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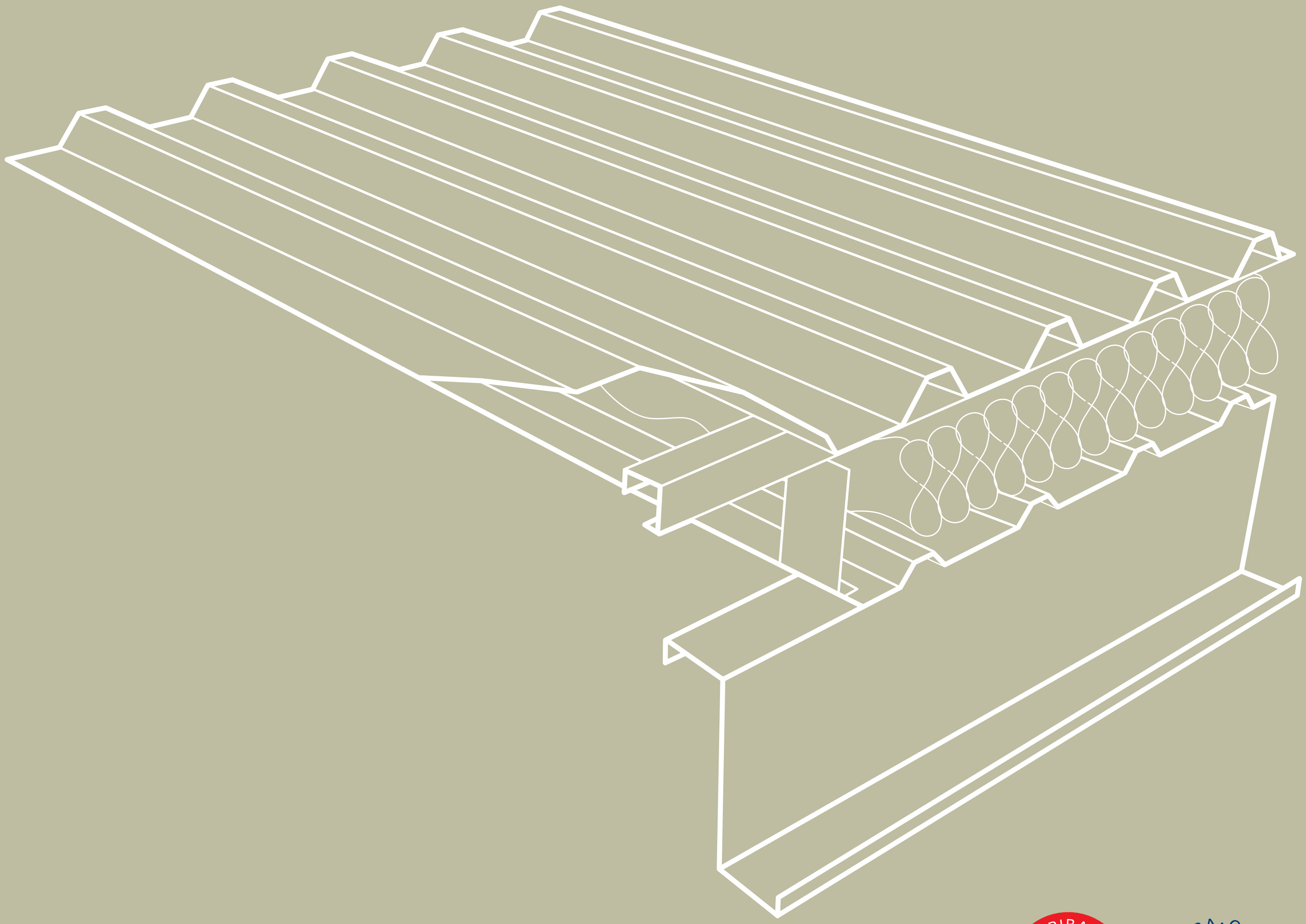
Corus Colors

Colorcoat® Technical Paper

Structural performance of built-up roof and wall cladding systems



Corus and structural integrity

Corus is a company committed to providing the very best pre-finished steel products for use in roof and wall cladding systems. These systems rely upon the structural integrity of the profile shape and the stability and interaction with other structural components to ensure fitness for purpose when subject to external forces.

Corus have a well established reputation for providing specifiers with comprehensive advice and guidance to support the design and construction of metal clad buildings. Together with the SCI, Corus have evaluated individual profiles from four cladding system suppliers and their associated components for use within built-up cladding systems to confirm their strength and stability to meet the structural requirements of the building regulations in the UK.

Working together with the Steel Construction Institute (SCI)

The SCI is an independent, member-based organisation. It is probably the world's largest research and technical organisation supporting the use of steel in construction. Since its formation in 1986, SCI has played a leading role in technical innovation and information dissemination; helping the steel construction sector achieve a world-leading market share for steel.

Contents

Overview

There are many considerations in specifying a metal roof or wall cladding system. While it is fashionable to talk about energy conservation and aesthetics, one of the fundamental and often forgotten considerations is the structural ability of the system as a whole. This Colorcoat® Technical Paper aims to give the specifier a good understanding of what structural performance should be expected of a cladding system and reassurance that by specifying a tried and tested system, the structural performance will be guaranteed.

Comparing today's pre-finished steel roof and wall cladding systems to those of 10 years ago, the key driver for change has been the integration of and increasing thickness of insulation within the cavity. Many cladding systems have been developed to allow for these deeper cavities, but it is essential to specify a system which is structurally proven in a real-life situation and to consider the necessary load-paths in the cladding design.

Corus have teamed up with the SCI to conduct an in-depth study into the structural behaviour of built-up cladding systems, including testing complete systems and their components and an evaluation of published load/span data for profiled sheets. This Technical Paper presents the principal findings of this study together with guidance on structural aspects of the specification of built-up cladding systems.

The results categorically prove the structural integrity of these systems up to a depth of at least 220 mm, giving confidence that even for U values as low as 0.20 W/m^{2}K, built-up wall and roof cladding systems will continue to perform.

Structural considerations

Built-up systems

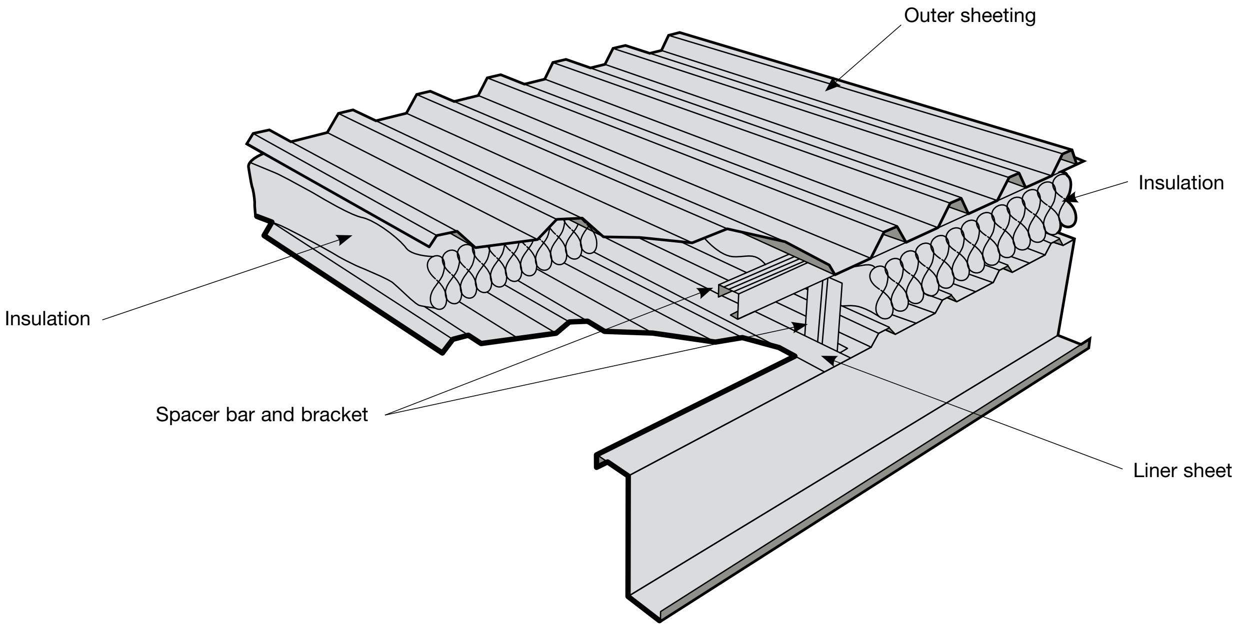
In its pure form, a built-up cladding system consists of a profiled metal liner, a layer of insulation material, a spacer system and an external metal sheet. The internal and external sheets have different functions and this is reflected in their design.

The primary functions of the internal liner sheet are to provide an airtight barrier, to support the weight of the insulation and to assist with purlin restraint. Liner sheets are not generally regarded as structural components and tend to possess a shallow trapezoidal profile. The dimensions of the profile vary from manufacturer to manufacturer, but a typical depth is 17 mm to 20 mm rising to 36 mm for certain applications. For steel liners, the sheet thickness is usually 0.4 mm or 0.7 mm.

As well as forming a weather-tight envelope, the external sheet also plays an important role as a structural element, supporting the externally applied loads. The external sheet must also provide a safe means of access during construction of the roof and any general maintenance that may be required. In order to meet these requirements, trapezoidal external sheets generally have a profile depth in the range 32 mm to 35 mm for a typical purlin spacing of 1.8 m. The steel gauge for these sheets is normally 0.7 mm for roof applications and 0.55 mm for wall.

The other structural element in built-up cladding systems is the spacer which transmits the loads to the supporting steelwork and provides the correct spacing between the internal and external sheets. The bracket and rail system shown in Figure 1 is one of several types of spacer system widely available. Specifiers should consult their suppliers for further details of individual products or systems.

Fig. 1. A typical built-up cladding system



Profile capacity

Profiled sheets are available in a wide range of shapes, sizes and forms. Variations include depth, pitch, gauge and the use of stiffening ribs. The correct choice of profile for a particular application will depend on the magnitude and direction of the applied loading, the distance between supports (purlins or rails) and whether the sheets are single, double or multiple spanning.

To enable specifiers to make an informed choice regarding the profile shape and size, the profile manufacturers publish tables of safe loads over a range of typical spans.

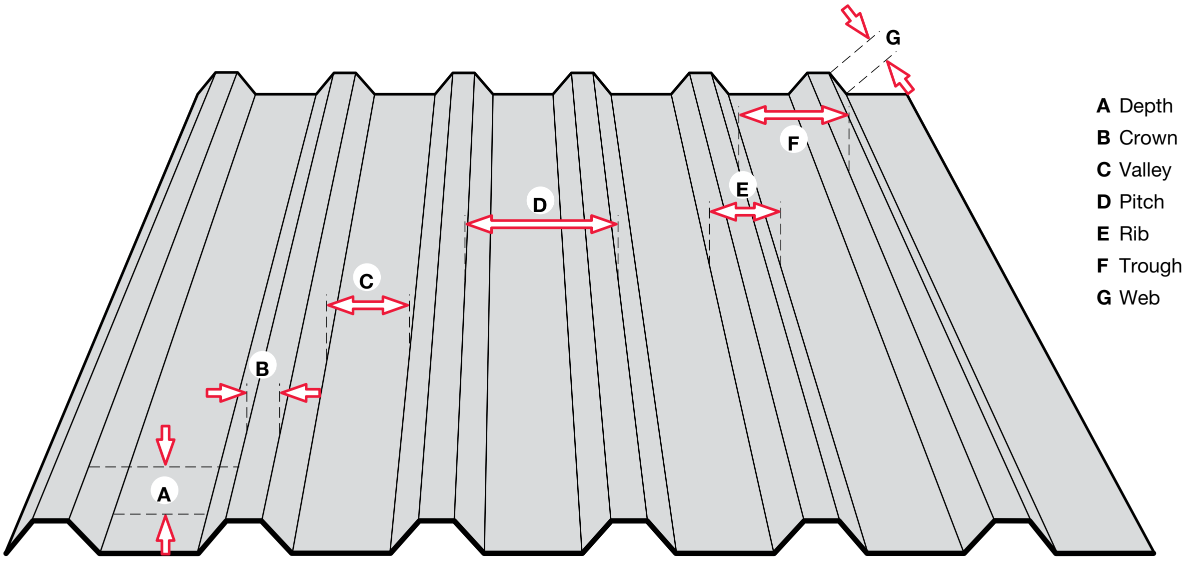
The data on which these tables are based is obtained either from tests or by calculation to BS 5950-6: 1995. Of these, the calculation approach is the more common for the types of profile used in roof and wall cladding.

Design to BS 5950-6: 1995 takes account of the following criteria:

- Ultimate bending capacity of the profile flanges
- Web crushing at the support
- Shear capacity of the webs
- Deflections
- Combinations of the above

The failure loads corresponding to each of the criteria listed above are calculated at either the ultimate or serviceability limit state according to the recommendations of BS 5950-6: 1995. However, for simplicity, any capacities calculated at the ultimate limit state are usually divided by a load factor of 1.5 to obtain working load values. The 'safe working load' given in published load/span tables is the lowest of the individual failure loads.

Fig. 2. A typical trapezoidal profile indicating common nomenclature



The load capacities calculated to BS 5950-6:1995 are only valid if the profiles have been manufactured to the tolerances specified in BS 5950-7: 1992 using material that has been produced to the appropriate British and European Standards. Specifiers should ensure that this is the case by specifying systems that have been assessed by Corus, SCI or an independent accreditation body.

Reliability of load tables

To ensure the reliability of information provided, Corus, with the support of SCI, have assessed the published load/span data provided by the leading roof and wall cladding manufacturers:

- **CA Building Products**
- **Corus Panels and Profiles**
- **Euroclad**
- **Tegral**

In each case, the load/span tables of the most popular profiles were investigated.

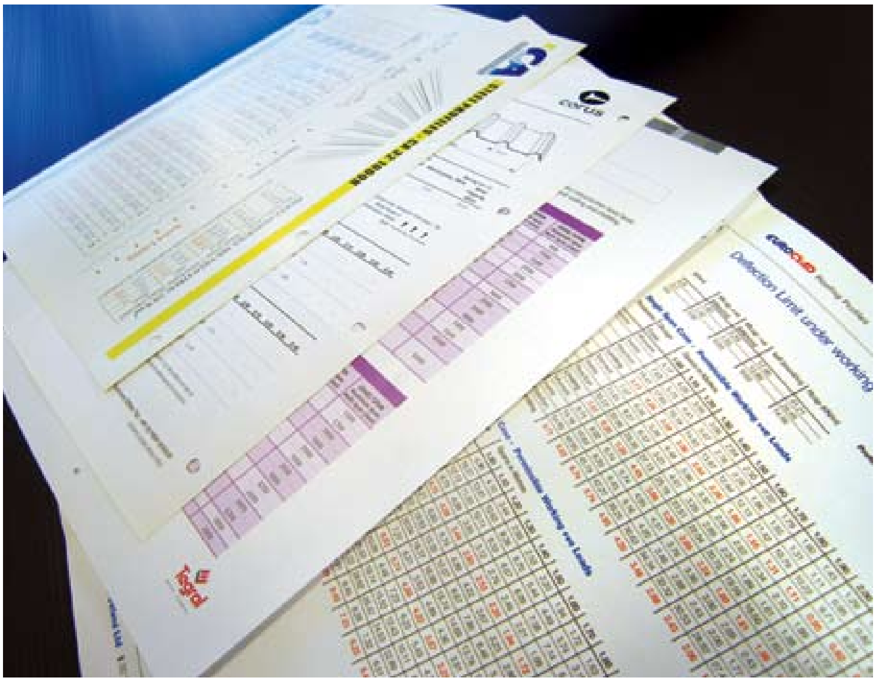
The load tables and supporting documentation were checked against the structural requirements of BS 5950 Part 6. The assessment included:

- a review of the design methodology and the equations used to generate the design data;
- a detailed examination of the implementation of these equations, including the accuracy of the results; and
- verification that the calculated capacities had been correctly presented in the published load/span tables.

Where appropriate, section properties and profile capacities were calculated independently using SCI's own software and compared with the manufacturers' data.

Note that the checks carried out by SCI and reported here were specific to the cladding systems of the four named manufacturers. The data published by these suppliers should not be applied to similar products manufactured by others.

In all cases it was found that the published load/span tables represent a safe estimate of the load/span capability of the profiled metal cladding sheets under the action of uniformly distributed gravity and wind uplift loads.



Leading roof and wall cladding manufacturer's load tables.

Load paths

The architect and the structural engineer, who between them are responsible for the specification of the cladding and the supporting steelwork, must give careful consideration to the load paths between the cladding sheets and the primary structural steelwork. This is especially important for roof cladding carrying down-slope loads and built-up wall cladding supporting vertical loads.

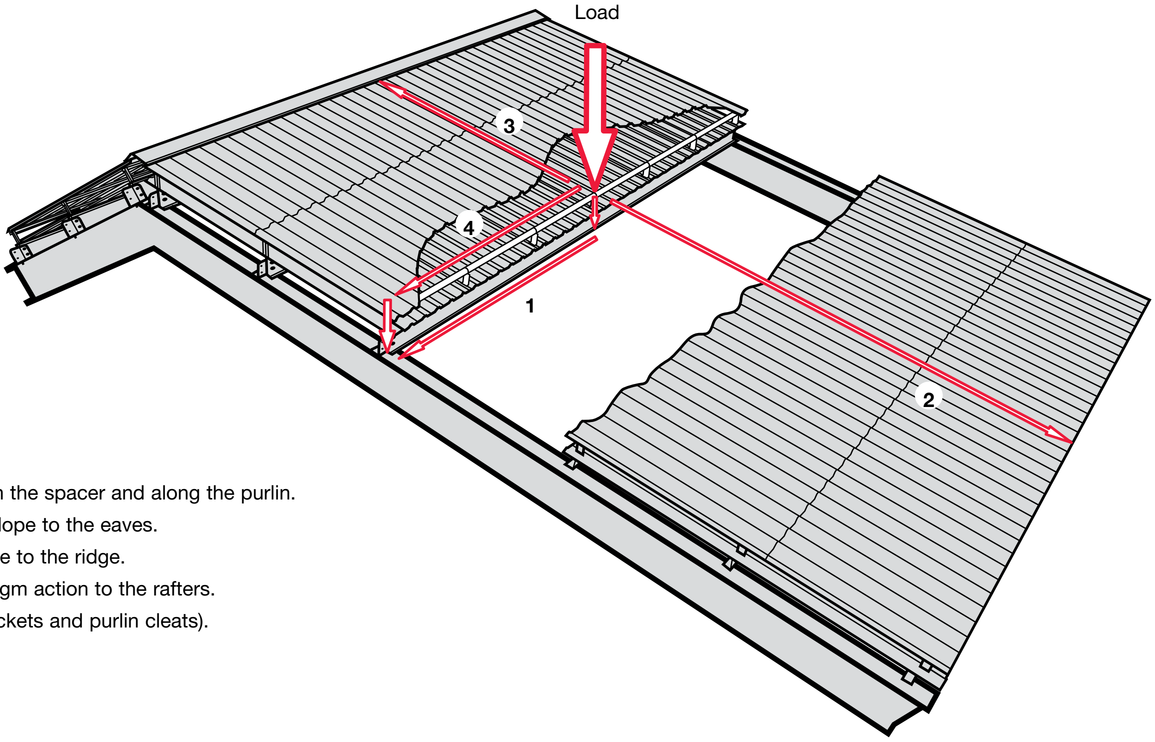
In the case of built-up roof cladding, there are four potential load paths as shown in Figure 3:

1. Through the spacer system to the purlins and then back to the rafters;
2. Through the external sheet down the slope to the eaves;
3. Through the external sheet up the slope to the ridge;
4. In diaphragm action through the external sheet and then via the spacer brackets to the rafters.

Where multiple load paths exist, the load will be distributed according to the relative stiffness of each path. Load path 3 will be particularly stiff (due to the cladding being in tension), but its ability to carry the load will depend on the detail at the ridge. Designers wishing to utilise this load path must ensure that sufficient fasteners are used together with a suitable tie rod between the ridge purlins. The ability of the cladding system to transfer load by diaphragm action (load path 4) will depend on the type of cladding, the number of seam fasteners and the presence of roof lights or other penetrations. It will also depend on the existence of suitable connections at the edges to permit load transfer into the rafters.

The proportion of load taken through the spacer system (load path 1 in Figure 3) will naturally depend on the stiffness of the spacer system relative to that of the other three load paths. This issue was the primary focus of the in-plane tests conducted at the NAMAS accredited laboratory and reported here.

Fig. 3. Load paths in a built up cladding system



1 Through the spacer and along the purlin.
2 Down slope to the eaves.
3 Up slope to the ridge.
4 Diaphragm action to the rafters.
(via brackets and purlin cleats).

Purlin restraint

Cold-formed steel purlins and side rails are extremely efficient at carrying loads by bending action, but they are susceptible to failure through lateral-torsional buckling unless they are adequately restrained. Suitable restraint can be provided by profiled metal sheeting, but it is important to ensure that the design of the sheeting (gauge, profile geometry and fastener arrangement) is suitable. Use of a built-up cladding system from a reputable supplier should ensure that this is taken care of.

In the gravity load case, where the connected purlin flange is in compression, the sheeting provides lateral restraint directly to the compression flange of the purlin through the fasteners.

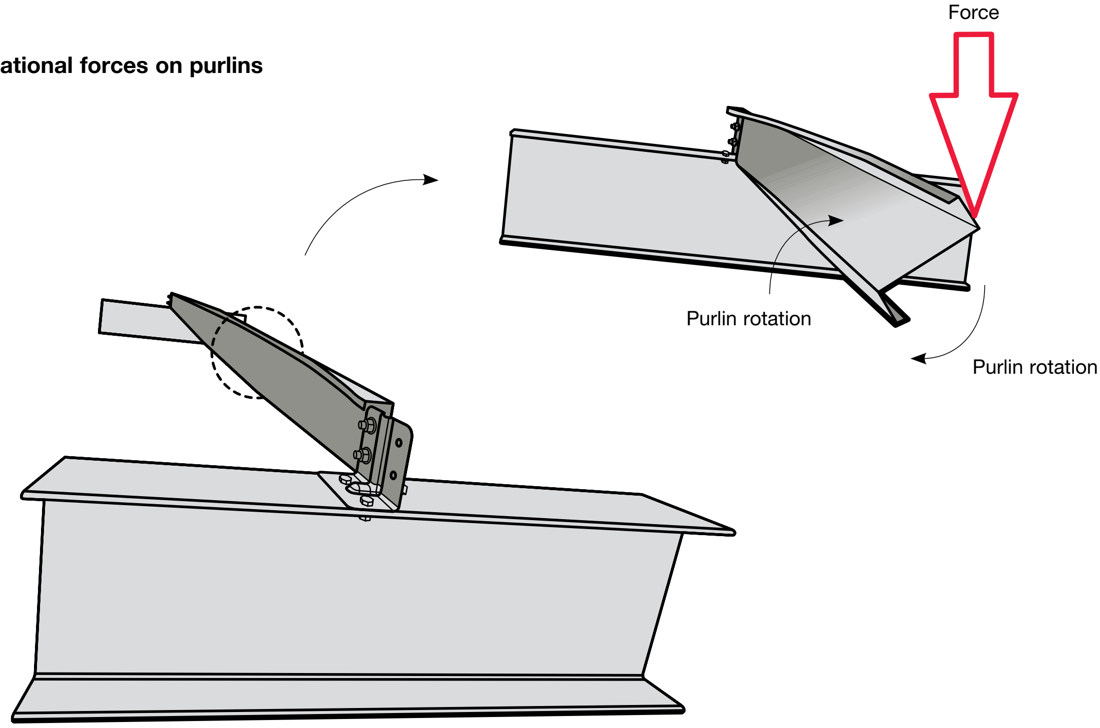
In the uplift case, where the connected flange is in tension, the sheeting provides a combination of lateral restraint to the tension flange and partial torsional restraint.

It is common for the manufacturers of purlins and side rails to assume that a certain degree of restraint is provided by the cladding sheets when producing the data for their load/span tables.

This approach permits a considerable improvement in the structural performance of the purlins and rails over their unrestrained capacity, provided that the assumed restraint is available in practice.

It is therefore important that the chosen cladding system is capable of providing the required degree of restraint and that it is detailed with the correct type and number of fasteners. The results of physical testing reported in this paper prove that for the systems tested, there is a high degree of restraint provided by the cladding system.

Fig. 4. Rotational forces on purlins



Structural test programme

Overview of tests

A programme of tests was undertaken at a NAMAS accredited laboratory No. 0312 to determine the performance characteristics of typical built-up cladding systems and to verify their structural adequacy.

There were three categories of test:

- In plane loading of the assembly to determine the component stiffnesses and identify the likely load paths.
- Gravity loading on an inclined roof assembly.
- Uplift test on purlin restrained by cladding assembly.

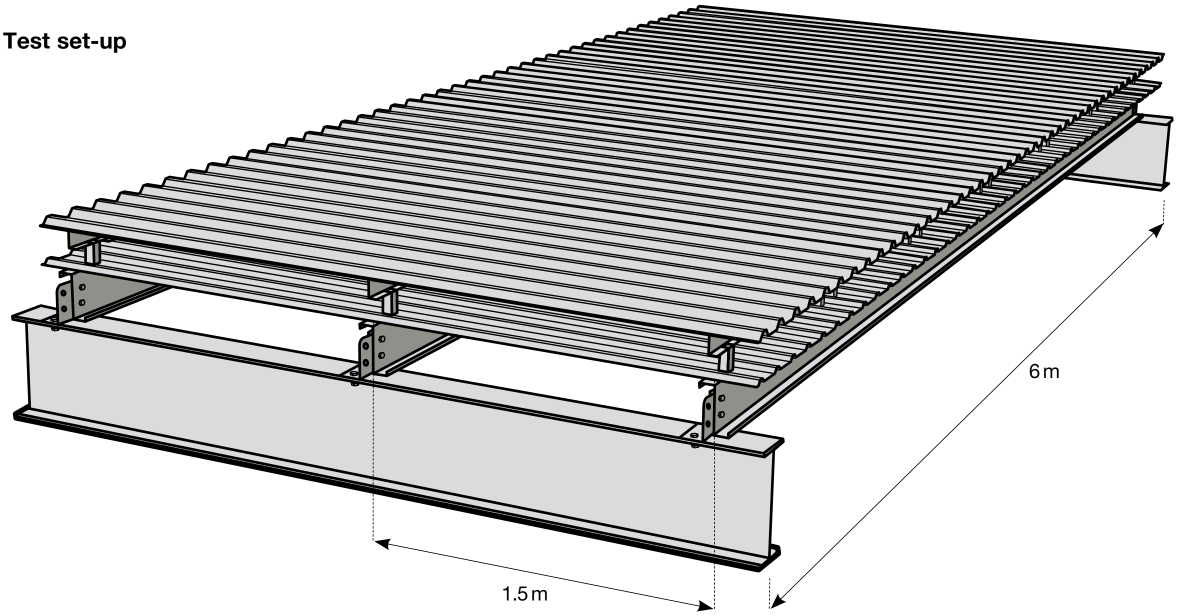
Test set-up

The configuration used was typical of that within a portal framed building. The tests were conducted on a 3 m x 6 m section of built-up roof supported on three 1.5 mm thick x 202 mm deep Zed purlins set at 1.5 mm centres spanning 6 m between hot rolled steel beams.

A steel trapezoidal external sheet with a profile depth of 32 mm and a nominal steel thickness of 0.7 mm was used together with a 0.4 mm thick 19 mm deep liner sheet as this is the most common combination of profiles used in practice. Testing was also performed using a 0.7 mm x 32 mm liner sheet which gave similar results.

Several types of spacer were included in the programme, including a bracket and rail system and proprietary spacers manufactured by CA Building Products and Euroclad. Spacer depths of 180 mm, and 220 mm were selected to represent the maximum foreseeable insulation thicknesses required for Building Regulations on the conservation of fuel and power. Although actual U values are dependant on insulation type and exact build-up, these spacer depths would typically give U values of around 0.25 W/m²K and 0.20 W/m²K respectively.

Fig. 5. Test set-up



In-plane tests

In-plane 'pull' tests were carried out to determine the in-plane stiffness of a typical built-up cladding system and the contribution of the liner and external sheets to the overall stiffness of the assembly. Tests were conducted with and without the external sheet and compared to the base case of purlin and spacer alone.

The in-plane tests were performed on:

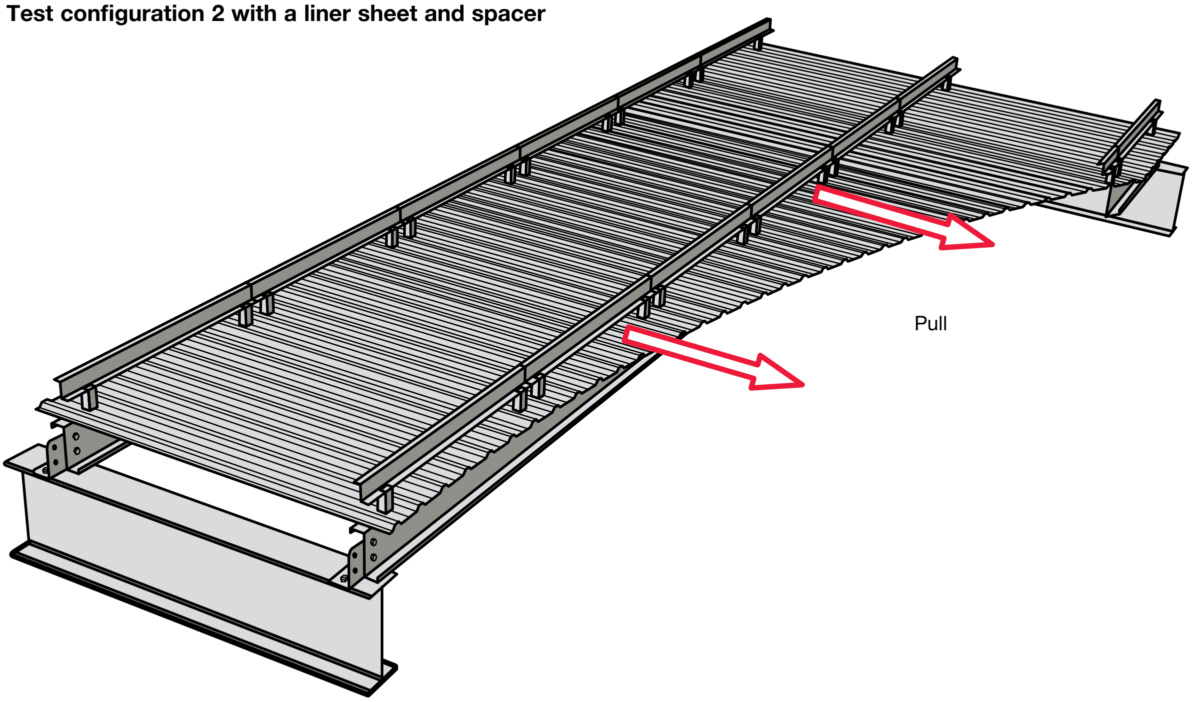
1 Spacers and purlins alone.
2 A partly completed assembly comprising the purlin, spacer and liner.
3 A complete built-up cladding assembly (minus the insulation).

This incremental approach permitted the contribution of the various components to the overall stiffness of the cladding assembly to be determined in addition to the performance of the complete system.

In this series of tests, horizontal forces were applied to the quarter points of the central purlin to produce lateral movements in the purlin and the other elements of the cladding assembly. The load was applied to the external sheet of the built-up system, or the top of the spacer if no external sheet was present, and deflections were measured at the key points.

Measurements of load and deflection were taken at frequent intervals throughout the tests. Analysis of these results yielded values of stiffness, which may be used to estimate the degree of purlin restraint available from the cladding and to predict the likely load path through the cladding assembly.

Fig. 6. Test configuration 2 with a liner sheet and spacer



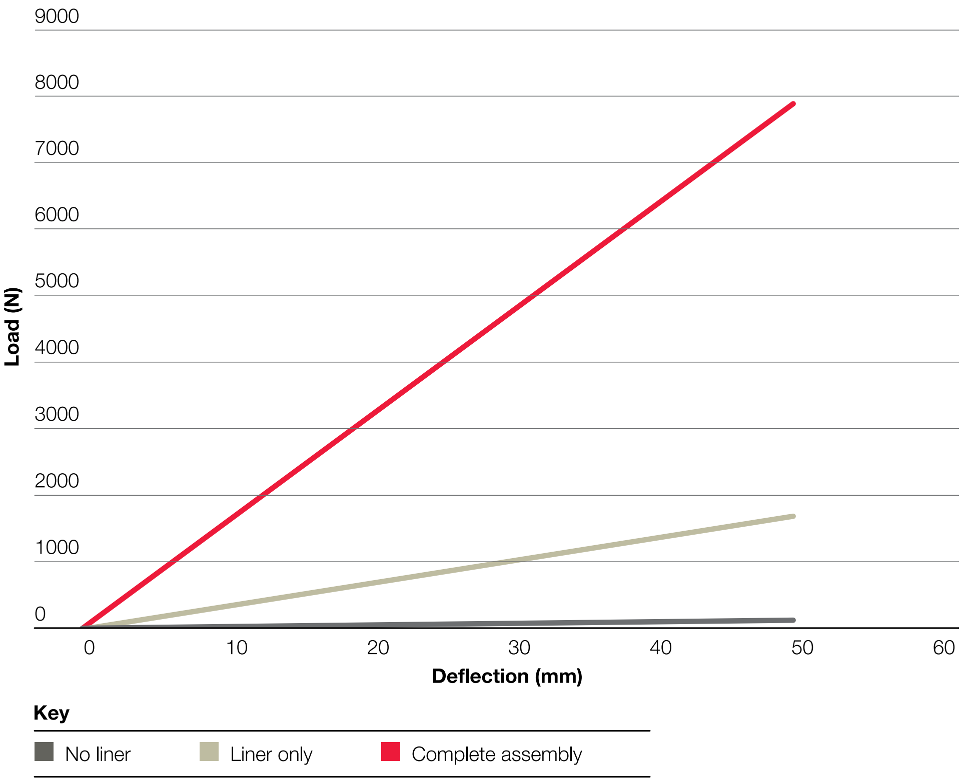
In-plane tests: results

Plots of load against mid-span deflection at the top of the spacer (calculated from measured stiffness values) are shown below. Plots are included for the spacer alone, the spacer with liner sheet and the complete assembly in order to illustrate the impact on the stiffness of the liner and external sheet. The results of these tests give the following values for overall stiffness of the system:

Table 1. Comparative stiffness results

Case	Stiffness (N/mm)
Spacer alone	1.81
Spacer with liner	33.8
Complete assembly	158

Fig. 7. In-plane stiffness with and without liner and external sheets



The results demonstrate that the liner and external sheets contribute significantly to the in plane stiffness of the built-up cladding assembly, resulting in an overall system stiffness 87 times greater than that of the spacer alone.

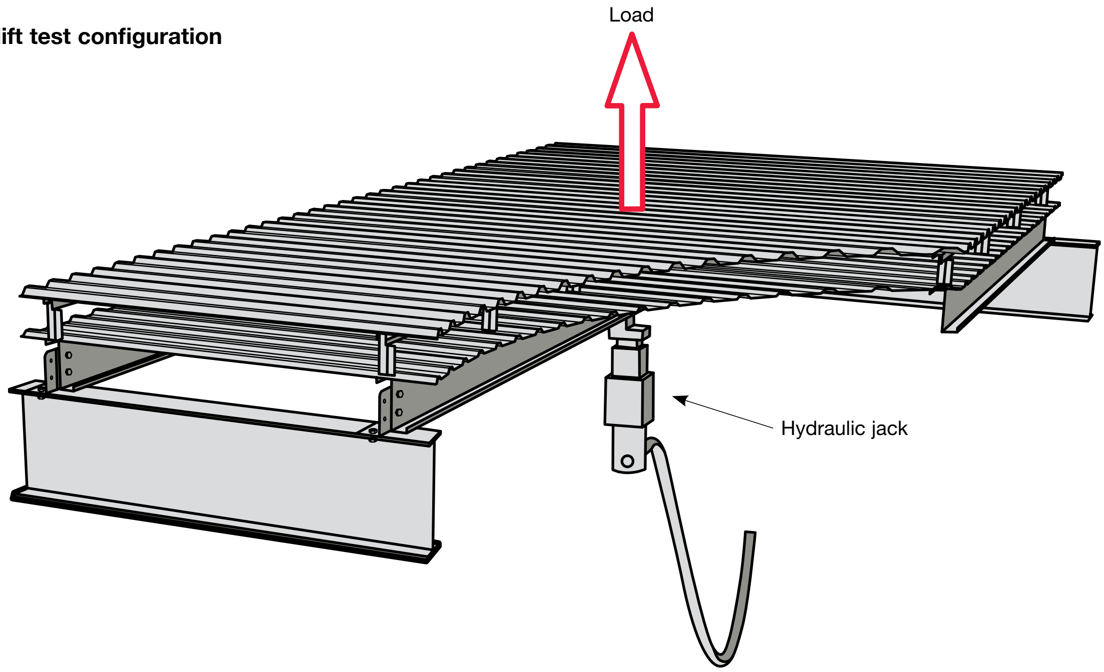
Uplift test

In the uplift condition, the cladding is required to resist lateral-torsional buckling of the purlin by preventing the purlin from twisting. In theory, the cladding is able to do this due to its flexural stiffness, but this has been brought into question recently as the cladding depth has increased. In particular, with a space of 180 mm or more between the internal and external sheets, can the two sheets be considered to act compositely together or should designers assume that the liner is acting alone?

The purpose of the uplift test was to answer this question and to determine whether sufficient restraint is provided to permit the purlin to support the required load. This configuration simulates the up-lift from wind and pressure differentials which are often the limiting load case for roofs.

The test was conducted on the same rig as the in-plane tests, but with the horizontal loading replaced by a vertical jack under the central purlin. The jack exerted a vertical uplift point load at the mid-span of the purlin, from which it was possible to calculate the bending moment on the purlin. This in turn was converted into an equivalent uniform moment to take account of the onerous nature of the point load applied during this test (compared to the more usual uniformly distributed load). Care was taken to ensure that no restraint was provided to the compression flange by the jack.

Fig. 8. Uplift test configuration



Results

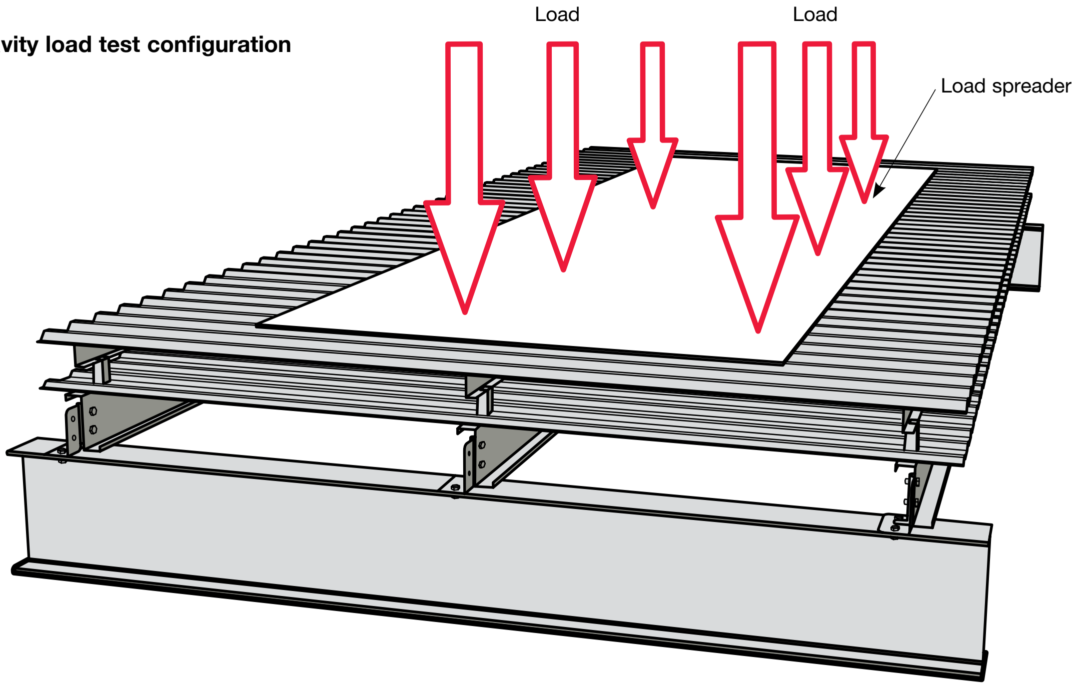
During the test, the load was increased in increments to a magnitude equivalent to 1.5 times the safe working load quoted in the purlin manufacturer's load tables. This load was sustained for a period of time without any visible signs of lateral-torsional buckling in the purlin. The horizontal movement of the purlin compression flange was very small compared with the vertical deflection of the purlin. This indicates that the cladding was providing sufficient restraint. Furthermore, there was clear visible evidence of good interaction between the internal and external sheets, with the latter contributing significantly to the stiffness of the cladding assembly.

Gravity load tests

One of the primary concerns regarding the use of ever deeper built-up cladding systems is the ability of the cladding assembly to support the down slope component of the gravity loading without sagging excessively. While the in-plane tests provided good numerical data regarding the down slope behaviour of the cladding assembly, full scale tests were needed to study the overall performance of the system under gravity loads.

The gravity load tests were conducted on the same sample of built-up roof cladding as the previous tests, again with 180 mm and 220 mm deep spacer systems. On this occasion the test rig was inclined to an angle of 10°. The loading was provided by means of 4 large bags of sand, weighing 15 kN in total, which were lowered and placed by crane over the central purlin. A spreader system was positioned between the sand bags and the cladding in an attempt to distribute the load over the test area. The magnitude and concentration of load represented an onerous load case, in excess of that normally experienced by most roofs in the UK.

Fig. 9. Gravity load test configuration



Results

Despite the onerous loading, which was equivalent to 1.44 kN/m^2 or a 1.6 factored 0.9 kN/m^2 load, the cladding assembly and supporting purlins performed well and carried the applied load without excessive deflection.

The load applied was 2.4 times greater than the widely-used value of 0.6 kN/m^2 which is the common snow-loading for much of the UK. This proves that the assemblies tested perform significantly in excess of the requirements of building regulations and BS5950-6. The maximum measured down slope sag equated to a working load deflection of span/253. This is well within the limits required to achieve a weather tight and airtight building envelope.

Conclusions

This study has demonstrated beyond doubt the suitability of built-up cladding systems for modern wall and roof applications. Architects and engineers can specify these systems with the confidence that the technology has been proven to provide a safe and reliable solution that fully conforms with all structural aspects of building regulations.

Structural performance of profiles

The structural performance of built-up cladding systems is dependent on the behaviour of individual components and the interaction between the components. The structural capability of profiled steel sheets is determined using BS 5950 Part 6 and is usually presented in the form of manufacturers' load/span tables. Specifiers should ensure that they compare published load/span data on a like by like basis.

- SCI have assessed the load/span data published by CA Building Products, Corus Panels & Profiles, Euroclad, and Tegral. In the cases considered the published load/span tables represent a safe estimate of the load/span capability of the profiled metal cladding sheets under the action of uniformly distributed gravity and wind uplift loads.

Integrity of systems

As with any cladding system, it is important to ensure consistency between the detailing and the assumed load paths. The chosen cladding system must be capable of providing at least the same degree of restraint as that assumed by the designer of the purlins and rails.

- The tests reported here show that the stiffness of the purlin/spacer assembly is increased significantly by the attachment of a liner sheet, providing a viable load path for the down slope loads. Furthermore, this has proved that properly designed built-up cladding systems using profiled steel sheets are more than capable of providing sufficient restraint to deal with the worst possible loading situations.

Depth of built-up systems

The current levels of insulation used in cladding systems provide a very thermally efficient building envelope. Whilst it is essential to look at other heat-loss paths such as air-tightness of the cladding system, there will inevitably be cases where increased levels of insulation are desirable for one reason or another.

- The tests reported here showed a high degree of interaction between the internal and external sheets for a system depth up to 220 mm which would typically be equivalent to a U value of 0.20 W/m^{2}K. This categorically proves the stability of these deeper built-up systems in the worst possible loading situation.

Note: The satisfactory performance of the cladding assembly is dependent on the correct specification of all of the components. Designers must ensure that the external sheet, spacer and purlin are suitable for the chosen application. Particular attention should be paid to the load capacity of deep spacer systems.

CPD accreditation

This paper has been assessed and approved as conforming to RIBA CPD guidelines. As such the content has been designated to fit under the following core curriculum headings:

General Headings
1 Professional context
2 Construction Skills
Subjects
1 Architectural design
2 Specification writing and choosing materials
Knowledge level
General awareness

To receive a CPD certificate for this paper, please go to www.colorcoat-online.com/cpd where you will be asked to correctly answer five short questions on the content of the paper before being issued with an electronic certificate.

The Colorcoat® brand

The Colorcoat® brand provides the recognised mark of quality and metal envelope expertise from Corus. Developed over 40 years, Colorcoat® includes a range of pre-finished steel products with a proven track record on countless buildings worldwide, supported by a range of services, including guarantees, colour consultancy and expert advice and guidance.

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Eco-designed exclusive coating technology, superior performance and the comprehensive Confidex® Guarantee make Colorcoat HPS200® the most specified pre-finished steel product in Europe for roof and wall cladding. Now maintenance free for up to 30 years.

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Confidex Sustain™

Provides a combined guarantee which covers the durability of the Colorcoat® pre-finished steel product and makes the pre-finished steel building envelope CarbonNeutral - the first in the world. Unavoidable CO_2 emissions from the pre-finished steel cladding system including fixings and insulation, are measured from cradle to grave and the impact offset. More than just offsetting, the aim is to encourage specification of the most sustainable pre-finished steel products and cladding systems.

Colorcoat® Building manual

Developed in consultation with architects and other construction professionals, the Colorcoat® Building manual incorporates over 40 years of Colorcoat® expertise. Recently been updated to cover the changes to Part L (2006) Building Regulations, it provides an invaluable guide to designing, specifying and constructing the metal building envelope.

If you require any further information please call the Colorcoat Connection® helpline. Alternatively, further information can be found in our Colorcoat® Building manual or at **www.colorcoat-online.com**

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