outlet
2) Highly insulated ducts are necessary

A more thorough evaluation and choice of concept has to be done for each project because the final concept will depend on the available space and maintenance priorities.

2. Mounting of elements

Mounting of SmartTES elements on an existing building may be solved in different ways. For elements with HVAC ducts integrated, some additional issues have to be taken into account. There will always be a need for ducts in vertical direction from the unit in the basement or at the attic/roof. Depending on the organizing of the duct installations, horizontal ducts may also be put into the elements. In the planning process it is also possible to choose between vertical elements, horizontal elements or a combination of both. A number of alternatives are therefore possible, but in practice the alternatives are limited when we integrate HVAC ducts, see chapters 2.1 to 2.3.

2.1 Vertical elements with pipes

For upgrading of residential buildings, it is strongly recommended to have separate ducts from the main unit to each apartment. This makes it possible to have a vertical element containing ducts for all apartments above each other. It may be a one piece element if the number of floors is limited to three or four. An example of this is presented in figure 2.1. In this case it is necessary with horizontal distribution of the ducts inside the apartments. An advantage of this solution is a limited number of duct connections between the prefabricated element and the existing wall and only one hole in the existing wall for each floor. A possible solution is presented in chapter 2.4.
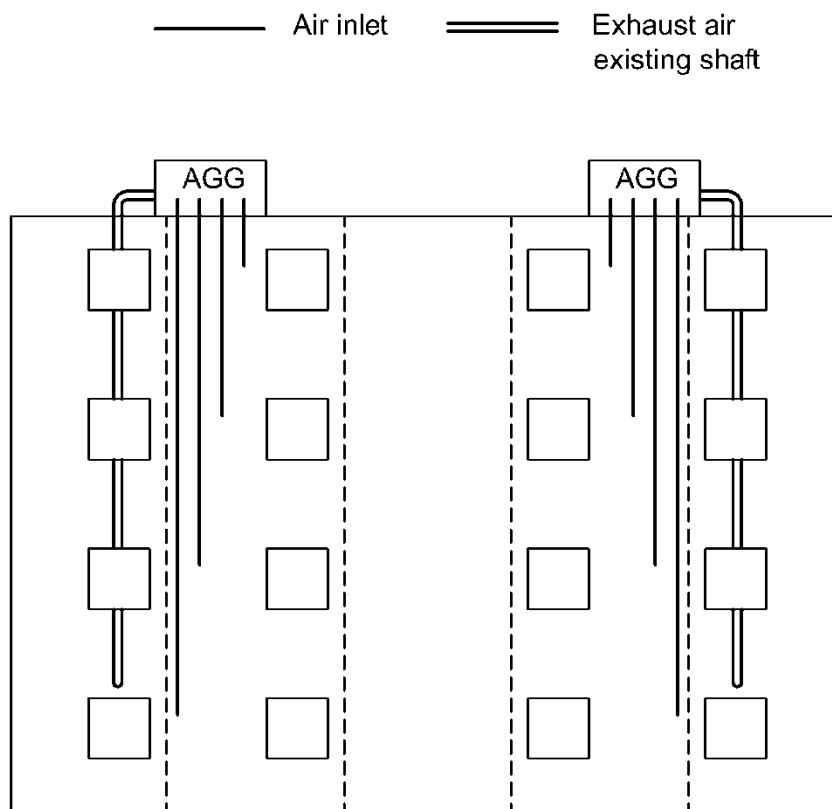

Fig. 2.1
Principal solution of vertical elements with HVAC air inlet ducts integrated in two of the five SmartTES elements

If the building is higher, it is probably necessary with more than one vertical element. An additional challenge to be solved then is the connection in the mounting phase between the duct from the lower and upper element.

Figure 2.2 shows a photo of an element in the production phase and a drawing of the cross-section with one duct. Airtightness between the backside of the element and the pipe is important and we also recommend a counterhold between the pipe bend and the exterior part of the element. Figure 2.3 shows a photo of an element with ducts in a vertical element, ready for assembling at site.

Elementen byggdes på fabrik.
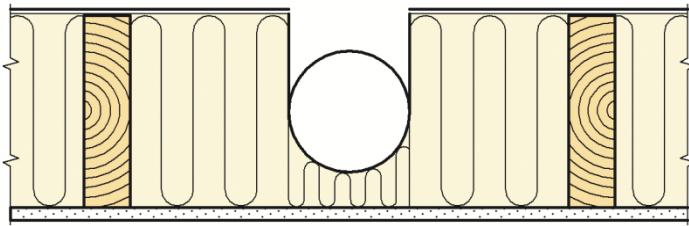
Fig. 2.2
Draw of the cross-section and a photo from the production phase, from Lindholm (2012)

Fasadelementen byggdes på höjden, observera hålen till installationerna.
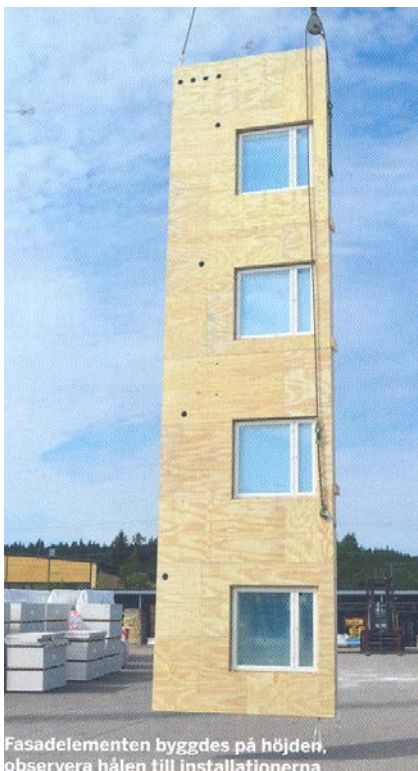
Fig. 2.3
Photo of a vertical element with ducts ready for assembling at site, from. Lindholm (2012)

2.2   Horizontal element with pipes

If only horizontal elements are planned, it will be much more complicated to have separate ducts for each floor, because of the necessity of a vertical pipe to the main unit. An example of a solution with common vertical duct is presented in figure 2.4. To prevent sound transmission between apartments through the ducts, silencers must be placed in the channel system at each floor. High damping is necessary, implying a thickness of the silencers of at least twice the duct diameter and an increased pressure loss of the HVAC system. In order to prevent fire spreading through the ducts, it is necessary to install fire dampers or inlet units classified with respect to fire resistance. Solutions with horizontal elements are therefore more difficult in practice.
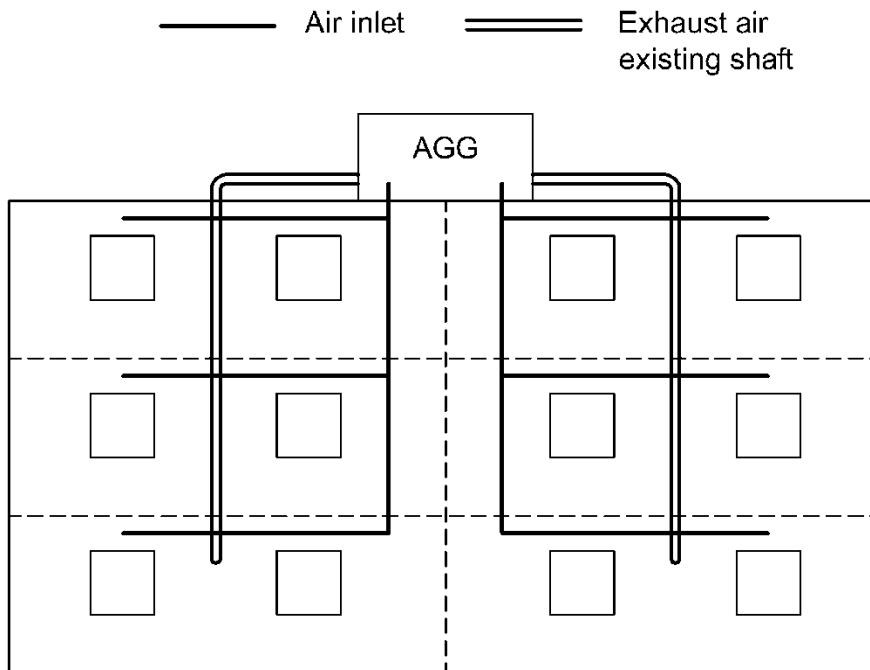

Fig. 2.4
Principal solution of horizontal elements with HVAC ducts integrated for the air inlet

Another challenge is the connection of the vertical ducts between the horizontal elements in the mounting phase. An advantage of the solution is that it is possible to avoid horizontal ducts inside the apartments.

2.3   Combination of vertical and horizontal elements

A combination of vertical and horizontal elements can give several advantages. All vertical ducts will be put into the vertical element and all horizontal ducts into the horizontal elements, see an example of such a mounting in figure 2.5. Another advantage is that it is possible to have all the horizontal ducts inside the SmartTES elements. The vertical element has to be positioned first. A challenge will be the connection of ducts between the vertical element and each horizontal element. With only one such connection per element, a practical solution is possible.
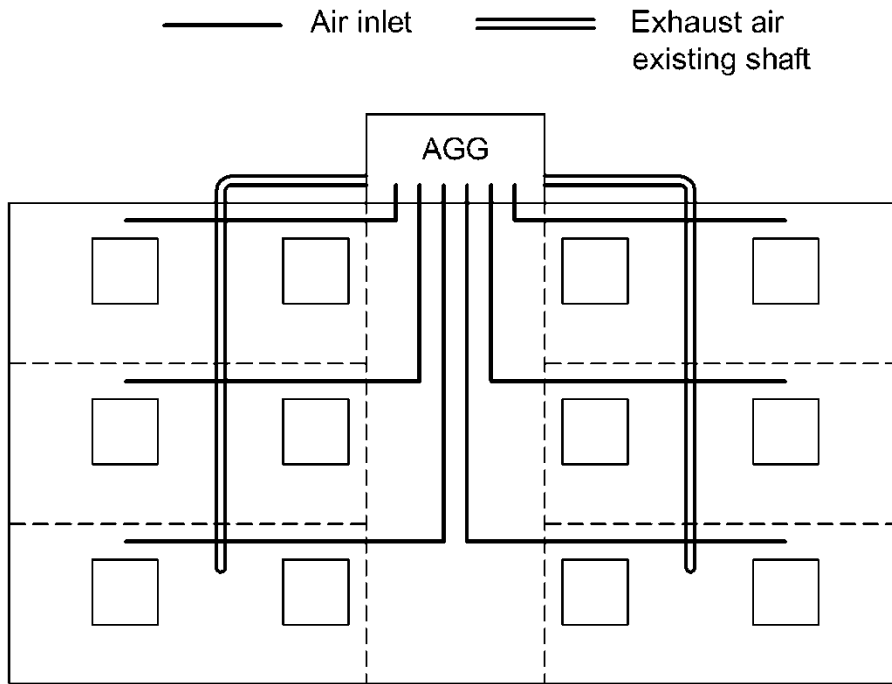
Air inlet   Exhaust air
             existing shaft

Fig. 2.5
Principal solution of a combination of vertical and horizontal elements with HVAC ducts

2.4 Existing wall of masonry or concrete

Several steps have to be planned and carried out in the assembling phase. On site, the existing walls have to be prepared with holes in the masonry/concrete wall. The dimension of these holes must be planned with respect to the position accuracy. The next step will be to mount the element towards the existing wall. After that, a duct piece with correct length should be attached from the inside. It is important to ensure sufficient tightness of this adaption, for instance with rubber ties at one of the duct pieces. Finally, the installation has to be completed with sealing between the duct and the existing wall and finishing of the surface at the inner wall. Figures 2.6 a) to 2.6 d) show suggested details of the necessary assembling steps.
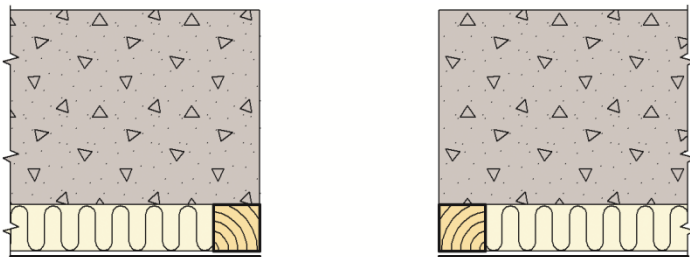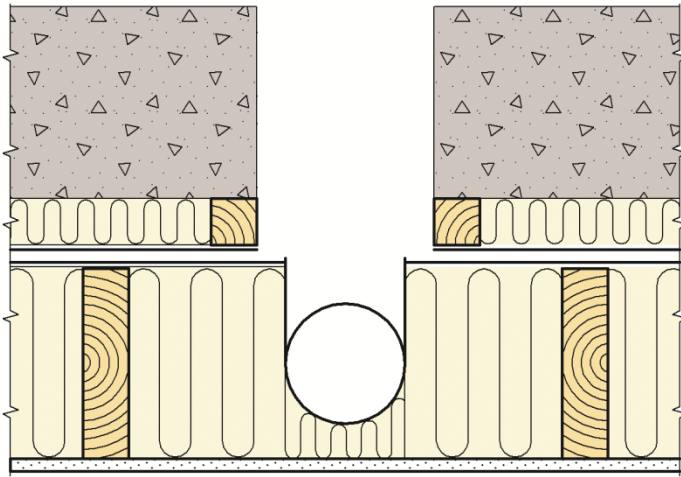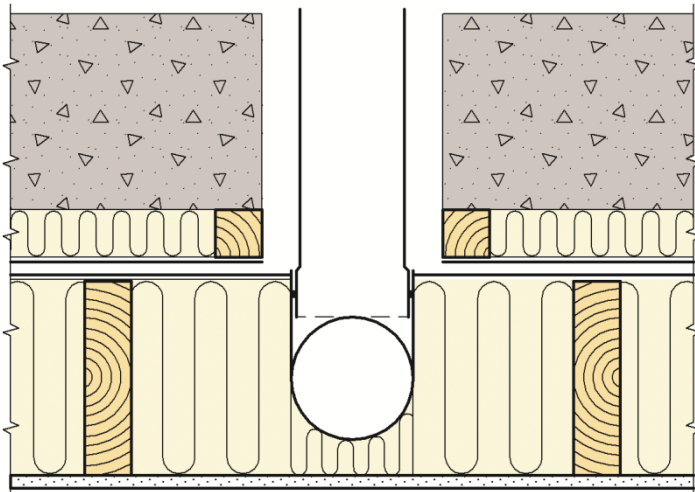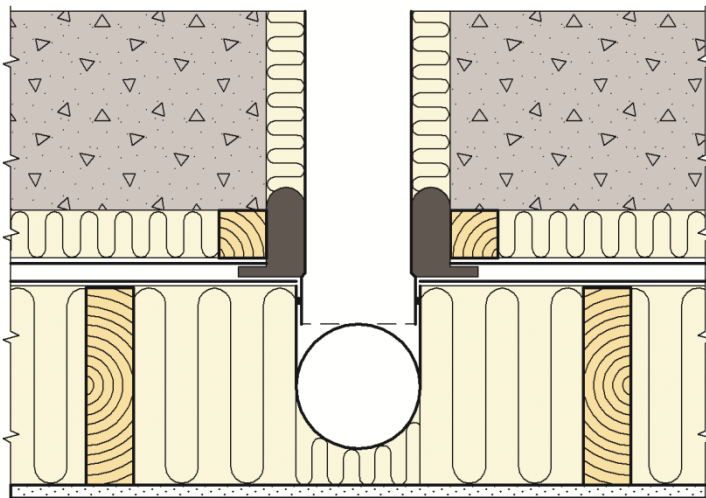

Fig. 2.6
a) Existing wall and an adaption layer (if necessary) at the exterior side with the prepared hole

b) SmartTES element with wind barrier at both sides, applied towards the existing wall.
50 mm insulation positioned between the duct and the exterior side.

c) Duct piece attached from inside

d) Sealing between duct and existing wall

2.5 Existing wood frame wall

Similar steps as described in chapter 2.4 have to be carried out for an existing wood frame wall. In this case, the preparation of the hole should be easier, but of course positioned with appropriate accuracy. The next step will be to mount the element towards the existing wall and apply a duct piece similar to description in chapter 2.4. Finally, the installation has to be completed with sealing between pipe and inner surface of the wall. A cuff foil on new studding is recommended to ensure an airtight connection. Figures 2.7 a) to 2.7 c) show suggested details of the necessary assembling steps.
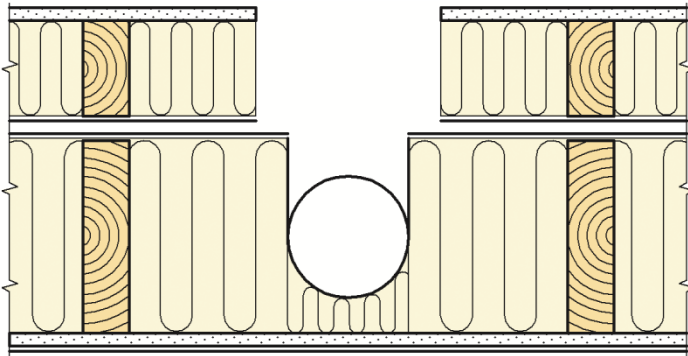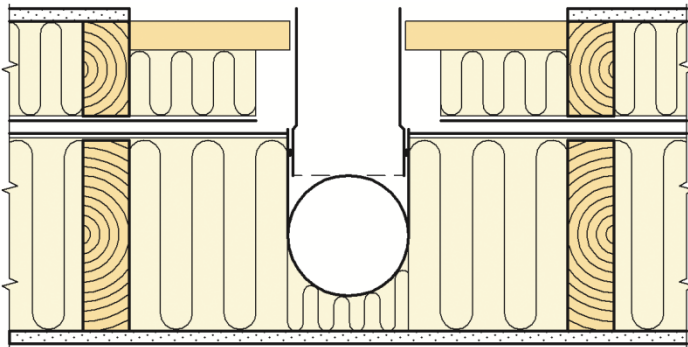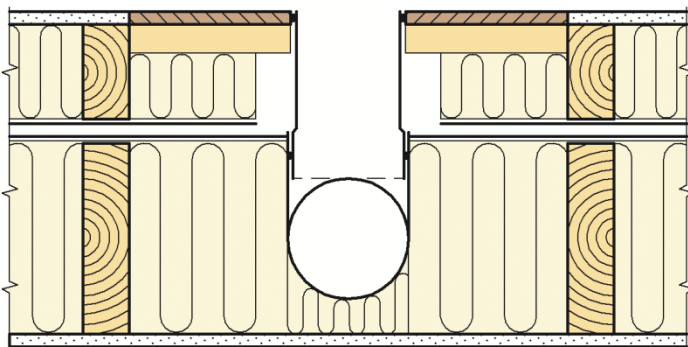
Fig 2.7
a) SmartTES element with wind barrier at both sides (lower part) applied at the existing wood frame wall (upper part) with the prepared hole. 50 mm insulation positioned between the duct and the exterior side.

b) Duct piece and an additional studding attached from inside

c) Sealing between duct and inner wall with a cuff foil

3. Heat flow and thermal losses

3.1 Numerical simulation procedures and objects

Installation of ducts in SmartTES elements will affect the temperature distribution and the heat transfer of the wall. Simulations have been performed using the 2D numerical simulation tool "THERM" ver. 6.3. The calculations have been carried out to determine the temperature decrease in an inlet air duct and the increased heat losses through the walls due to the installed ducts. The heat losses include the transmission heat losses caused by the reduced insulation thickness around the ducts as well as additional heat losses associated with the temperature decrease of the inlet air. In table 3.1, the different cases are described by key parameter values and boundary conditions.

Table 3.1
Case studies and the boundary conditions

	Existing wall Wood frame	Existing wall Masonry
Thickness of existing insulation thermal conductivity	100 mm 0,037 W/mK	200 mm 0,5 W/mK
Thickness of SmartTES element	200 mm	200 mm
External insulation cover of inlet air duct	0 mm 50 mm 100/75 mm	0 mm 50 mm 100/75 mm
Duct diameter	Ø 100 mm Ø 125 mm	Ø 100 mm Ø 125 mm
Outdoor / indoor temperature	0 ^{o}C / 20 ^{o}C	0 ^{o}C / 20 ^{o}C

The simulations are based on a heat exchanger efficiency of 80 % of the main HVAC unit and 0,5 air changes per hour in the apartments.

3.2 Temperature decrease in inlet air

In figures 3.1 and 3.2, the results from the calculation of the temperature decrease of the supply air between the heat exchanger and the inlet vents are given. The calculations are based on the boundary conditions given in table 3.1

Wood frame wall
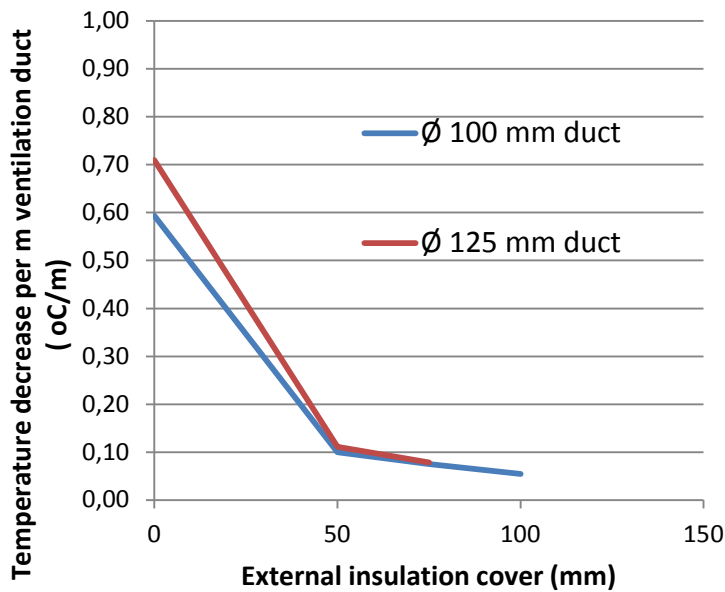
Fig. 3.1
Temperature decrease per unit (m) ventilation duct in a SmartTES element applied to an existing wood frame wall

Masonry wall

Fig. 3.2
Temperature decrease per unit (m) ventilation duct in a SmartTES element applied to an existing masonry wall

The results presented in figures 3.1 and 3.2 show a relatively high temperature decrease for the case without external insulation cover. With at least 50 mm of external insulation cover, the temperature decrease is rather low. Remember to multiply with the real length of the ducts from the main unit to the inlet vent to get total temperature drop for a specific flat.

3.3 Thermal performance of walls with ducts

In figures 3.3 and 3.4, results from calculation of the additional heat loss per unit (m) ventilation duct are given. The calculations are based on parameter values and boundary conditions given in table 3.1.
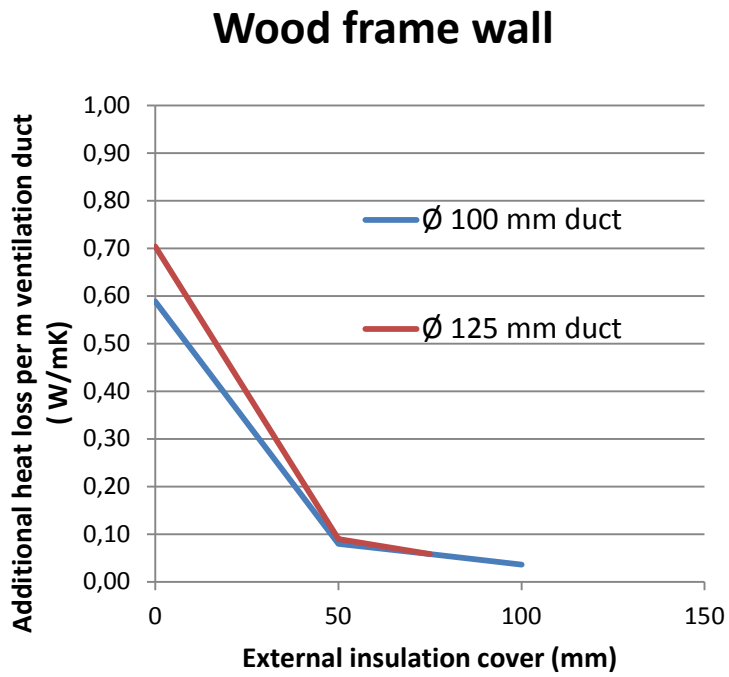
Fig. 3.3
Additional heat loss per unit (m) ventilation duct in a SmartTES element applied to an existing wood frame wall
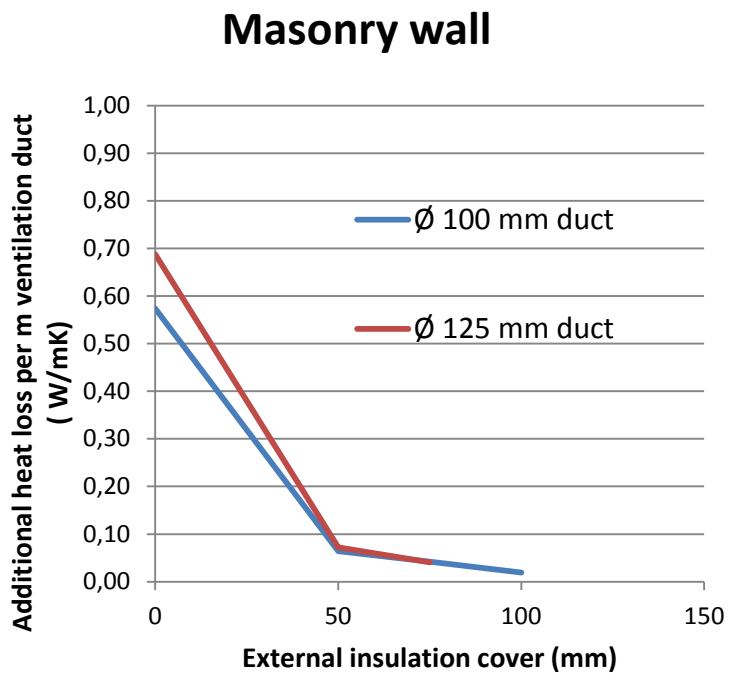
Fig 3.4
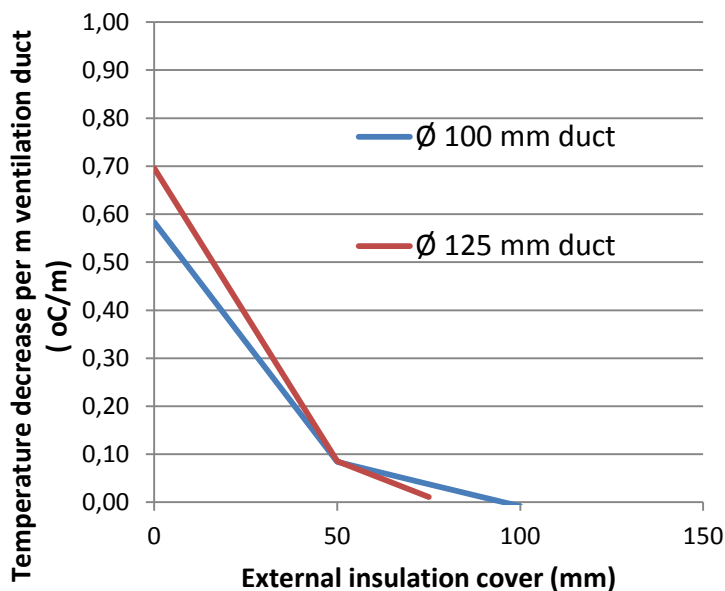Additional heat loss per unit (m) ventilation duct in a SmartTES element applied to an existing masonry wall

The results presented in figures 3.3 and 3.4 show a relatively high increase of the heat loss for the case without external insulation cover. With at least 50 mm of external insulation cover, the additional heat loss is rather low. For real cases remember to multiply with the length of the ducts from the main unit.

3.4 Recommendations

The calculation results presented in chapter 3.2 show that the temperature decrease in inlet air ducts can be kept to a minimum if substantial exterior insulation thickness is provided. Our recommendation is at least 50 mm exterior insulation thickness. The results from the calculations show that additional transmission heat losses and heat loss related to the temperature reduction of the inlet air can be kept as low as 2-6 % if a substantial exterior insulation thickness is provided, see the results in chapter 3.3.

4.   Moisture conditions at the ventilation ducts

4.1   Assessment of risk of mold growth

The moisture conditions and risk of mold growth in a timber frame element with ventilation ducts has been assessed on the basis of moisture and temperature calculations at stationary conditions. The calculations have been performed using a spreadsheet software tool developed at SINTEF Building and Infrastructure. The main construction data of the wall is shown in the figures 4.1 and 4.2. Monthly mean values at ten meteorological stations in Norway have been used as outdoor climate. Indoor there is presupposed an air temperature of 20 °C, moisture supply of 4 g/m³h (common, average used value), mechanical supply and exhaust air with heat recovery with 80% efficiency. Examples of results from the calculations are shown in the figures 4.1 and 4.2.

4.2   Air tightness

The overall air tightness of the building may be improved by the new wall element, provided that the new wall elements and adjacent joints have good airtightness. A vapor barrier between the existing wall and a new timber frame element is not recommended because it may give mold growth conditions on the warm side of the vapor barrier. The necessary airtightness of the new timber frame element may however be achieved by use of an exterior wind barrier with air tight joints. Boards with sufficiently tight joints on the warm side of the element will also contribute to the airtightness of the wall element.

4.3   Normal operation

During normal operation the warm supply air in the duct will raise the temperature of the insulation near the duct. The relative humidity, RH, near the duct will therefore be lower than in wall sections without ducts.

If normal wind barriers with low vapor resistance are used on the cold side of the new insulation, there will be no risk of condensation or mold growth in the mineral wool. See calculated distribution of temperature, relative humidity (RH), water vapor pressure and saturation vapor pressure in figures 4.1 a, b and c.

4.4   Ventilation stop

If the ventilation fans stop functioning, the temperature of the ducts will be adjusted to the temperature of the wall. However, the temperature of the duct will still be high enough to avoid condensation and risk of mold growth at the surface of the ducts when the insulation thickness outside the duct is 50 mm or more. See calculated distribution of temperature, relative humidity (RH), water vapor pressure and saturation vapor pressure in figures 4.2 a, b and c.

4.5   Construction period

If the existing wall is wet when the new wall is mounted, there might be a temporary risk of mold growth conditions at the surface of the existing wall and at the wind barrier layer of the new wall. Dry conditions during the construction period and using a wind barrier with as low vapor resistance as possible will reduce this risk.

Fig. 4.1 a
Horizontal section of an existing wall (right side) with external additional insulation in the form of a wall element with a steel duct for supply air (left side). The figure shows estimated temperature distribution in the wall with a duct with a flow of 16 °C warm air. Indoor moisture supply of 4 g/m³.

Fig. 4.1 b

Fig. 4.1 c
The diagrams show estimated distribution of temperature, relative humidity (RH), vapor pressure and satura-tion vapor pressure for the cross section of the wall near the ventilation duct. The calculations are done for normal operating conditions on a winter day. Normal airflow in the duct with a temperature of 16 °C and indoor moisture supply of 4 g/m³.
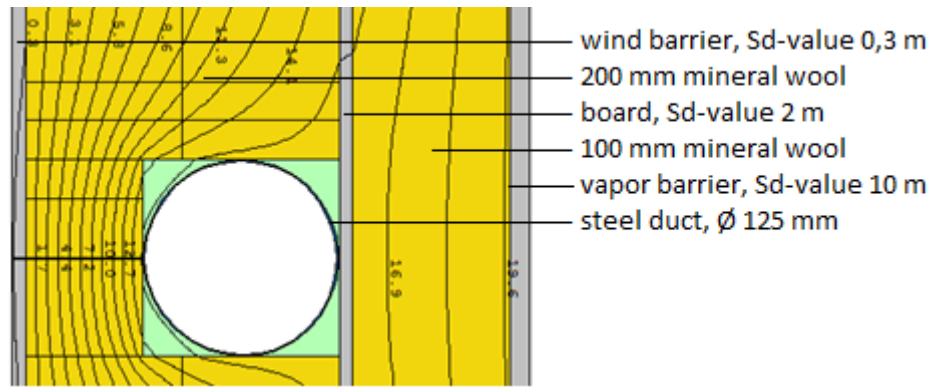
23
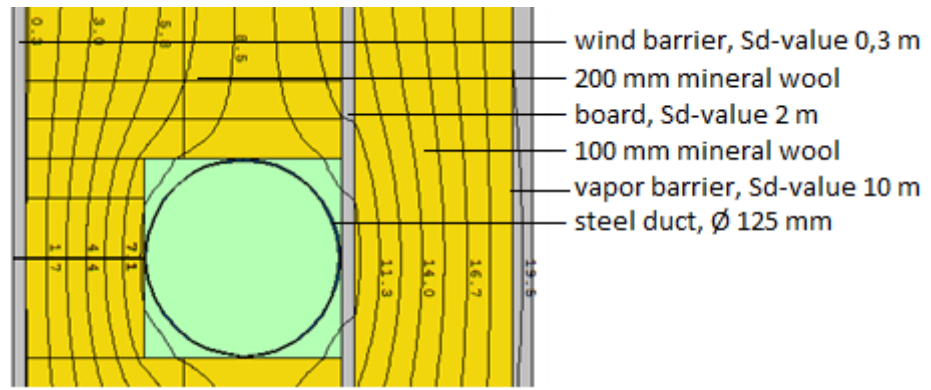
Fig. 4.2 a
Horizontal section of an existing wall (right side) with external additional insulation in the form of a wall element with a steel duct for air supply. No airflow in the duct. Indoor moisture supply of 4 g/m³.

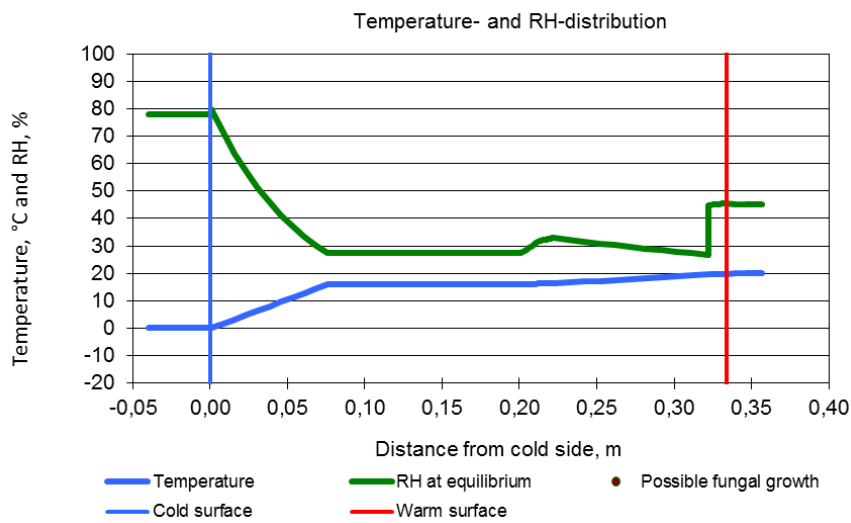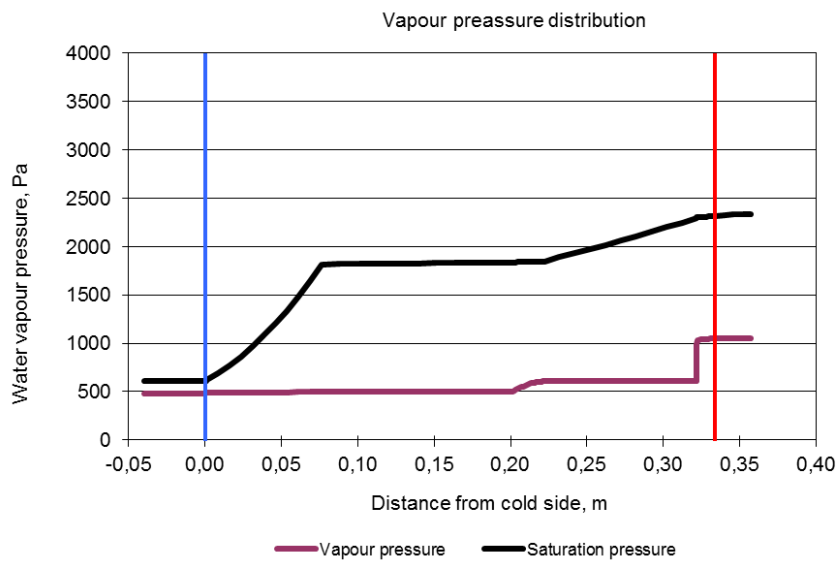Fig. 4.2 b

 Fig. 4.2 c
The diagrams show how temperature, relative humidity (RH), vapor pressure and saturation vapor pressure is distributed for the cross section of a wall near the ventilation duct when the fans have stopped on a winter day. No airflow in the duct and indoor moisture supply of 4 g/m³.

5. Noise distribution

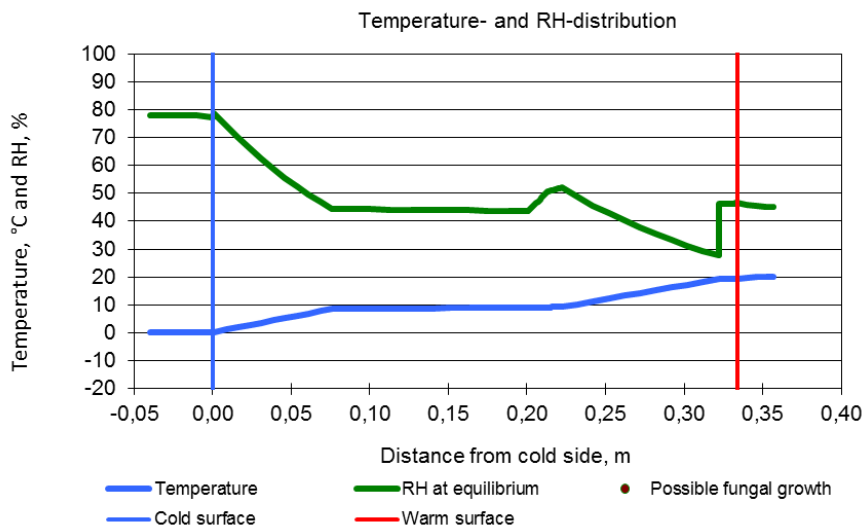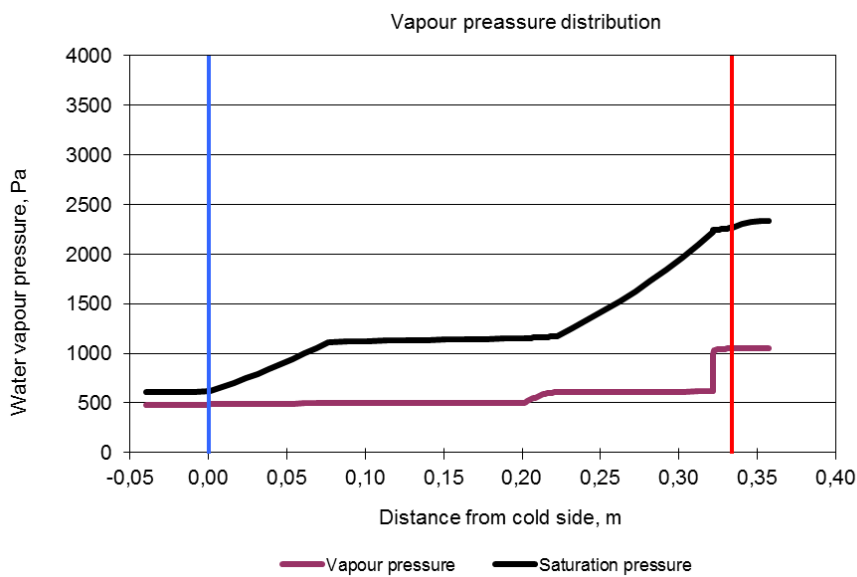In addition to fulfilling air conditioning requirements, an air handling system must meet acceptable noise and vibration criteria. The purpose of the following section is to give some guidelines for selecting proper criteria and some tools for designing the system. Methods for specification and reduction of noise from ducted systems will be given. The designer should be aware of noise and vibration principles, since these have become a major concern in the acceptability of air handling systems. While designing a system too conservative with respect to noise and vibration is not cost effective, disastrous results may occur if potential problem areas are not considered during the design stage. The optimal design meets accepted criteria for the use of building space without being too conservative.

5.1 Noise from the HVAC system

Ducted systems are used to transmit air from a fan or blower to the relevant locations. Although the fan or blower is usually considered the major source of noise in such systems, the flow of air through duct elements like bends, turning vanes and flow control valves can also generate noise and vibrations. To meet the objectives mentioned above, knowledge about the following aspects is needed:

a) Fan noise. This data should be available from the manufacturer as octave band sound power levels in the desired operating arrangement. The experience is that predictive techniques need to be employed in many situations.
b) Ductwork noise. Ductwork, bends, branches, flow control valves and terminations generate noise depending on the flow velocity and component resistance.
c) System attenuation. The attenuation within the system provided by duct runs, bends, branches and terminations
d) Room or atmosphere corrections. The sound power emerging from the ductwork system modified by corrections such as directivity, distance, room volume and room reverberation time.
e) Sound reducing techniques. If required, measures to reduce the sound level by use of attenuators/silencers, duct linings, plenum chambers or modification to the system design.

The recommended method to calculate the noise from a HVAC system is to consider each noise source separately with all attenuation components to the receiving room. Then summarize all contributions and calculate the A-weighted sound pressure level in the room.

An HVAC system for 4 to 8 apartments for instance, have rather few components generating and attenuating noise when we consider each transmission path to a receiving room. In our SmartTES case we can consider only the inlet air, because the outlet air will be handled through shafts from another room. If we presuppose rather low air velocity in the ducts, we can simplify the noise generation part of the system to the fan, one flow control valve and probably the termination unit. Table 5.1 presents a setup for calculation of noise from the inlet air system based on the assumptions above.

Table 5.1
Setup for calculation of noise from the air inlet system

Component	Source 1) Fan	Source 2) Control valve
Fan sound power level	From manufacturer	-
Silencer attenuation	From manufacturer	-
Branch attenuation	Volume based distribution	-
Control valve sound power level	-	From manufacturer or calculated
Bend attenuation	Tabulated values	Tabulated values
Termination unit and end reflection	From manufacturer or calculated	From manufacturer or calculated
Room corrections	Input, acoustic parameters	Input, acoustic parameters
Summarized level	Sound pressure level contribution from fan	Sound pressure level contribution from control valve

Input values have to be given and calculations have to be carried out in 1/1-octave band from 63 Hz to 4000 Hz. Summarize these two contributions, make correction for the A-weighted levels in each 1/1-octave band and finally summarize to a single-number value. According to the Norwegian requirements for residential rooms, the $L_{pA,eqT} \leq 30$ dB and the $L_{pA,max} \leq 32$ dB, see NS 8175, sound class C. For more details on sound level calculations from HVAC systems, see SINTEF Byggforsk (1988) or Fry (1988).

5.2   Transfer of noise between flats/sections

As mentioned in chapter 2, it is strongly recommended to have separate ducts from the main unit to each apartment. In such cases, the sound attenuation from one apartment to the branch after the fan/silencer, into another duct and through this path to another room will normally be satisfactory to prevent disturbing sound transmission through the ducts.

If a concept with a common duct between apartments is chosen, disturbing sound transmission is expected and we strongly recommend to perform calculations. Such calculations will quantify the necessity of attenuation/silencer in the system between the apartments. High damping will normally be necessary, implying a thickness space of the silencers positioned in the SmartTES element. Fig. 5.1 shows a common type of duct silencer. Silencers or other attenuators will also give increased pressure loss of the HVAC system. Figure 5.2 shows a principal drawing of such a system. A calculation method for the sound transmission through such a system is given in Vigran (2008).

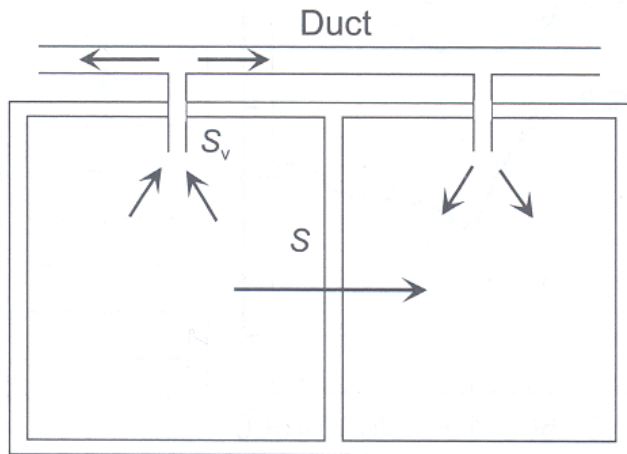Fig. 5.1
Common type of duct silencer

Fig 5.2
Sound transmission between rooms by way of a common duct system, from Vigran (2008)

5.3   Calculation example

In table 5.2 we present a calculation example of noise from an air inlet system. The calculations are based on sources and components from table 5.1. Input parameters for calculation of numbers in table 5.2 are not given.

Table 5.2
Calculation example of noise from an air inlet system

Component / Frequency band	63	125	250	500	1000	2000	4000
Fan sound power level, example	50	63	77	79	80	78	75
Silencer attenuation, example	-8	-15	-21	-33	-36	-31	-23
Branch attenuation	-7,2	-7,2	-7,2	-7,2	-7,2	-7,2	-7,2
Bend attenuation	0	0	0	0	0	-3	-6
Termination unit and end reflection	-21	-14	-7	-3	-4	-6	-8
Room corrections	-5,0	-5,0	-5,0	-5,0	-5,0	-5,0	-5,0
Level from fan source	8,8	21,8	36,8	30,8	27,8	25,8	25,8
Control valve sound power level, ex.	35,1	36,1	37,1	38,1	38,1	35,1	32,1
Bend attenuation	0	0	0	0	0	-3	-6
Termination unit and end reflection	-21	-14	-7	-3	-4	-6	-8
Room corrections	-5,0	-5,0	-5,0	-5,0	-5,0	-5,0	-5,0
Level from control valve	9,1	17,1	25,1	30,1	29,1	21,1	13,1
Summarized level Fan + Control Valve	12,5	23,1	37,1	33,5	31,5	27,1	26,0
Factors A-weighting	-26	-16	-9	-3	0	1	1
A-weighted level ∑ = 36 dB	0,0	7,1	28,1	30,5	31,5	28,1	27,0

To summarize logarithmic dB-levels, the following general equation has been used:

$$L_{total} = 10 \times \log \sum_{i} \left(10^{L_{wi}/10} \right)$$

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The calculation example in table 5.2 shows an A-weighted level of 36 dB. This is higher than the Norwegian requirement, see chapter 5.1. If relevant fan levels, control valve levels and silencer attenuation levels have been used, it will be necessary to put another silencer into the duct system. In this case it is necessary with increased attenuation especially at 500 and 1000 Hz.

5.4   Recommendations

A principal solution with separate ducts from the main unit to each apartment is strongly recommended. Then, the sound attenuation from one apartment to the next will normally be satisfactory preventing disturbing sound transmission through the ducts. Solutions with common ducts will be challenging with respect to sound attenuation in the duct system and challenging with respect to fulfilling fire resistance requirements.

In all cases we recommend to conduct calculation of the sound pressure level in, at least, the apartment nearest to the main unit. Such calculations will quantify the necessity of attenuation/silencer in the system between the apartments. When the air velocity is below approximately 2 m/s, it is normal to take only the sound generation from the main unit into account.

With respect to components, we strongly recommend to use well documented values from the producers of the planned HVAC components.

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HVAC pipes in wooden elements

CONCEPT, THERMAL LOSSES AND NOISE IN SMARTTES SOLUTIONS

SINTEF Building and Infrastructure has been a partner of the recently finished WoodWisdom project «SmartTES – Innovation in timber construction for the modernisation of the building envelope».

The work presented in this report gives a contribution concerning integration of HVAC pipes in SmartTES, exterior wall elements. The focus has been on evaluation of mounting possibilities and calculation of thermal losses, moisture conditions and noise. See www.tesenergyfacade.com for more information about the main project.