Smart bonding.

# Adhesive Films for the Production of Aluminium Honeycomb Panels

Kurt Jud, PhD, Technology Manager, Collano Adhesives

**Minimum Product Input without abandoning Performance!**
**A combination of adhesive film and a special production method affords a way of making aluminium honeycomb panels which offer much higher peel strengths than obtainable by today's standards. Studies have also shown that the peel strength is not diminished in alternating climate tests but actually even increases in some cases, with the result that aluminium honeycomb panels produced in this way are suitable for outdoor use.**

The main requirement in the manufacture of aluminium honeycombs is the efficient application of adhesive to the correct spot. However, as the honeycombs have very little contact area with the skin, close attention needs to be paid to the transmission of forces from the honeycomb edge to the skin.

Until now, for the sake of convenience, the adhesive was applied to the skin and the honeycomb core was placed in the adhesive, this is also called embedding. A distinct drawback of this method is that more than 90 percent of the adhesive is in the wrong place, even if rheological tricks are used to form a meniscus on the edge of the honeycomb. The adhesive inside each honeycomb cell has no benefit whatsoever and, if anything, is somewhat disadvantageous because it increases adhesive costs and unnecessarily raises the flammable mass. In most cases, moreover, the bond strength is impaired too if the force is transmitted unproductively or wrongly. This is always problematic for aluminium honeycomb sheets which are expected to offer high standards of fire resistance, bond strength, durability, weather resistance and impact strength. Such expectations can only be met if the honeycomb edges are properly embedded in the adhesive and the adhesive itself is ductile.

A system has now been developed that meets the requirements of an effective and efficient way of manufacturing aluminium honeycombs in which the adhesive concentrates around the cell edges from a continuous film of adhesive (Figure 1).

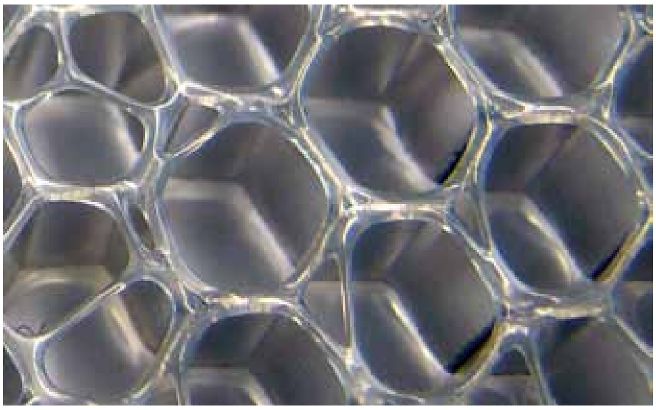

Figure 1: Film adhesive concentrated around the edges of the aluminium honeycomb.

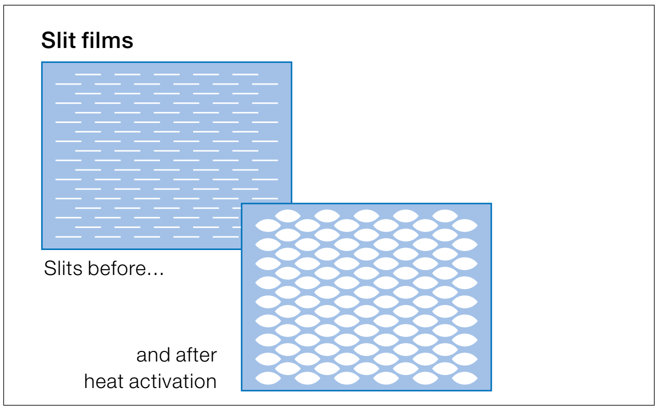


Figure 2: Heat treatment causes the slits to open.

With this new method, the adhesive is concentrated so effectively that just half the amount of adhesive can produce a 3 to 5 fold increase in strength, provided that it has the proper rheology in the molten state, i.e. adhesion to the substrate needs to be perfectly coordinated with the mechanical performance of the adhesive.

### Simple method

The method utilises a specially prepared film that contains a great many slit-like perforations which open upon being heated to the melting temperature or a little above it, to yield an adhesive network (Figure 2). The challenge now is to control the formation of the network so that it is in register with the honeycomb structure.

For this, three basic conditions must be met:
1. The film must rest freely on the honeycomb core
2. The film must be stretched biaxially, i.e., the polymer molecules must be homogeneously oriented in the surface
3. The film must contain a pattern of slits

The «secret» of this bonding method lies in the fact that the adhesive automatically seeks out the edges at the very moment that heat is being transferred to the adhesive film. However, the process needs to be adapted so that these conditions are met. Although time-consuming process optimisation is needed before industrial use, the results make it worth-while.

Comparison of the bond strengths yielded by this method with those of other adhesive methods shows it is extremely effective at producing aluminium and steel honeycomb panels. Compared with conventional aluminium honeycomb panels, not only are much better peel strengths achieved but the flexural strengths too are similar, and even the creep resistance at elevated temperatures is usually sufficient.

The resulting strength is astonishing, even on untreated metal, and nor are small amounts of drawing oil able to detract from this performance, as they exhibit outstanding compatibility with the apolar adhesive films.

### Weatherability

Cladding panels are exposed particularly intensively to the elements for protracted periods. To examine whether the panels produced by the new method are equal to the ever-increasing climatic stress, alternating climate tests in a humid climate followed by very low temperatures were performed in very quick succession. This accelerated aging was carried out for three months. Moreover, the honeycomb panels were continuously exposed to a salt spray environment for one month. Although this attacked the untreated aluminium surface, it failed to cause infiltration of the adhesive layer and so did not lead to delamination. Nor did these harsh conditions impair the excellent strength of the bond between the skin and the honeycomb core.

### Attainable strengths

The strength tests were performed on six different film adhesives at a specific weight of about 100 g/m$^2$. These are all olefinic films modified with MAH (maleic anhydride). The melting ranges vary with the degree of co-polymerisation and the chemical nature of the basic chain, but lie between 80 °C and 160 °C. All six adhesive films show excellent adhesion to untreated metal, but differ in their rheology in the molten state and in their potential

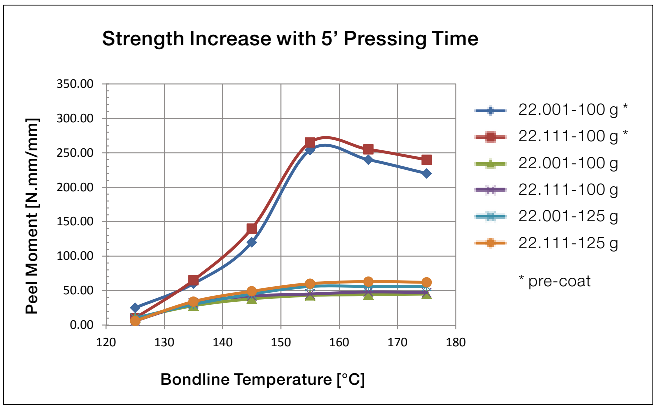


Figure 3: Change in strength for different process temperatures.

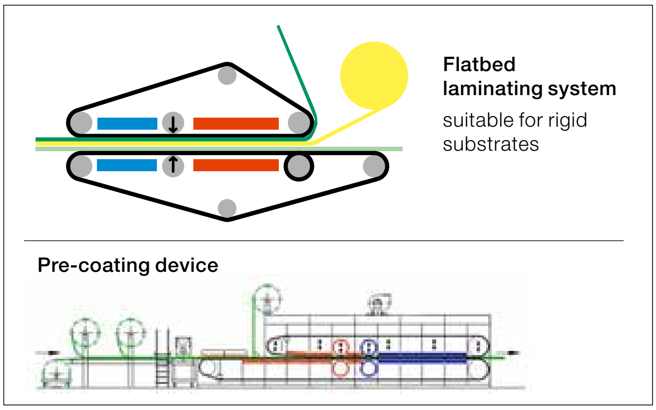


Figure 4: Schematic illustration of the method, which can also be performed discontinuously with heated platen presses if necessary.

for plastic deformation in the solid state – these are parameters which substantially affect the bond strength. The properties of the films and bonded honeycomb panels are presented in Table 1. The optimum process temperature for a given process time can be determined with the aid of Figure 3, from which the maximum of the strength curve and thus an optimum process temperature window can be discerned.

Comparison of the strength values of non-pre-coated honeycomb cores and pre-coated honeycomb cores (Figure 3) and the plastic deformation undergone by the layer of adhesive when the skin is peeled from non-pre-coated honeycomb cores and from pre-coated honeycomb cores (Figure 5 and 6) reveals that embedding the honeycomb edge in the pre-coated adhesive (process details in Figure 4) yields much better results.

However, once the optimum process time for a given process temperature has been determined, attainment of the maximum bond strengths with time is found to be asymptotic, i.e. the temperature critically determines how quickly the required process time is reached. Figure 7 shows how to determine the process time when, for example, the process temperature may not exceed 125 °C, this with or without pre-treatment

## Comparison of mechanical values

Aluminium honeycomb panels are widely produced using 2 component adhesives (2C PUR or 2C EP), usually at a rate of about 300 g/m². Figure 8 juxtaposes the properties obtained when different adhesive systems are used; for comparison, a 2C polyurethane and a 2C epoxy resin are shown as well. The chosen reactive adhesives, Collano RP 3007 and RE-EC, are standard 2C systems which lead to relatively low peel strengths even though significantly more adhesive was used than in the film adhesive method. Significant improvements in this regard are offered by new, thermally activated 2C polyurethane systems, but these still have deficits compared to the film adhesives presented here.

## Creep strength

Honeycomb panels are exposed to extremely high local stresses (honeycomb edges), which constitute a danger to the heat resistance. As shown in Figure 9, which illustrates the results of drum peel tests performed at various temperatures ranging from room temperature to 115 °C, thermoplastic film adhesives certainly have the potential to bond honeycomb panels to the extent that the heat resistance required for outdoor applications is achieved. Three different film adhesives were used in this study, in which the same bonding technology was always employed. Surprisingly, there is no direct correlation between melting range and heat resistance. 22.001-125 g softens between 115 °C and 130 °C, 22.111-100 g between 120 °C and 130 °C, 23.111-100 g between 140 °C and 150 °C. Nevertheless, we find that 22.001, on account of its strong tendency to flow at elevated temperatures, exhibits sufficient heat resistance only up to 60 °C, whereas 22.111, which has a slightly higher melting range, can be used up to about 95 °C. It is also surprising that 23.111, with a much higher melting range, cannot be used at much higher temperatures than 22.111, as the peel strength measured at 100 °C was on a par with that for 22.111. This shows that the softening range alone is no guarantee of adequate heat resistance. Also, 3- and 4-point bending tests conducted for comparison with bonds made with a reactive epoxy adhesive system show that thermoplastic film adhesives are certainly able to compete in terms of strength at half the quantity of adhesive up to 80 °C. The mechanical properties measured on commercially available panels are summarized in Table 2.

## Impact strength

Aluminium honeycomb panels were subjected to impact in three different directions. Steel hammers weighing 7–10 kg were propelled at a speed of about 50 km/h, both across and at the 3 honeycomb panels bonded with various adhesives, and the force curve necessary for the hammer to penetrate the honeycomb panel was recorded. Figure 10 shows the resistance which a honeycomb panel offers to destruction by impact in the cleavage mode at constant impact force/energy, but different bonding modes.

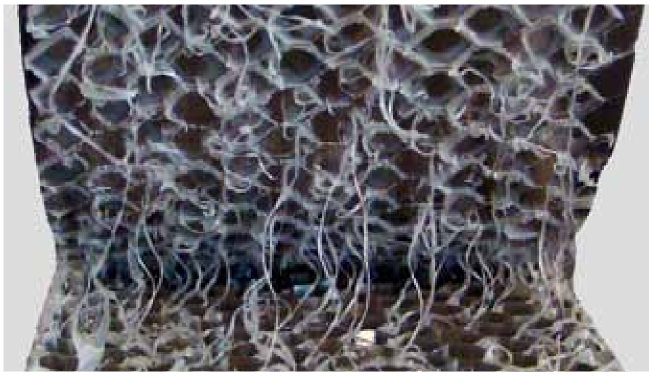

Figure 5: Peeled-off skin with pre-coating.

Figure 6: Peeled-off skin without pre-coating.

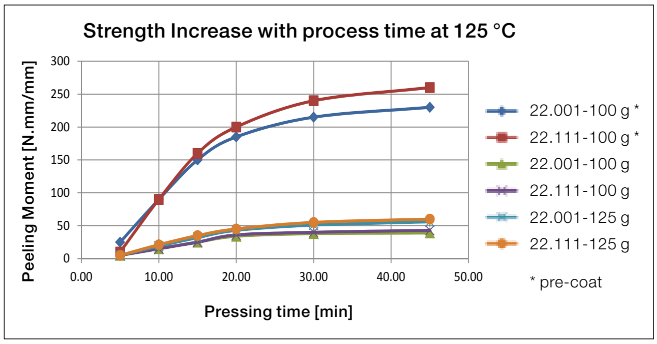


Figure 7: Dependence of drum peel strength upon curing time as per DIN 53 295.

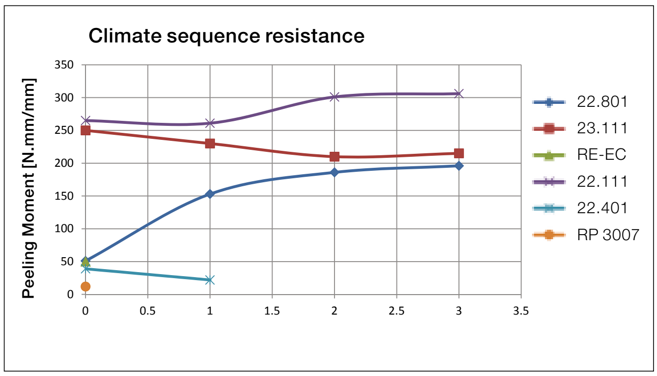


Figure 8: Drum peel strength determined as per DIN 53295 in [N mm/mm] following climate sequence tests (according conditions in Table 1).

The green curves show the resistance of a honeycomb panel which was bonded with 300 g/m² 2C PUR. The blue curves represent the resistance of a panel which was bonded in a conventional manner with a thermoplastic film adhesive (22.111-100 g). The red curves show the strength values obtained for the same film adhesive, but applied as mentioned above by the innovative technique of concentrating the adhesive at the honeycomb edges. The fracture energy is significantly higher than in the case of the 2C PUR bond, even though only 1/3rd of the weight of adhesive was used. This technology therefore offers significant technical advantages, without the need to allow for increased costs. A picture of the destroyed sample under the diagram illustrates the degree of plastic deformation, which arose from the strong resistance offered during impact.

## Conclusion

The method presented here, which utilises a film adhesive with slit-like perforations, affords a way of making aluminium honeycomb panels that is economical on adhesive and does not sacrifice performance. Under certain conditions, this new method can yield 3 to 5 times the strength of a conventional epoxy resin, with half the amount of adhesive. Various practical trials performed under industrial conditions have shown that the new method requires just 75 g/m² film adhesive to achieve the required properties.

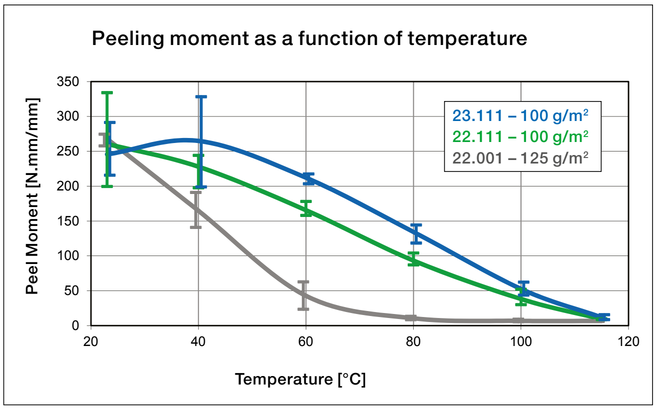


Figure 9:Drum peel test as per DIN 53295 at different temperatures.

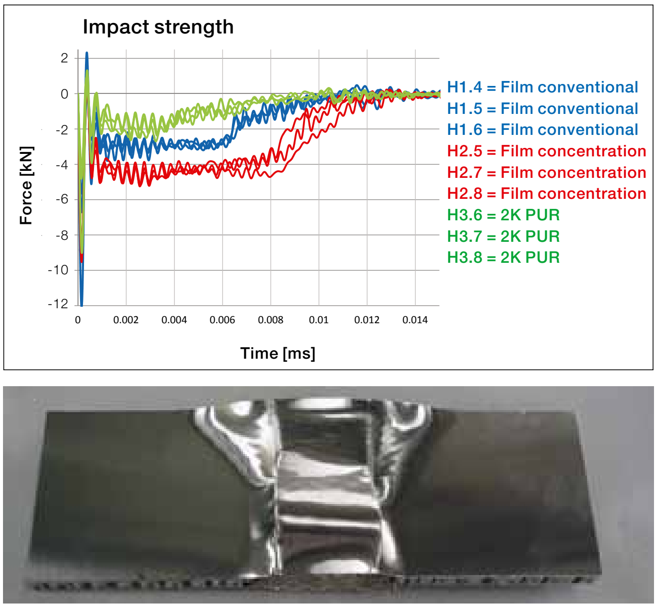


Figure 10: Change in force during impact strength tests and associated test specimens after the test.

| Properties/Designations | Unit | RE-EC | Collano 22.111 |
|---|---|---|---|
| **Thickness** (ASTM C366) | mm | 10 ± 0,3 | 10 ± 0,3 |
| **Panel Weight** (ASTM D898, DIN 53 855) | kg/m² | 4,60 | 4,30 |
| **Compression Resistance** (ASTM C365, DIN 53 291) | MPa | 4,25 | 4,25 |
| **Drum Peel Resistance** (ASTM D1781, DIN 53 295)<br>Longitudinal<br>Transverse | Nmm/mm | <br>> 50<br>> 50 | <br>> 250<br>> 250 |
| **4 Point-Bending Test** (ASTM C393, DIN 53 293)<br>Longitudinal<br>Transverse<br>Flexion at 450 N, Centrer longitudinal<br>Flexion at 450 N, Center transverse | N<br><br><br>mm<br>mm | <br>1700<br>1540<br>4,90<br>5,44 | <br>1480<br>1420<br>6,00<br>6,10 |
| **3 Point-Bending Test** (ASTM C393, DIN 53 452)<br>Longitudinal<br>Transverse | N | <br>3170<br>1940 | <br>2380<br>1810 |
| **Possible Exposure to Temperature Range** | °C | -55 °C to +100 °C | -55 °C to +80 °C |

Table 2: Test scores for aluminium honeycomb panels made with 300 g/m² EP adhesive (RE-EC) or 150 g/m² film adhesive (Collano 22.111).

Smart bonding.

# Adhesive Films for Aluminium Honeycomb Panels

| Properties | Unit | Collano 20.801 | Collano 20.301 | Collano 22.001 | Collano 22.111 | Collano 22.401 | Collano 23.111 |
|---|---|---|---|---|---|---|---|
| Chemical basis | | EVA | EAA | LLDPE | LDPE | HDPE | PP |
| Melting range (Koflerbench) | [°C] | 80–90 | 90–105 | 115–130 | 120–130 | 125–135 | 140–150 |
| Melt Flow Index DIN 53735 (190 °C/21.2 N) | [g/10 min] | 6–9 | 6–9 | 3–8 | 3–6 | 3–8 | 5–8 |
| Density | [g/ml] | 0,94 | 0,93 | 0,90 | 0,91 | 0,93 | 0,91 |
| Minimal bond line temperature | [° C] | 100 | 115 | 130 | 140 | 140 | 165 |
| Open time | sec | <1 | <1 | <2 | <1 | <1 | <1 |
| Heat deflection temperature (DMTA) | [° C] | 75 | 80–90 | 105 | 110 | 120 | 135 |
| Plasticizer resistance | n.a. | no | no | no | no | no | no |
| Pressing time | min | 5 | 3 | 3 | 5 | 5 | 5 |
| Pressing pressure | bar | <1 | <1 | <1 | <1 | <1 | <1 |
| Pressing temperature | [° C] | 105 | 120 | 155 | 155 | 155 | 170 |
| Adhesive film weight | [g/m$^2$] | 100 | 95 | 100 | 100 | 100 | 100 |
| Shear modulus | [MPa] | 20 | 60 | 60 | 100 | 800 | 360 |
| Modulus of elasticity | [MPa] | 20 | 120 | 115 | 75 | 1460 | 870 |
| Yield stress | [MPa] | 4 | 4,8 | 3,8 | 7,7 | 13,9 | 17,2 |
| Tensile strength | [MPa] | 26 | 24,3 | 14,1 | 27 | 13,9 | 30,3 |
| Ultimate strain | [%] | 1100 | 1020 | 1430 | 1200 | 460 | 1050 |
| Lap shear strength on aluminium (LSS) 23 °C | [MPa] | 10 | 10,2 | 11 | 12 | 12,8 | 11 |
| LSS 47 °C | [MPa] | 5 | 6 | 6,5 | 10 | 10,6 | 9,6 |
| LSS 70 °C | [MPa] | 0,7 | 1 | 2 | 6 | 8,2 | 8 |
| LSS 90 °C | [MPa] | --- | --- | 0,5 | 4 | 6 | 7,5 |
| Climbing drum peel strength (DPS) 23 °C | [Nmm/mm] | 51 ± 2 | 54 ± 4 | 254 ± 13 | 265 ± 26 | 39 ± 3 | 250 ± 19 |
| DPS after 14 days SST 35 °C | [Nmm/mm] | 76 ± 5 | 49 ± 5 | 239 ± 3 | 298 ± 30 | --- | --- |
| DPS after 28 days SST 23 °C | [Nmm/mm] | 73 ± 3 | 48 ± 2 | 245 ± 22 | 314 ± 19 | --- | --- |
| DPS after 30 days CST 23 °C | [Nmm/mm] | 153 ± 17 | 103 ± 9 | 245 ± 11 | 261 ± 24 | 22 ± 2 | 230 ± 25 |
| DPS after 60 days CST 23 °C | [Nmm/mm] | 186 ± 16 | 118 ± 9 | 176 ± 35 | 301 ± 4 | --- | 209 ± 30 |
| DPS after 90 days CST 23 °C | [Nmm/mm] | 196 ± 15 | 127 ± 12 | 239 ± 13 | 306 ± 11 | --- | 214 ± 28 |

**SST** = Salt spray test at 35 °C

**CST** (Climate sequence test)
40‘ +23 °C, 30% r.F., 90‘ cooling / 60‘ -35 °C, <30% r.F., 80‘ heating / 120‘ +50 °C, 80% r.F., 30‘ heating / 240‘ +80 °C, 30% r.F.

**Collano bonding process** is a binding condition to obtain the above mentioned properties

Table 1: Aggregate data for bonded honeycomb panels.

Collano Adhesives AG, CH-6203 Sempach Station
Switzerland, Phone +41 41 469 91 11, Fax +41 41 469 91 12
collano@collano.com, www.collano.com