

TECHNICAL NOTE #17

Recommended practice for insulated cavity wall construction

The insulation of external masonry walling in the RSA buildings is not mandatory in terms of the National Building Regulations. This Technical Note details the requirements for walling in terms of Regulation XA and SANS10400XA.

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RECOMMENDED PRACTICE FOR CAVITY WALL CONSTRUCTION

INTRODUCTION

Thermal insulation or thermal resistance is achieved by means of three different mechanisms of attenuation of heat transfer: these define the three types of thermal insulation: resistive, reflective and capacitive, two of which are commonly present in insulated masonry wall assemblies. The third, reflective insulation, is often used in low mass (timber or light steel frame) walling constructions.

RESISTIVE INSULATION

Resistive insulation materials use trapped air or gases which have relatively low thermal conductivity in the structure of the material to limit the amount of heat which can pass through the product.

The condition for effectiveness is that the air (or low conductivity gas) is kept still and dry in tiny pockets, as per the divisions achieved by fibres or cells which entrap the gases.

In an unobstructed wall cavity without insulation, air is entrapped in one large volume, with some lowering of heat transfer. However, convection currents increase the transfer of heat from the warm to the cooler face, and thus a cavity wall without thermal insulation does not have the thermal resistance of one with insulation affixed.

Resistive insulation (also known as bulk insulation) is low in mass and strength, but low in conductivity and thermal capacity. It is supplied in the form of boards, batts (stiff), blankets (flexible), loose fill or is sprayed-on. It is important to have thickness – without thickness the insulation is of little value. It must also be kept free of moisture.

Of all commercially available insulation materials, rigid expanded phenolic foam (PF) achieves lowest conductivity. Rigid expanded polyurethane foam (PUR), expanded polystyrene (EPS) or extruded polystyrene (XPS) board, mineral or rock wool batts (MW), fibreglass (FG) and polyester (PEF) fibre blankets are effective alternatives. Each has an optimal density, fibre length and fibre diameter, or type of gas fill.

The direction of heat flow has no effect on the amount of heat flow in resistive insulation.



CAPACITIVE INSULATION

Capacitive insulation (or mass effect) relies on the high mass and therefore the thermal capacity of dense or heavy materials and their delaying effect on heat flow. The delay of the peak inside temperature to outside temperature is referred to as the time-lag (or flywheel-effect), measured in hours (± 25 mm/h for brick masonry, i.e. 9h for a 225 mm thick wall). Capacitive insulation provides a control of the timing of heat input as it can store the surplus heat at one time, for release at another time when the wall surfaces are cooled.

Heat flow resistance of envelope masonry walls can be gauged by the CR-value, e.g. a 220 mm double leaf brick wall has a CR-value of 40 hours, and a 270 mm cavity wall a CR-value of 60 hours. The CR-value is analogous to the thermal diffusivity of a material.

Capacitive insulation benefits are greatest in climates with a high daily temperature variation, i.e. from 10 to 20 K, as applies in most inland RSA regions, i.e. climate zone 1, 2, 3 and 6, and particularly when the temperature fluctuation coincides with the range of human comfort.

Tables 3 of SANS 204 provide suitable combinations of thermal mass and thermal resistance in the recommended CR-value for various occupancies and climatic zones of South Africa. Table 4 provides how this can be achieved with combinations of thermal insulation and double brick masonry constructions. See also the CBA web-site calculator on www.claybrick.org.

REFLECTIVE INSULATION

Reflective insulation, usually a thin film shiny metallic product (often aluminium foil), has both low emittance and low absorption of infra-red radiation, making it an effective insulator, but only when the foil is facing a cavity of at least 15 mm is it of any value. If in contact with another material a foil will have no effect, as heat flow would take place to or from the foil by conduction.

Foil does not itself have an R-value, but it modifies the thermal resistance (R-value) of the associated air cavity. In a wall configuration reflective foil insulation (with shiny surface facing into an air space) would contribute as long as it remains free of dust or cement or mortar contamination.

Reflective insulation (or reflective foil laminate), usually consists of a laminate of shiny smooth un-lacquered aluminium foil bonded onto a paper and/or plastic layer and reinforced with a fibre scrim. Reflective foil laminate can be combined with resistive insulation to form batts or boards. Such reflective insulation may also be used as a vapour barrier.



INSULATION LAYER SEQUENCE

The sequence of layers with respect to the direction of heat flow is important when capacitive and resistive insulation is combined.

To illustrate this aspect; a concrete roof slab with resistive insulation affixed above the slab will show reduced downwards heat gain to a structure. The high mass slab further delays heat transfer and results in a more stable indoor temperature, compared with insulation on the underside which cuts off the slab's capacitive potential from the room, leading to an unstable indoor temperature. This principle will be true for any part of the building envelope with mass.

Thermal movement of elements on the outside of insulation, e.g. a screed or plaster, being cut off from a heat sink like a concrete slab, will be subject to high temperature fluctuations, often leads to cracking and failure.

CAVITY WALLING DESIGN

GENERAL CONSTRUCTION REQUIREMENTS

The insulation of external masonry walling in the RSA buildings is not mandatory in terms of the National Building Regulations. Details of the requirements for walling in terms of Regulation XA and SANS10400XA are set out below.

The envelope of the habitable portions of buildings of occupancy type where people work, live and assemble, particularly where energy is used in maintaining comfort conditions, can justify the usage of insulated cavity wall construction.

Thermal insulation is sometimes porous, usually relatively soft and is easily damaged. Porous insulation must be kept dry (wet insulation is highly conductive and is therefore worse than no insulation). Therefore thermal insulation will often need to be protected from mechanical damage and moisture ingress.

Insulation must as far as possible be continuous. Thermal bridges must as far as possible be avoided. Gaps or discontinuities and heat bridges can bring about a 20 - 50% reduction in thermal efficiency as heat takes the line of least resistance and finds heat paths around the thermal insulation.

MASONRY WALL INSULATION (HEAVY CONSTRUCTION)

The traditional 200–220 mm wide double leaf solid or cavity masonry wall and the 140 mm single-leaf hollow concrete block wall plastered and painted both meet the SANS10400XA insulation requirements, as does any other masonry wall achieving an R-value of 0.35m²K/W



High thermal performance is achieved from cavity walls with or without insulation. Alternatively they may be solid walls covered on the outside by insulation and cladding or coating systems (External Thermal Insulation Systems). Insulation added to the internal surface of masonry is not ideal as per the layer sequence guidance above, as this leads to temperature instability.

Cavity wall construction will prevent moisture from migrating through porous outer masonry to the inner leaf, and is a useful thermal and acoustic barrier as well. Adding insulation to the cavity is a logical improvement because it can be relatively easily and therefore relatively inexpensively installed. Thermal insulation is well protected between leafs of brickwork.

The construction of cavity walls is as laid down in SANS 2001–CM1 Masonry Walls, particularly in regard to the spacing of wall ties, the cleaning the cavity of mortar droppings and the size of wall panels which may be permissible.

The provision of weep holes at the bottom of the cavity is unnecessary in dry areas since any moisture in the cavity will leave the external leaf by diffusion, but is recommended by some sources for winter rainfall areas and damp climates and is referenced by the NHBRC .

Further good thermal design and practice will require that:

- insulation boards or batts are tightly fitting
- insulation is not damaged or compressed so that the required thickness is maintained
- insulation runs up tight against window and door frames
- thermal bridges are avoided or restricted: reveals around window and door frames should be separated;
- wall ties should be of a non-metallic material
- insulation is kept dry.

The cavity between masonry leaves may be between 50-110mm in thickness, but no thermal advantage is obtained by increasing cavities beyond this. The revised regulations and SANS 10400 Part K is silent in the density of wall-ties but SABS2001Construction works Part CM1 Masonry walling specifies a distribution of not exceeding 450mm vertical centres/spacing and horizontal spacing of 600mm irrespective of the cavity thickness. The SABS 0400 National Building Regulation KK6 (now superseded) required a wall tie distribution of one per 2.5m2 (50mm cavities) greater the 3.0 wall-ties per square meter (70mm cavities) but the requirement is now 3.7 ties per square meter.

Wall ties are also required to be positioned every second course within 300mm of corners for hollow units and within 150mm of the edges of any opening or control joint and at 300mm vertical centres (every fourth course for standard brick sizes).

Brick-force is not recommended but will need to installed above lintels as per the detailed provisions of SANS2001 CM1.



CATEGORIES OF WALL INSULATION

A) FULL FILL CAVITY

In areas where the cavity does not perform a moisture barrier function (most inland regions with summer rainfall) or where exterior wall faces are protected by plaster and paint or by roof overhangs, the cavity width should be the thickness of the required insulation, thus 20–40 mm. Insulation can be added as the wall rises, in heights equal to the vertical spacing of wall ties (<450 mm). Alternatively the inner leaf is built first, with brick-force or wall ties built in, after which excess mortar and droppings can be removed, insulation placed against the cavity face and inspected for tightness, followed by the construction of the outer leaf. Some products advocate that the wall ties are pulled through slits cut in the insulation.

Cavities that do not perform a moisture barrier function can be fully filled by means of loose fill thermal insulation after constructing the cavity wall and cleaning out the cavity. However, care should be taken to ensure that the fill is not affected by moisture or compaction with a reduction in efficiency, and in the upper parts of the wall not having any insulation.

B) PARTIAL FILL

In areas where insulation is to be installed in a cavity that also acts as moisture barrier, the residual cavity is recommended to be at least 20 mm wide plus the thickness of the insulation, totalling a cavity width of 50–110 mm.

The insulation should be placed against the outer face of the inner leaf (the dry side), held in position with clips or fixed onto the wall ties. The best way to achieve this would be to build the inner leaf first, with wall ties at the correct spacing.

Excess mortar and droppings can then be removed and the insulation installed, perhaps by a separate team, before proceeding to build the outer leaf, taking care to regularly clean out the cavity as should be normal practice.

For existing cavity walls, insulation in the form of loose fill can be pumped or blown into the cavity through holes drilled in the external wall face. The holes are filled up later. This method will mainly apply to the winter rainfall areas which have a cavity wall stock. Since these walls were primarily built to act as a moisture barrier, expert advice should be sought regarding the effect of moisture on the insulation (wet insulation is worse than no insulation) and the probability of moisture migration to the inner leaf which needs to be mitigated against.



C) EXTERNAL INSULATION

Insulation on the external face of masonry envelope walls implies that the wall can be a solid wall without cavity, and that when insulated the thermal capacity of the full wall is harnessed. Suitable cladding could be sheeting, board, tile or proprietary coating systems. Sheeting and board could be of metal, plastic or wood, fixed to battens, the space between wall and cladding can be filled with insulation. The contact faces of cladding to battens should have a thermal break consisting of a material with an R-value of not less than 0,2 m²K/W.

Proprietary cladding systems can be used. These are such as sheets, tiles or boards prefixed onto rigid insulation panels and screw-fixed to the building fabric.

RELATED MASONRY AND THERMAL INSULATION ASPECTS

The structural and fire requirements of masonry wall insulation are generally met by virtue of the design and use of clay or cement bricks and mortar of appropriate strength and durability. The masonry will contribute in a minor degree to the resistive insulation aspects, which are mainly met by the positioning of thermal insulation in the structure. Masonry will however add to the capacitive insulation performance of the walling. The combination of thermal mass and thermal resistance is accommodated in a cavity wall construction.

The structural requirements of cavity walling are documented in SANS 2001 CM1 as set out above and result in a distribution of 3.7 wall-ties per square meter.

For cavity insulation the presence of the masonry wall provides the necessary fire protection to the thermal insulation and is deemed to satisfy the regulations. In the case of internal and external wall insulation the protection of combustible insulation materials will require a covering with a fire performance as classified in terms of National Building Regulations and SANS10400 Part L in accordance with a test result to SANS 10177;2006 Part 2 – Fire Resistance.

There are no RSA regulatory or standards aspects dictated for damp and moisture management in insulated walls or the positioning of vapour barriers. However good practice is to follow International practice and those set out in insurance industry standards, such as The Loss Prevention Council.



BUILDING CAVITY WALLS

The correct design of insulated cavity walling is the first step in correctly building long lasting insulated walling. Actually building the walls requires attention to the following aspects:

A) FOUNDATIONS

Strip foundations for cavity walls should be built to the standard 500mm width. Foundation walls should be built to the normal (280/290mm) width and will be collar-jointed walls or grouted walls with wall-ties.

B) WALL DIMENSIONS

Free-standing external walls up to 2.6m can then be constructed with piers (2.2m without piers). The cavity width may not exceed 110mm and should be constructed to a minimum of 50mm thick. Wall panel and gable sizes are constrained by the masonry unit used and the maximum allowable panels sizes and spans are set out in Tables 1 to 6 of SANS2001 CM1.

C) DAMP PROOFING

Weep-holes should be formed in the outer leaf at intervals not exceeding 1.0m and should be immediately above a 200micron PVC damp-proof course (DPC) layer. This DPC shall be constructed so as to step down from one course of brick to a lower level on the outer leaf such as to shed moisture outwards. In cases where the insulation is installed into the foundation wall below slab level it may be necessary to use single course damp-proofing.

D) CAVITIES

The cavity between courses of brick shall be kept clean of mortar droppings. A 38 x 38 mm timber brandering strip dragged progressively up the wall cavity on strings between the fixings of wall ties can be used to this end. Cavities may be between 50mm and 110mm maximum width.

E) WALL TIES

Butterfly or PWD Wall ties in accordance with SANS 28 shall be used for cavity wall construction. In coastal regions shall be manufactured from galvanised wire and in sea spray zones stainless steel of grade 816. Wall ties shall be fixed at not greater that 450mm spacing in height and 600mm horizontal interval.

Additional wall ties shall be fixed adjacent to openings and movement and control joints. These shall be at minimum 300mm vertical spacing if within 150mm of such openings or joints.



F) WINDOW AND DOOR DETAILING

The design of cavity walling around openings should provide to avoid heat bridging. The sketches below provide guidance.

G) THERMAL INSULATION POSITIONING

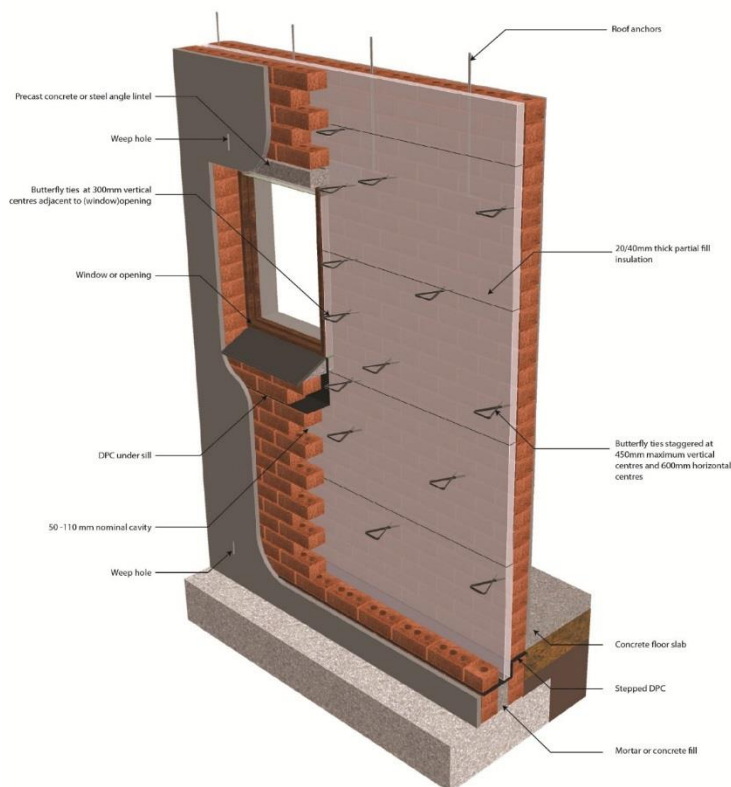
Thermal insulation should be selected in accordance with the guidelines given above in relation to full or partial cavity fill. Thermal insulation should be positioned against the internal leaf (built up to a convenient height) and slits cut in the boards opposite the protruding wall-ties and these wall ties should then be pulled through the insulation such as to hold the insulation in place.

Care should be taken to align insulation joints which is suggested are ship-lapped rather than tongue and grooved.

F) SEALING OF WALL PLATE TO TILE UNDER-LAY

The continuity of the cavity wall insulation with roof insulation is important. Gaps and discontinuities in the insulation will severely compromise its performance.

CONSTRUCTION DETAILS





RECOMMENDATIONS FOR LONG TERM THERMAL PERFORMANCE

For long term efficacy the specification of and fixing of thermal insulation in cavity walls should be such that the material is sufficiently rigid, dimensionally stable and is adequately fastened such that it will maintain its position, thickness and coverage. The quality of workmanship will need to be taken into account by building professionals. Discontinuities and gaps of a few millimetres between sheets of insulation can cause significant loss (20 to 50%) of thermal performance, and hence the supervision of workmanship is an aspect which can add to installed material performance.

Thermal bridging via wall ties and brick force will undermine the theoretical values obtained with traditional Thermal Resistance calculations, and allowance for these highly conductive elements should be built into calculations. Estimation methods to be applied to account for these conductive elements are provided for in ISO6946, the Building Research Establishment publication: Conventions for U-value calculations, 2006 and via the ASHRAE Zone Method.

If the design does not build in for protection of the systems via moisture barriers, these moisture effects should be allowed for in the Thermal Resistance calculation, particularly in damp climates in accordance with ISO10456; Building materials and products – Hygrothermal properties – Tabulated design values and procedures for determining declared and design values.

The Clay Brick Association and Thermal Insulation Association members have tested a number of insulated masonry systems to ASTM C1363; Thermal Resistance using the Hot Box method and the correlation to calculated Thermal Resistance is good, provided allowance is made for the highly conductive wall reinforcing .

Consideration should also be given to discontinuities between insulation systems in between the roofs and walls, and in between walls and floors/perimeter insulation as it is in these areas that heat leaks often take place.

CONCLUSIONS

It should be clearly stated in drawings and specifications as to where and how thermal insulation is positioned and fixed in masonry walls. It is intended that this document will serve as a guide to insulated cavity wall construction and that the further development of this material into National Standards will follow.



In this paper the design R-Values and insulation thicknesses have been selected by applying SANS/ISO6946; Building components and building elements – Thermal Resistance and thermal transmittance – Calculation method, and thermal conductivity co-efficient results as published by the various suppliers, in order to meet the requirements of South African National Building Regulations and Standards. Design R-values should be adjusted for the thermal conductivity co-efficient test conditions where these test conditions are not appropriate.

Thermal insulation systems available for use with masonry walling are many and varied. Specifiers should therefore familiarise themselves with the relative advantages and disadvantages of these possible solutions.

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For further information:

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