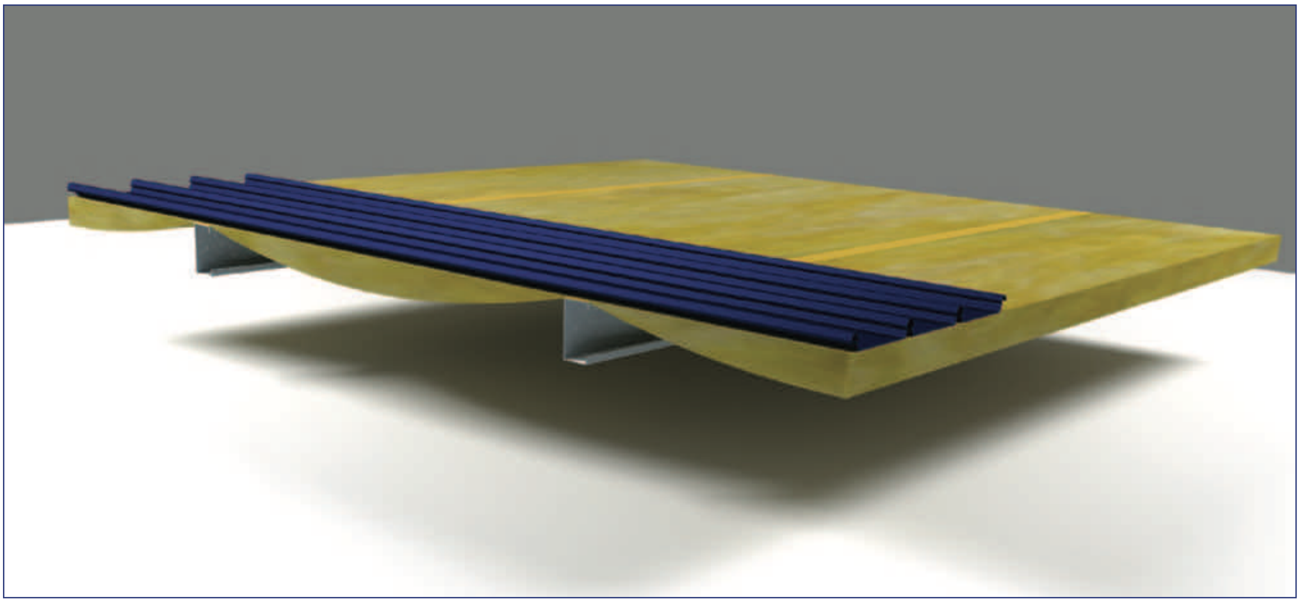
Dissecting the effects of compression

Recent 2D thermal simulations carried out on common South African roof assembly details have provided valuable new data on the detrimental effects that compression of bulk insulation has on the overall thermal performance and energy efficiency of roofs. Dion Marsh tells us more.

Article and images provided by: Dion Marsh, General Manager of Ash & Lacy South Africa (Pty) Ltd.



Insulation over purlin with no spacer.

The prescriptive route of compliance in SANS10400-XA stipulates that a prescribed total minimum R-value be achieved in roof assemblies based on the building classification and geographical location. It is widely accepted that the most efficient location for insulation is over purlin. A continuous layer of insulation is achieved and, if installed correctly, it eliminates thermal bridging almost entirely.

Bulk insulation blankets or quilts provide a cost-effective and flexible solution in achieving these prescribed R-values. However, the insulation needs to maintain its thickness and position *throughout the building envelope assembly* in order to achieve its designed thermal resistance. Compression of insulation will proportionately *lower* the thermal resistance of the material, resulting in a reduced thermal performance.

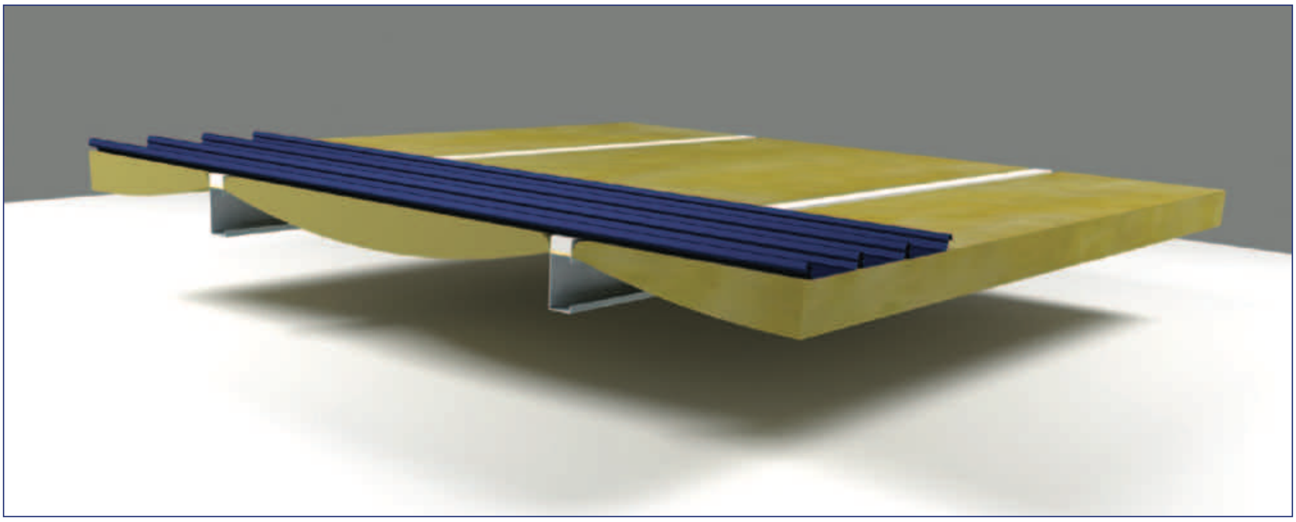
It is still common practice for glass fibre blankets or quilts to be installed over purlin below a single skin steel roof assembly without the use of a roof spacer system. The insulation is supported by basic straining wire and draped between purlins to allow for some recovery in the material's loft. Variations of this detail utilizing continuous XPS or timber packers are sometimes employed to improve loft recovery, but these methods still result in varying degrees of compression.

These roof assembly details have been the topic of discussion at both TIPSASA (Thermal Insulation Products & Systems Association SA) and SAMCRA (Southern African Metal Cladding and Roofing Association) technical committee meetings, and have come under increased scrutiny. The question being asked is whether the current construction details and methods being used are achieving the prescribed minimum requirements stipulated in the National Building Standards.

COMPRESSION TESTS

A recent series of compression tests were commissioned by Ash & Lacy Building Systems Ltd UK and carried out by Oxford Brookes University to establish the effect of compression on the thermal conductivity and thermal resistance of a glass fibre quilt under these particular site assembly conditions.

The tests revealed that, when fixed directly below a steel roof sheet and/or packer, a 155mm glass fibre quilt with a density of 12kg/m^3 is compressed at the purlin to a thickness of less than 5.0mm, resulting in a density of 328.6kg/m^3.



Insulation over purlin with XPS or timber packer.

The thermal conductivity of the compressed insulation increased marginally from 0.038W/mK to 0.046W/mK, whilst the thermal resistance decreased dramatically from 4.079m^{2}K/W to 0.109m^{2}K/W.

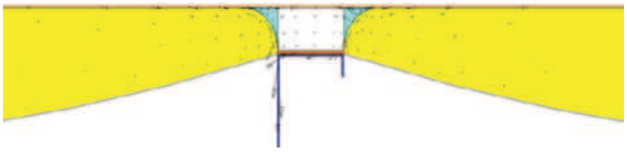
South African Building Standards stipulate that an overall minimum R-Value has to be achieved by building envelopes, but allows for insulation to cross purlin lines *provided that* a thermal break of 0.2m^{2}K/W is introduced. The Oxford Brookes University test results confirmed that a compressed 155mm, 12kg/m^3 glass fibre quilt between a single skin steel weather sheet and purlin does not achieve this required thermal break requirement.

The results of the Oxford Brookes University tests, coupled with a distinct lack of credible thermal performance data on SA roof assemblies, prompted Ash & Lacy South Africa to undertake an accurate thermal simulation study using THERM 7.4.3.0 Thermal Simulation Software developed at Lawrence Berkeley National Laboratory. The aim of the study was to produce a comprehensive set of accurate and definitive thermal performance data for commonly used insulated roof assemblies in SA by means of thermal modelling, utilizing data obtained from practical field mock-ups, case studies, accredited third-party test results, and published material properties.

TEST RESULTS

A total of twelve (12) roof assemblies were modelled and simulated. Nine (9) of these assemblies were based on actual assemblies commonly used in South Africa whilst three (3) models were based on theoretical assemblies with a continuous uncompressed layer of insulation with no thermal bridges. The simulation results of the actual assemblies were compared to the theoretical assemblies to show the percentage of total R-value loss.

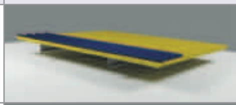
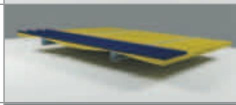
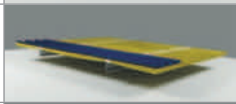
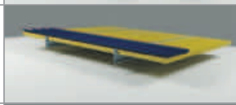
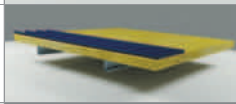
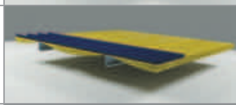
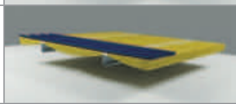
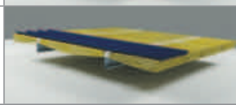
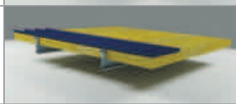
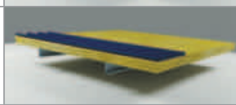
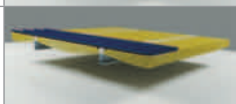
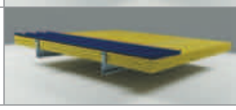
1. The percentage in R-value loss varied dramatically, ranging between 2% - 72% depending on the assembly, the presence of a spacer system, the type of spacer system, and the extent of compression incurred by the insulation.
2. The simulated flux vectors and isotherms revealed that a significant amount of thermal movement (bridging) occurs at the purlin lines when the insulation is compressed directly below a roof sheet.



Example of flux vector paths at purlin lines.

3. A similar pattern in flux vector movement occurs in assemblies where the insulation is compressed below the XPS packer/spacer. Although the XPS packers have an excellent thermal resistance, the compressed insulation that exits from below the packer on either side of the purlin is only 4mm - 5mm thick, with a thermal resistance of between 0,086m^2.K/W - 0,108m^2.K/W. A significant amount of thermal bridging occurs at these lines. The flux vector movements in the simulation are concentrated in these areas.

   Another significant result of the simulation was the flux vector paths at mid purlin. These vectors, which would ordinarily have had a more vertical path, tend to travel more horizontally within the insulation directly below the steel roof sheet – in a path that gravitates towards the air gaps and compressed insulation at, and adjacent to, the purlin lines. This increased thermal movement gravitating towards the purlin lines also results in thermal movement diagonally through the sides of the XPS packers where their thickness is only a percentage of their overall depth.
4. Only three (3) out of the nine (9) typical assemblies achieved an R-value percentage loss of less than 5%. These were the assemblies that utilized a bar and bracket-type mechanical spacer system, which does not cause compression of the insulation at purlin lines. The fractional R-value losses incurred by these assemblies were attributed to small air gaps below the profiled bars and a thermal bridging percentage of approximately 0.1% at the bracket positions.

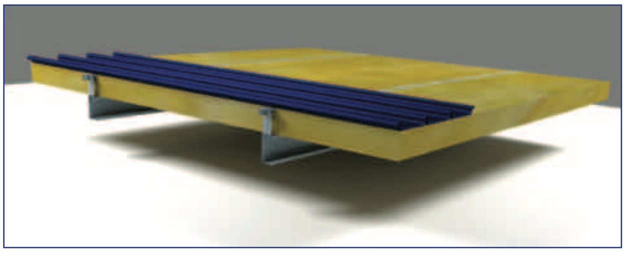
SUMMARY OF SIMULATION TEST RESULTS			
DESCRIPTION OF ROOF ASSEMBLY	**IMAGE OF ROOF ASSEMBLY**	**TOTAL R-VALUE (ACTUAL)** $m^2.K/W$	**R-VALUE PERCENTAGE LOSS** %
75mm Glass Fibre 12kg/m^3, Over Purlin 1800mm Centres, Uncompressed (Theoretical), Concealed Fix Weather Sheet		2.1451	0% LOSS
75mm Glass Fibre 12kg/m^3 Over Purlin, 1800mm Centres , Concealed Fix Weather Sheet		1.0043	53% LOSS
75mm Glass Fibre 12kg/m^3 Over Purlin 1800mm Centres, 40mm XPS Spacer, Concealed Fix Weather Sheet		1.8114	16% LOSS
75mm Glass Fibre 12kg/m^3 Over Purlin 1800mm Centres, 85mm Ashgrid Spacer, 10mm Airgap, Concealed Fix Weather Sheet		2.1165	1% LOSS
135mm Glass Fibre 12kg/m^3, Over Purlin 1500mm Centres, Uncompressed (Theoretical), Concealed Fix Weather Sheet		3.7435	0% LOSS
135mm Glass Fibre 12kg/m^3, Over Purlin 1500mm Centres, No Spacer, Concealed Fix Weather Sheet		1.0341	72% LOSS
135mm Glass Fibre 12kg/m^3 Over Purlin 1500mm Centres, 40mm XPS Spacer, Concealed Fix Weather Sheet		2.6077	30% LOSS
135mm Glass Fibre 12kg/m^3 Over Purlin 1500mm Centres, 75mm XPS Spacer, Concealed Fix Weather Sheet		3.1181	17% LOSS
135mm Glass Fibre 12kg/m^3 Over Purlin 1500mm Centres, 135mm Ashgrid Spacer, Concealed Fix Weather Sheet		3.6425	3% LOSS
150mm Glass Fibre 12kg/m^3, Over Purlin 1500mm Centres, Uncompressed (Theoretical), Concealed Fix Weather Sheet		4.0972	0% LOSS
150mm Glass Fibre 12kg/m^3 Over Purlin 1500mm Centres, 75mm XPS Spacer, Concealed Fix Weather Sheet		3.3288	19% LOSS
150mm Glass Fibre 12kg/m^3 Over Purlin 1500mm Centres, 150mm Ashgrid Spacer, Concealed Fix Weather Sheet		4.0343	2% LOSS

CONCLUSION

SANS10400-XA stipulates that a prescribed minimum total R-value be achieved based on the building classification and geographical location. These minimum requirements are not being achieved in a large majority of new buildings being constructed in South Africa, due to compression caused by incorrect installation methods. This negatively impacts on the overall energy efficiency and associated operational costs incurred over the life cycle of the building.

The additional costs associated with the incorporation of a suitable spacer system into the roof assembly design remain negligible when considering the cost savings achieved by insulation that ultimately achieves its full design capability over the life cycle of the building.

Achieving energy-efficient, structurally sound and compliant roof assemblies no longer has to be an onerous task for professionals and contractors.



Insulation over purlin with bar & bracket spacer.

With proven installation methods and tighter on-site quality control, bulk insulation, whether used in single skin or dual skin applications, can still achieve its well earned reputation as an affordable solution in achieving excellent thermal, acoustic and fire performance.

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