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Cavity Wall Insulation in existing buildings

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Foreword

Increasing sensitivity to environmental issues and rising energy costs mean that house-owners have had to think hard about energy-saving measures. In the north of Germany, cavity-walls with an air-gap are the predominant form of house construction. One quick, cost-effective and energy-saving renovation technique is to insulate outer cavity walls by completely filling the gap with insulating material.

The intended function of the air gap, namely to ventilate and reduce dampness in the masonry, is rendered completely ineffectual by this measure which could lead, potentially, to damp-related damage.

In order to examine the impact and possible risks of cavity wall insulation for existing buildings, a two-year research project was launched at the Jade University of Applied Sciences in Oldenburg. The project, led by the Department of Building Material Sciences and Building Conservation, had the title „Nachträgliche Hohlraumdämmung – Anwendung und Dauerhaftigkeit“/”Cavity wall insulation of existing buildings – techniques and durability”. The focus of the study was the precise assessment and testing of the physical conditions under which cavity wall insulation of existing buildings is possible. To this end, laboratory tests were carried out on insulating and building materials to gain the data necessary for subsequent numerical simulations of the behaviour of insulated walls under the influence of moisture and temperature. Moreover, a field study was carried out to examine water absorption in the insulating material and settling of the material over time. Tests were also carried out on buildings before and after the cavity wall insulation procedure. This guide is a summary of the results of the research project.

This guide is intended as an overview of the possibilities and limitations of external cavity wall insulation of existing buildings. It includes instructions and recommendations for preliminary tests of the building, the preparatory steps for the work itself as well as for subsequent quality control examinations. The guide provides a working basis for energy consultants, architects, engineers and construction companies as well as house-owners.

The Project Team

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1 Advantages

1.1 Cavity wall insulation saves money…

According to figures published by the Institute for Building Research in Hanover (Institut für Bauforschung e. V.) in October 2007, only 10 % of the current building stock was built after the energy crisis of the 1970s. Thus, only 10 % of buildings come close to meeting the requirements of the Energy Saving Regulations (2nd issue) of 1982. Since then the requirements have become more stringent with, of course, the intention of reducing energy consumption even further. This can only be achieved, however, with extensive renovation or rebuilding measures.

Houses built in north Germany between 1900 and 1970 were, as a rule, constructed with cavity walls: The internal masonry shell is load-bearing and the external shell provides protection against the elements. Between these two walls there is an air gap of 4 cm to 9 cm.

It is the case that an un-insulated detached house loses 25 % of its heat energy via the outer walls so, clearly, it makes good sense to insulate the walls of existing houses. In this way savings of up to 15 % of the heating energy costs for a detached house can be achieved.

Cavity wall insulation of existing houses is, thus, extremely cost-effective. The investment can pay for itself within a few years.

1.2 … and improves home comfort and well-being

An un-insulated external wall with an air gap has a co-efficient of heat transfer (U-value) of about 1.5 W/m^2K. If a 6 cm air gap (TCG 045) is insulated, this figure is reduced to 0.5 W/m^2K. This represents a reduction of about 66 %. The reduction in heat transfer results in a temperature rise of the interior wall surface which, in turn, leads to improved home comfort and well-being and reduces the risk of mildew growth.

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2 Insulating materials

2.1 Insulating materials in the research project

In the research project a selection of insulating materials was examined. It has to be mentioned, however, that new products regularly appear on the market.

Hyperlite KD

The raw material for the insulation material Hyperlite KD is perlite, a silicate rock. Perlite is a glass-like rock derived from the lava of under-sea volcanoes. This volcanic rock is ground to perlite grains and then shock-heated to 1000 °C. This drives out the crystallization water which is chemically bound in the sand-grain-sized pieces which then expand to 20 times their original volume. The resulting product is a granulate with numerous air-pockets and correspondingly good insulating properties. In a final step, the granulate undergoes a process which makes it water-repellent.

RigiBead 035

The insulating material RigiBead 035 is foamed particle polystyrene in granulate form. It is produced using a volatile propellant such as pentane. The expansion of the polystyrene balls takes place at temperatures of over 100 °C and with the addition of steam. Its closed-cell structure prevents the uptake of water. This means that no subsequent process is required to make the material water-repellent.

HK 35

HK 35 like RigiBead 035 belongs to the group of polystyrenes. The material consists of 60 % foamed particle polystyrene in granulate form and foamed particle polystyrene in powder form. The granulate is produced in exactly the same way as RigiBead 035. The powder which is a by-product from cutting polystyrene sheets fills up the cavities between the granulate balls. HK 35 does not have to be treated to make it water-repellent due to its closed-cell structure.

SLS 20

The light-weight silicate foam SLS 20 is manufactured from recycled glass. The fine silicate sand made by grinding glass is mixed with additives to produce a water-repellent material. The mixture is then heated to 500 °C which causes the grains to expand. This fine-particle, foamed-glass granulate is light-weight and is available in two grain-sizes with different thermal conductivities.

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Durolan

The insulating material Durolan is a two-component, open-cell foam made from foam and synthetic resin (Urea-formaldehyde resin-foam). The components are made from the raw-materials in the factory, mixed on-site with air in a special process and then injected into the cavity wall.

Rockwool Granulat KD

Rockwool is an inorganic, fibrous insulating material which is also known as glass or mineral wool. The raw materials for rock wool include, variously, lime-stone, dolomite, feldspar, basalt, diabase, sand and cement. These minerals are derived from natural sources and the supply is considered to be unlimited. Additives used (up to 7%) are organic materials and binding agents made mainly of synthetic resin as well as water-repellent substances. The raw materials are melted at around 1400 to 1500oC and mechanically shredded into fibres.

Nanogel Aerogel

NanoGel is manufactured from silicic acid and was included in the study on the grounds of its low thermal conductivity. The material has an extremely fine glass lattice with very small pores and consists of 95 % air and 5 % solid material. One great advantage of NanoGel is that it can be used in cavity walls with an air gap of as little as 1.5 cm to 2 cm. Other insulating materials require a minimum of 5 cm to be effective.

2.2 Demands on the insulating materials

Cavity wall insulation of existing buildings is carried out using granulates or foams which are injected into the cavity via small openings. To ensure success the following material requirements should be met:

General approval for construction purposes

Only materials which have been granted the general approval of the German Institute of Building Technology (DIBt) may be used for cavity wall insulation. The approval documentation lists the properties of the material as well as important regulations for its use.

The German Institute of Building Technology (DIBt) has the authority to grant general approval for building products and techniques in Germany as well as technical approval of building products and components for Europe. General approval for construction purposes is granted for building products and techniques within the area where the federal state regulations apply, if there are no generally applicable technical regulations (German DIN-standards, for example) or if existing regulations are significantly divergent from such standards. Such approval is a reliable indicator that a given building product or technique is fit for purpose and meets relevant technical requirements.

Heat insulation

The thermal conductivity grouping of the insulating material is the key to the heat insulation. It should be as low as possible to get the greatest possible insulation. The materials examined in the study have a TCG ranging from 0.05 W/mK to 0.018 W/mK.

Damp protection

In order to prevent moisture which penetrates the external shell of the wall from being transported to the internal shell and impairing the insulating effect of the filling material, only water-repellent materials which meet the German standard DIN 1053-1 (11-1996) may be used. Moreover, the material should have the lowest possible resistance to water vapour diffusion (μ-value).

Fire protection

A further criterion in selecting an insulating material is the fire protection classification of the material. This is quoted as either DIN 4102-1 (8-1998) or EN 13501-1 (1-2010). The applicable fire protection classification depends on the federal state in question.

Building regulation designation	Fire protection classification to EN 13501-1 (1-2010)	Fire protection classification to DIN 4102-1 (8-1998)
non-flammable	A1, A2	A1, A2
hardly flammable	B,C	B1
normally flammable	D, E	B2
highly flammable	F	B3

Settling and shrinkage

If the insulating material settles or shrinks, air spaces open up in the insulating layer which act as thermal bridges and can be detected by a quality control procedure. These areas should be re-filled to prevent damage to the building substance. Not all of the general approvals specify a volume percentage for settling of the material in a wall cavity.

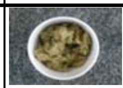
The material in use

When injecting the material the dust given off can be unpleasant for the worker (see the health and safety data sheet for the insulating material) and can seep into the house interior.

The way in which the material flows is of relevance when modernizing the house at a later date (installing new windows, for example). If the material is free-flowing the insulating material may run out of the openings necessary for such modernization. It is, however, possible to set the granulate using an adhesive compound.

2.3 Material properties

The following table lists the properties of the materials which were examined in the study.

Insulation material properties as stated in general building approval documentation	Hyperlite KD	SLS 20	RigiBead	HK 35	Rockwool Granulat KD	Durolan	Nanogel Aerogel*
							
Constituent parts	volcanic rock	recycled glass	foamed particle polystyrene		natural rock, glass	urea-formaldehyde resin	silicate (silicic acid)
Thermal conductivity λ [W/mK]	0.05	0.035[1] / 0.04[2]	0.035	0.034	0.04[3] / 0.045[4]	0.039	0.021
Resistance to water vapor diffusion (factor) μ [−]	3	3	5	5	1 - 2	2.4	n. a.
(Fire protection classification) DIN 4102-1	A1	A1	B2	B2	A1	B2	B1
(Fire protection classification) EN 13501-1	A1	A1	D / E	E	A1	D / E	B / C
Emissions classification	no data given in the general approval for construction purposes (see safety data sheet)					ES 3 (ETB-Ri UF-foam, April 1985)	n. a.
General approval for construction purposes	yes	yes	yes	yes	yes	yes	yes
Flowability	yes	yes	yes	yes	no	no	yes
Bulk density [kg/m^3]	90	18 - 30	16 - 20	22 - 26	80 - 100[3] / 100 - 150[4]	n. a.	75-80
Settling volume [%]	n. a.	< 10	< 5	< 9	n. a.	n. a.	< 10
Grain size [mm]	0 - 6	0 - 2[1] / 0 - 8[2]	< 6	4 - 8 / < 4 (small particles)	n. a.	n. a.	< 4
Water-repellent effect [V.-%]	18.8	18.8	n. a.	5	1.0 kg/m^2 (after 4 h) / 4.0 kg/m^2 (after 28 d)	15	n. a.

* Nanogel Aerogel has been granted general approval for construction purposes since 9/2010.

Moisture absorption (Laboratory and Field trials)

Moisture absorption for a given material can be determined by testing its water-repellent effect. This is of great significance for damp protection of the internal wall. Thus, the general approval for building use for each insulating material states maximum permissible values of water absorption. The tests

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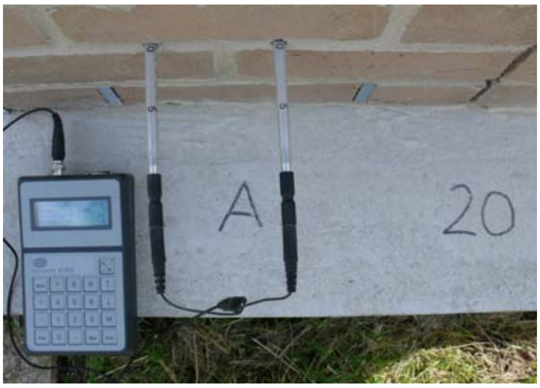
described in the approval documentation were carried out to check that these limits were not exceeded. To allow for comparison, the required levels were converted to percentage volume (V.-%) – see table. The maximum permitted values for the various insulating materials vary greatly but were not, however, exceeded in the laboratory tests.

In addition, field trials were carried out on test pieces which were exposed to the elements. The test pieces are cavity walls in which the air gaps are filled with different insulating materials. Each wall has two test areas. On one side ventilation openings were arranged in the lower part of the masonry; on the other side they remained closed. In both test areas moisture content could be measured at two points using a Gann-DEVICE (moisture gauge).

View of the test pieces in field trial



Measuring moisture on a test piece (GANN-DEVICE)

To what extent the ventilation openings served as drainage holes for moisture could only be recorded for the material SLS 20. In the case of the other materials no clear effect could be detected.

The settling and shrinkage of the materials were also observed. The settling matched the values given in the approval documentation. The insulating foam showed significant cracking at all levels.

3 Building surveys

3.1 Why carry out a survey?

No one building is like another so it is essential to carry out a detailed survey of each individual building and the air-gap before beginning modernization work. If the work to be undertaken is extensive or the building itself unusual in any way, then it is advisable to consult a planner or an energy advisor as well.

One aspect of the research project involved doing preliminary surveys of un-insulated buildings in order to address the following points:

- Which tests is it advisable or necessary to carry out in advance (before insulation is in place) of cavity wall insulation work in order to minimize the risk of damage to the structure?
- How exactly should the tests be carried out and which potential difficulties could arise, depending on the various characteristics of the building materials?

3.2 Condition of the outer masonry shell

If the external wall shell is carefully examined before insulation work starts, potential problems of moisture ingress or rising damp can be anticipated and prevented. To this end, the external masonry or its rendering is examined for weak-points such as cracks or flaking. If there are signs of salt efflorescence, this is an indication that the moisture content in the masonry is abnormal. It may then be necessary to test the bricks and mortar to establish their water absorption quotient. If the façade is rendered or painted then the resistance to water vapour diffusion must be measured for this layer.

For some of the insulation materials the general building approval documentation specifies that the outer shell should or must be tested.

3.3 Condition of the cavity and the masonry ties

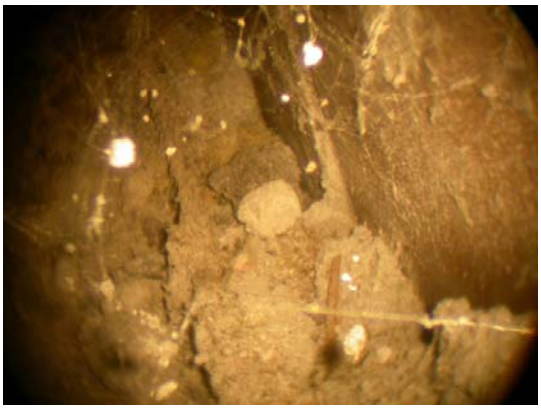
Before insulation work is carried out, the condition of the cavity must be examined. This is a visual test done using an endoscope introduced into the cavity. Depending on the quality of the workmanship the cavity may contain rubble or pieces of mortar. After insulation these would build a thermal bridge which could have a damaging effect. In addition, the approval documentation states that the viability of the masonry ties (wire ties) must be tested as they are essential to the structural integrity of the outer wall. The examination of the cavity allows the contractor to assess whether further measures (removal of mortar and rubble, use of additional masonry ties) are necessary before insulation work can start.

3.4 Leakage test of the walls

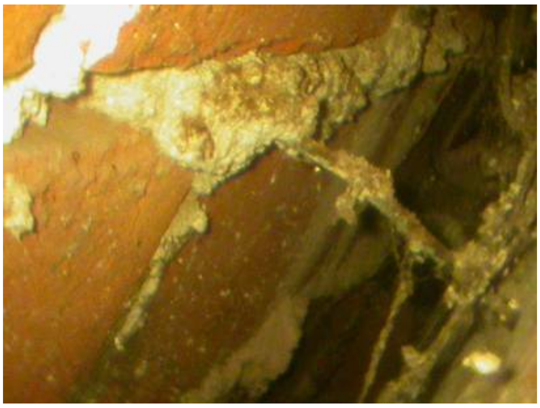
Immediately before the cavity wall is filled with insulation material, a leak test of the inner and outer shells should be carried out to ensure that the material does not trickle out after installation. This can be done using synthetic smoke which is pumped into the cavity via the filling holes. If smoke comes out the hole can be sealed on the spot. The problem areas where leakage typically occurs are often around windows and roller-shutter casing.

3.5 Other critical features of the building

The occupants of the house can be an important source of useful information which should be taken into account when insulating cavity walls in existing houses. Are there problems with damp around the base of the house? Is there any cladding on the interior walls which would prevent an examination of the masonry? In any case, an on-site meeting with the contractor should be arranged.



Mortar pieces/rubble in the cavity



Endoscope photo of cavity with masonry tie

4 Supplementary examinations

4.1 Thermal bridges

A thermal bridge is defined as a separate and localized area of a building which transmits more heat than the surrounding area. The effect of a thermal bridge is to create spots of reduced temperature which then are prone to condensation and its associated damage as well as mildew. Moreover, these localized thermal bridges lead to increased heat loss and, thus, greater energy consumption.

Filling a cavity wall with insulating material can increase the effect of any thermal bridges such as window reveals. This can result in mildew growth and condensation. Using the WinIso® simulation program, heat flow patterns can be calculated for any given shape or layout and in a wide variety of materials. In the course of the research project, typical construction features (window to wall join, radiator niches) were examined and the impact of cavity wall insulation on them was evaluated.

Particular attention must be paid to the area of the window reveal. If the cavity of an existing house is insulated a displacement of the temperature gradients takes place. In the large majority of cases this increases the risk of mildew and condensation. This effect can be minimized by further insulation of the window reveal using, for example, sheets of calcium silicate. In each case, the specific local circumstances must be considered.

The area surrounding a radiator niche normally presents a similar situation. If the niche itself is insulated or bricked up, condensation can form here too. It must be noted, however, that this is not so critical as in the above case of window reveals. Use of the radiator in winter prevents condensation as the wall surface temperature around the radiator is increased.

Additionally, the influence of header bricks in the walls was examined. The study could not identify any risk of mildew related to headers functioning as thermal bridges. The effect of these areas is insignificant and the surface temperature of the header increases after insulation.

4.2 Damp-related behaviour of walls

One part of the project was to run simulation-based calculations on the thermal and moisture-related (temperature and water) behaviour of external cavity walls. This was done with the help of the Delphin® simulation program and used various given parameters.

These calculations showed that the masonry of an external cavity wall still has the ability to dry out, even after the cavity has been insulated. If, for the purposes of the simulation, it is assumed that the internal wall is damp, then the drying time for an insulated wall is three times as long as a wall with a ventilating (non-insulated) air gap. The drying process takes place towards the interior. Given normal conditions in the room itself (20 °C, 50 % relative humidity) then all of the requirements for effective damp-protection are fulfilled as long as drying out of the wall towards the interior is not inhibited. If, however, the air in the room is not able to absorb sufficient moisture (low temperature, high relative humidity) or if there is a barrier on the interior surface which prevents moisture transfer, then drying out can be inhibited to such an extent that damp-related problems arise.

The results of the project provide a framework for predicting the thermal and moisture-related behaviour of outer walls based on given input data. However, it is recommended that specific data gained from the survey of a house should be used to run a tailor-made simulation. This is of particular importance if the circumstances are unusual e.g.:

- low room temperatures (< 20 °C)
- high humidity in the interior room (> 50 % relative humidity)

water vapour diffusion is inhibited on the exterior surface and/or the interior surface by, for example, a paint layer or tiles

5 Techniques and instructions

The work itself should be carried out by a specialist building contractor.

Sealing the cavity

Before the cavity is filled with insulating material it must be checked to ascertain if it is open at the gable or the eaves. To do this the roof tiles are removed in this area and any sheeting underneath must be cleaned and cut open to reveal the wall cavity. If it is not sealed with header bricks or plates of some kind, the insulating material could leak out at the top of the wall. If this is the case then the cavity must be sealed appropriately. Finally the roof sheeting is fixed back in position using adhesive tape and the tiles replaced.

Insulating via the roof

If it is the case that the cavity must be sealed at the top then it makes sense to take advantage of this and fill the cavity from the top – the tiles have to be removed in any case and the roof sheeting must be cut open – thus making it unnecessary to drill so many holes in the façade. However, some holes will still be required under windows and in sections of wall with restricted accessibility.

Positioning of the injection holes

The insulation material is pumped into the cavity through holes in the façade. The number of holes required and their positioning depends on the material used and the specific circumstances of the house in question. Problem areas such as windows, doors and sections of wall with restricted accessibility must be taken into account when positioning the holes. Thermal bridges will be created at these spots if the cavity is not completely filled.

Injection using small holes

If the cavity is already sealed at the gable end and the eaves then small-hole injection is generally used. In this technique the insulating material is injected through 20-30 mm diameter openings positioned at the intersection of the butt-joint and the bed-joint in the external wall. After injection the openings must be re-pointed and colour-matched. If the interior of the house is being extensively modernized then the injection process can be carried out from inside.

Injection using large holes

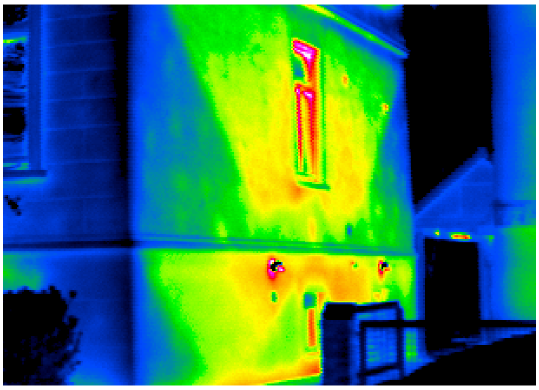
If the joints are not wide enough then complete bricks have to be removed before injection can take place. After injection they are re-inserted using colour-matched mortar.

Small-hole injection uses openings with a diameter of 20-30 mm at the intersection of the bed-joint and the butt-joint.

For the large-hole injection technique complete bricks have to be removed.

6 Quality control

The research project demonstrated that it is highly advisable to carry out a quality control check after completion of the insulation work. 17 buildings were subsequently checked using a thermal imaging camera. In 7 out of 17 cases there were, following an initial assessment, reasons to suspect defects in the work. Working on the basis of these suspicions, the areas with visible defects on the photos were tested using an endoscope and it was confirmed that material was, indeed, missing here. Reasons for suspecting defects are wrong positioning of the filling holes or settling of the material, thus creating thermal bridges where mildew may grow. These areas should be re-filled.



Thermal imaging showing clearly visible defects

Endoscope image → in the area where a defect was suspected there is, indeed, no insulation!

The endoscope examinations show that thermal imaging can be strongly recommended for quality control and as a reliable tool for locating defects. To ensure consistent and reliable results from thermal imaging, the following conditions should be maintained:

- a temperature difference of approx. 15 Kelvin between the interior room and outside the house
- a constant temperature difference
- the area to be examined must not be in sunlight
- other heat sources should be taken into account (neighbours' houses etc.)
- the façade must be dry (no precipitation)
- wind strength < 3 m/s

It must be stressed that some defects caused by settling only become apparent after a certain time. So it is recommended that thermal imaging not be carried out directly after completion of the insulation but during the next heating period.

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