# New flame retarded rigid foam systems for applications in the construction industry

Over the last few years PU material has shown strong growth in the application of metal-faced sandwich panels in the construction industry. The superior properties of metal panels will face new challenges when the new EU-fire test regulation is introduced in the future. Bayer has developed new approaches offering solutions aimed at passing the critical SBI test (EN 13823) and meeting the requirements for smoke density reduction.

Rigid polyurethane foam products are combustible building materials and will have classifications of E, D, C or B. The smoke density and burning droplets are also to be evaluated in sub-classes (S3-S1). For classification in D, C or B the small burner test must also be passed (Fig. 1).

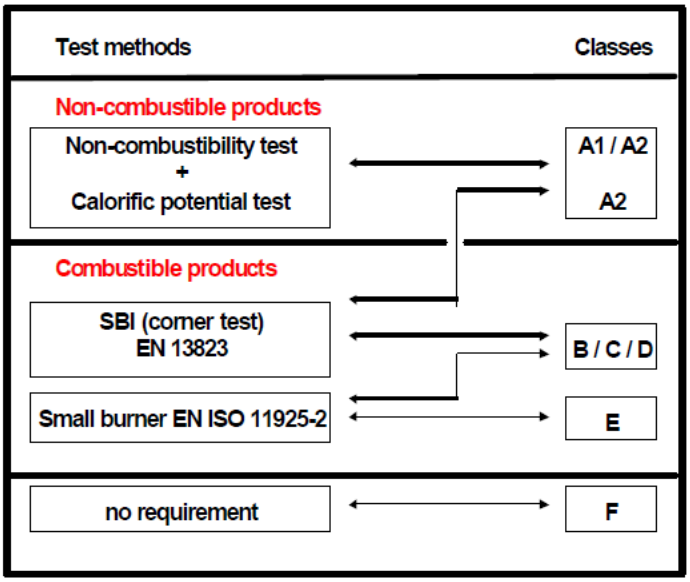



Figure 1: Classifications and test methods of SBI-Test

In order to meet the stringent requirements of the SBI test and to attain a high classification, particular importance is attached to the polyurethane or rigid polyisocyanurate foam used, as well as to panel and joint design. The results of various continuously produced metal-faced sandwich panels subjected to the SBI fire test are summarized in the following table (Fig. 2). 80 mm thick wall panels based on rigid polyurethane (PUR) and polyisocyanurate (PIR) foams were investigated.

| Product | SBI-Test | | | | | | Fire resistance | | |
|---|---|---|---|---|---|---|---|---|---|
| | Heat release | | | Smoke | | | Wall panel | | |
| | FIGRA | THR | Class | SMOGRA | TSP | Class | 100 mm | 110 mm | 200 mm |
| PUR/B2-Pentane (1) | 86 | 7-8 | B-C | 89 | 609 | S3 | | | |
| PUR/B2-Pentane (2) | 75 | 7.2 | B | 65 | 657 | S3 | | | |
| PIR/B2/M1-R141b | 32 | 3.4 | B | 19 | 307 | S3 | | | |
| PIR/B2-Pentane (1) | 48 | 5.4 | B | 30 | 260 | S3 | | | |
| PIR/B2-Pentane (2) | 47 | 2.9 | B | 15 | 112 | S2 | 26 min | 34 min | 68 min |
| Limit value | 120 | 7.5 | B | 180 | 200 | S2 | | | |

Figure 2: SBI-Tests and fire resistance results

All the foams used met the fire safety requirements of Class B2 construction material. Apart from R141b, the main blowing agent used was n-pentane. The panels investigated achieved the classification B or B-C. Only panels produced with a polyisocyanurate foam were able to achieve smoke gas classification S2, however.

The PIR/B2-pentane (2) system satisfied the requirements of various fire resistance classes, as also shown in Fig 2. A fire retardance of 34 minutes was achieved with a wall panel having a thickness of 110 mm and 68 minutes with a thickness of 200 mm. Comparable results have not so far been achieved with rigid polyurethane foam panels, however.

In a comparison with the SBI- test, the ISO room-corner test to ISO CD 13784-1 was also carried out using 80 mm thick wall panels (Fig. 3).

| ISO-Room-Corner<br>ISO CD 13784-1 | | |
|---|---|---|
| Product | Flashover-time | Burning after end of test |
| PUR/B2 - Pentane - 1 | 13 min | high |
| PUR/B2 - Pentane - 2 | 15 min | medium |
| PIR/B2/M1 - R141b | none | less |
| PIR/B2 - Pentane - 1 | none | less |
| Limit value | > 20 min (B) | |

Figure 3: Results of the ISO-Room-Corner-Test

Wall panels based on polyisocyanurate foams also passed the tests in these experiments. No flashover was observed within the required 20 minutes. Burning of the panels after the flame had been removed was classified as low.

In conclusion it can be stated that the more stringent fire performance requirements (SBI test) for metal-faced sandwich panels in Europe and the increasingly important smoke density are easier to satisfy in panels produced from rigid polyisocyanurate foams than from rigid polyurethane foams.

Fig. 4 provides a guide formulation for continuous production of an 80 mm thick wall panel containing the PIR/B2 pentane system 2. The raw materials were processed with an index of 280. Mechanical data can be found in Fig. 5.

**PIR/B2 - Pentane ( 2 )**

| Guide Formulation : | 80 mm wall panel |
|---|---|
| Esterpol blend | 100.0 parts |
| Activator ( I ) | 3.7 parts |
| Activator ( II ) | 2.0 parts |
| n - Pentane | 17.8 parts |
| Desmodur VP.PU 22HB50 | 170.0 parts |
| Index | 280 |

Figure 4: Guide formulation

| PIR/B2 - Pentan (2)<br>Mechanical properties : 80 mm wall panel | Unit | |
|---|---|---|
| Core density | kg/m³ | 45 |
| Compressive strength | N/mm² | 0.157 |
| Tensile strength | N/mm² | 0.135 |
| Compressive modulus | N/mm² | 4.550 |
| Tensile modulus | N/mm² | 4.687 |
| Elasticity modulus | N/mm² | 4.619 |
| Shear modulus | N/mm² | 3.900 |
| Adhesiveness | | |
| - top | N/mm² | 0.166 |
| - bottom | N/mm² | 0.481 |

**Figure 5: Mechanical properties**

**Another way of improving the flame retardance of rigid polyurethane foams in metal-faced sandwich panels is to add solids such as expandable graphite. Expandable graphite is a solid which expands at specific temperatures and is therefore a flame retardant. Expandable graphite known as Grafgard 160 - 50N from Nordmann and Rassmann[1)] was used. This type of graphite expands at a temperature of 160°C and has a mesh size of 50. The volume of graphite increases about 200 times as a result of expansion (Fig. 6).**

Figure 6: Expandable graphite

The machinery and the metering method are particularly important for the continuous processing of solids in metal-faced sandwich panel production. To this end a 3-component mixing head allowing a "splitting method" of processing has been developed and patented (Fig. 7).

Figure 7: 3-component mixing head for processing expandable graphite and other solids

Polyol, polymeric MDI and polymeric MDI containing expandable graphite and the fire retardant TCPP (tris-trichloropropyl phosphate) are mixed together under high pressure in the mixing head and discharged through a specially designed perforated pour pipe or discharge pipe (Fig. 8). The 3-component mixing head is particularly flat in design, making it suitable for the production of 40 mm thick panels. On completion of foaming and curing, the expandable graphite is distributed uniformly over the entire thickness and width of the panel (Fig. 9).

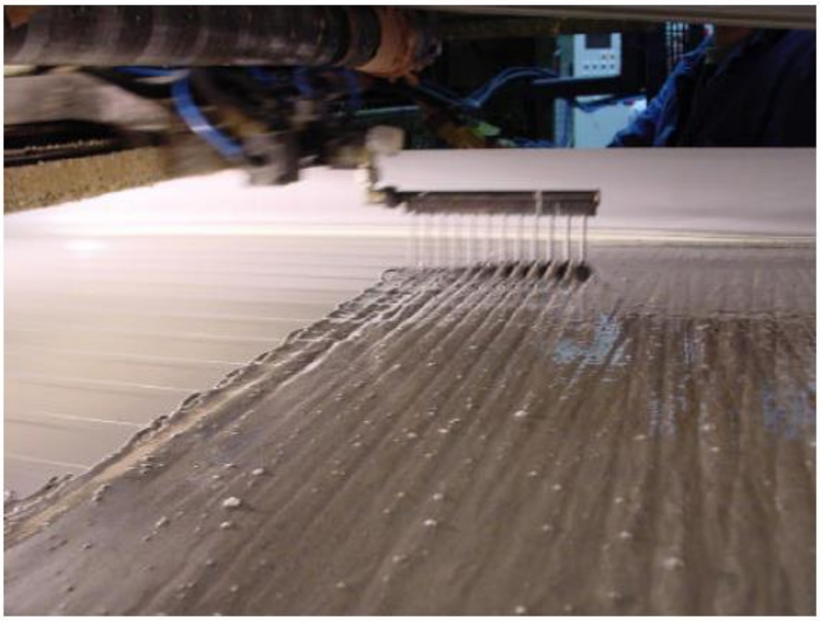


Figure 8: Lay down of a reaction mixture with expandable graphite

Figure 9: Distribution of expandable graphite in rigid PUR-foam

Using this technology, a metal-faced sandwich panel manufacturer who normally processes a Class B3 raw material system can manufacture Class B2 sandwich panels by adding a polymeric MDI/expandable graphite mixture without having to interrupt production. The PMDI/expandable graphite/TCPP mixture is produced by the batch method and is continuously pumped into the machine tank during production. Machinery suitable for this continuous process is sold by Hennecke, St. Augustin, Germany.

The table below summarizes the results of fire tests on an 80 mm wall panel (Fig. 10).

| | | | SBI - Test | | | |
|---|---|---|---|---|---|---|
| | | | Heat release | | Smoke | |
| | B2-Test according DIN 4102 | BVD-Test | FIGRA | THR | SMOGRA | TSP |
| PUR/B3-Pentane with expandable graphite | B2 | | 112 | 8.6 | 33 | 299 |
| Flame highness (mm) | 110 - 130 | 100 -130 | | | | |
| Smoke grade (%) | | 99.2 | | | | |
| Class | | 5.3 | | C | | S3 |

Figure 10: Results of fire tests with expandable graphite

Using expandable graphite/TCPP made it possible for a Class B3 polyurethane/pentane system to satisfy the requirements of Class B2 construction materials during the small burner test with a maximum flame height of 110 to 130 mm. The classification 5.3 was attained in the Swiss BVD test. The SBI fire test resulted in the classification C/S3.

Fig. 11 shows a guide formulation for producing 80 mm wall panels. The total content of expandable graphite is about 14 % of the polyol formulation and 6.5 % of the total reaction mixture. Fig. 12 shows the most important mechanical data.

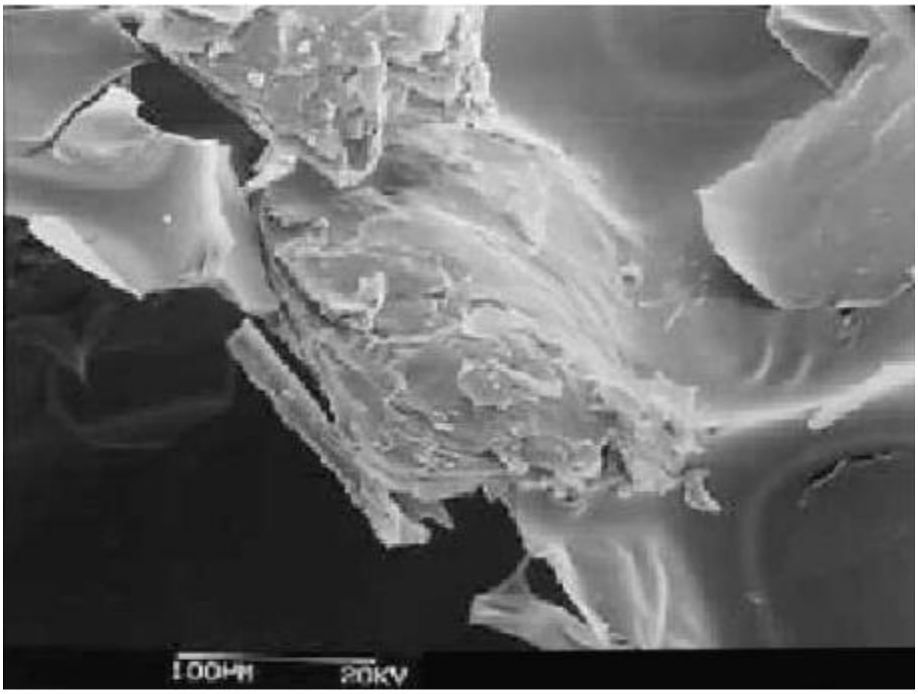
## Expandable Graphite

**Guide Formulation : 80 mm wall panel**

| | |
|---|---|
| Esterpol blend | 100.0 parts |
| Activator ( I ) | 3.3 parts |
| Activator ( II ) | 3.8 parts |
| Expandable graphite | 20.0 parts |
| Flame retardant TCPP | 15.0 parts |
| n - Pentane | 7.4 parts |
| Desmodur 44V40L | 160.0 parts |

**Figure 11: Guide formulation**

Scanning Electron Micrograph of Graphite Based PIR foam



| Expandable Graphite | | |
|---|---|---|
| Mechanical properties : 80 mm wall panel | | |
| | Unit | |
| Core density | kg/m³ | 42 |
| Compressiv strength | N/mm² | 0.11 |
| Tensile strength | N/mm² | 0.12 |
| Compressive modulus | N/mm² | 2.50 |
| Tensile modulus | N/mm² | 4.30 |
| Elasticity modulus | N/mm² | 3.40 |
| Shear strength | N/mm² | 0.17 |
| Adhesiveness : bottom | N/mm² | 0.30 |
| Open cells | % | 4.00 |
| Thermal conductivity | mW/mK | 22.40 |

Figure 12: Mechanical properties

The test results are within the range generally demanded by metal-faced sandwich panel manufacturers. It is particularly noteworthy that the added solid expandable graphite does not increase the open cell content. The open-cell content was 4 % and the coefficient of thermal conductivity was 22.4 mW/mK.

In conclusion it can be stated that metal-faced sandwich panels based on rigid polyisocyanurate foams perform better in the SBI test than rigid polyurethane foams. A higher classification is easier to achieve with these systems, especially when determining the smoke density.

The addition of solids enables a metal-faced sandwich panel manufacturer to produce a Class B2 panel instead of the more conventional Class B3 panel, without interrupting production or needing to stock a second raw material system.