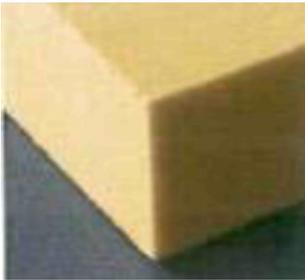


SANDWICH PANEL FILLING MATERIALS

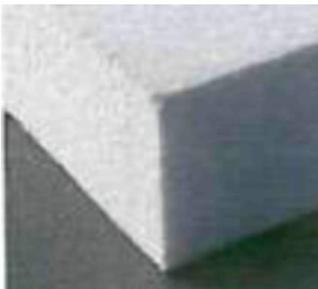
Materials such as Polyurethane, PIR, Polystyrene, Phenolic Foam and Rockwool, etc. are the filling core materials mostly preferred in sandwich panel applications. All the materials are classified in two groups as Plastic Foam including Polyurethane, PIR, Polystyrene, and Phenolic etc. and as Inorganic fiber materials including Rockwool. The difference between them or the offered performance advantages are the frequently asked and wondered subjects. Besides the serious misunderstanding concerning the technical specifications of the sandwich panels which have a wide area of utilization, the presence of incomplete information flow must also be accepted. The type of the core material plays an important role in choosing the correct composite sandwich panel by considering the mechanical strength, insulation, fire performance and production processes according to the building physics. When considered from this perspective, the accurate determination and accurate comparison of the performances expected from the materials gain further importance.

PUR / PIR (Polyurethane): Polyurethane (PUR) and Polyisocyanate (PIR) are the most preferred plastic foams used in sandwich panel production. The adhesive feature available during the foaming process of these types of plastic foams which are generally preferred at laminated lines, offers very serious advantages. In recent years, their chemical specifications have been improved more and their fire performances have been enhanced. Environment-friendly n-pentane inflator gas is preferred at its production. Used for around 50 years at sandwich panel production, polyurethane is known to be the most reliable insulating material.

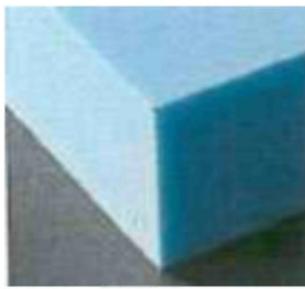


PUR / PIR (Polyurethane)

XPS / EPS (Polystyrene): There are two forms of polystyrene foams as Extruded (XPS) and Expanded (EPS). They are affixed to the metal surfaces by using additional adhesive in sandwich panel applications. The polystyrene foams qualified as thermoplastic, melt at low temperatures.

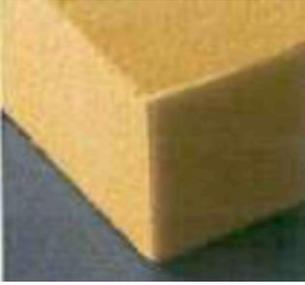


EPS (Expanded Polystyrene)



XPS (Extruded Polystyrene)

Phenolic (PF): The phenolic foam is a newer material compared to the other plastic foams. They are preferred quite rarely in sandwich panels. They present the best fire performance among the plastic foams.



Phenolic

Rockwool: It is a type of mineral wool obtained by melting and atomizing the rocks such as basalt, diabase, dolomite and mixing these with bakelite and then entreating through special processes. Giving perfect results in fire resistance and sound insulation, the rockwool has lower values in thermal insulation compared to plastic foams.



Rockwool

The technical specifications given below are not peculiar to a special manufacturer and they are general comparative data for the purpose of suggestion:

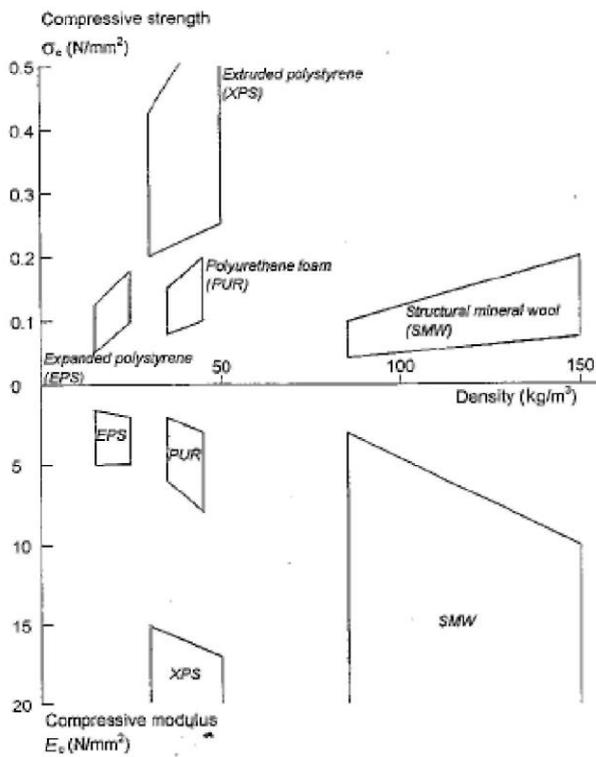
1. Mechanical Strength

The parameters such as compression strength, tensile strength, sliding strength and sliding module, etc. are the most important values that determine the mechanical strength performances of the composite materials. Furthermore, the strength at the composite materials is directly related to the behavior between its components. The materials such as polystyrene foam and rockwool are affixed to the metal surfaces by means of additional polyurethane based adhesives whereas the Polyurethane, PIR and Phenolic foams are automatically affixed to the metal surfaces by expanding from the liquid mixture form. Although EPS and XPS are good insulation materials due to the low-cost production process, the need for additional adhesive makes it less preferred in sandwich panel applications. In general, the tensile strength of the adhesive on the metal surfaces is higher than the tensile strength of filling materials of polystyrene; however, the analyses show that this value must not decrease under 0.10 N/mm². Otherwise, the possible stresses may cause torsions on the surface.

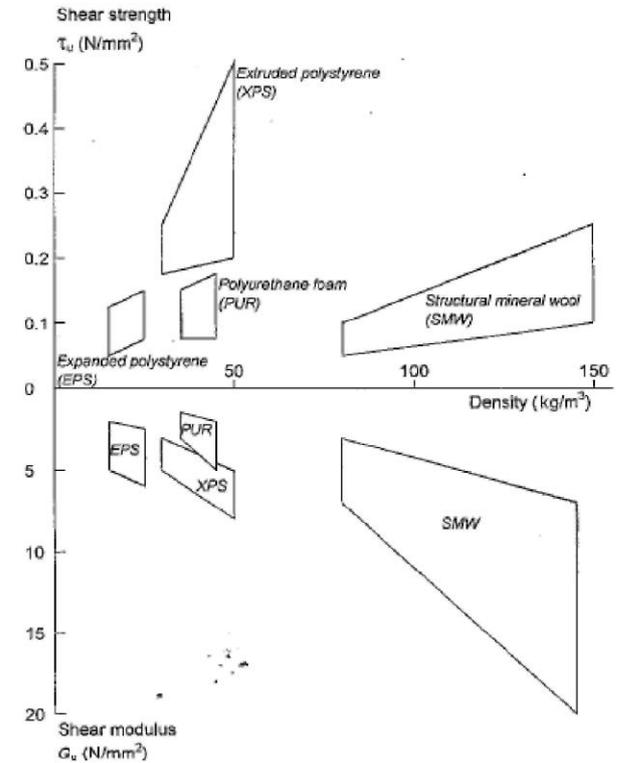
Besides the ambient temperature and the possibility to be affected by the humidity, the features of the materials with such type of polymer content must be carefully evaluated during the sandwich panel designing phases in order to enable the foam materials to cause viscoelastic behavior, in other words swelling, following the long lasting loadings. The mechanical specifications of the plastic foams of sandwich panels are directly related to the density, however it is not the primary factor at materials such as rockwool, and may vary by the production processes such as the specification of the fiber structure.

The difference of PIR foams from PUR polyurethane foams is the variety in the component rates used in the production. Therefore, besides the foaming process of both of them, their mechanical and physical specifications are very similar to each other.

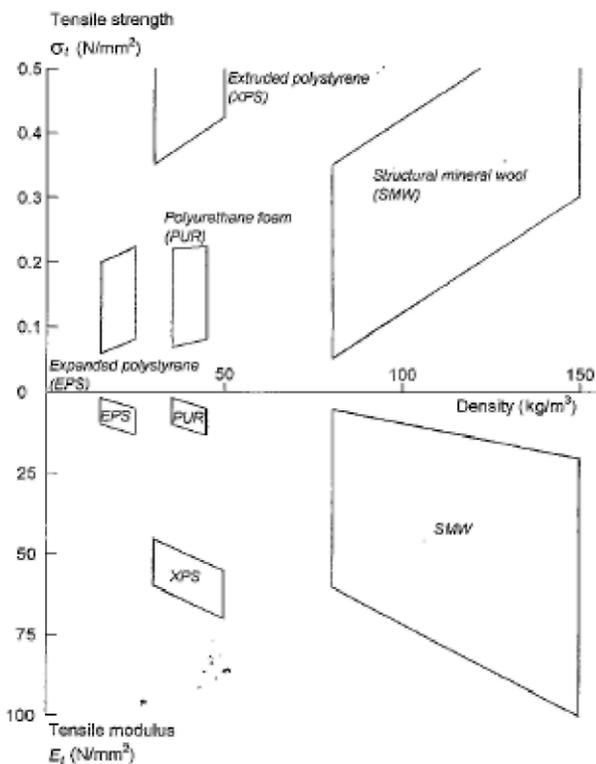
Recently, some problems have been detected concerning the mechanical strength of the Phenolic foams that have been developed in order to improve the fire performance of the polyurethane as of the 1970s. Early panel separations considered as resulted from the Phenolic structure within the time, have been observed in the sandwich panels which contain Phenolic, which is particularly preferred in roof applications where there is important amount of pedestrian traffic. The specifications of the sandwich panel filling materials must be known very well for the buildings having repeated loadings.



Compression Strength and Module



Sliding Strength and Module



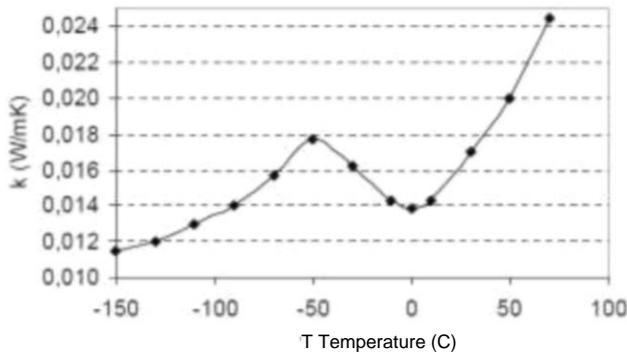
Tensile Strength and Module

| | PUR/PIR | EPS | XPS | PHENOLIC | ROCKWOOL |
|---|-----------|-----------|-----------|-----------|-----------|
| Sliding Strength (N/mm ²) | 0.08-0.15 | 0.09-0.16 | 0.18-0.5 | 0.05-0.15 | 0.03-0.2 |
| Sliding Module (N/mm ²) | 1.2-5.0 | 3.0-7.2 | 3.2-8.4 | 2.0-4.0 | 2.0-15.0 |
| Tensile Strength (N/mm ²) | 0.07-0.22 | 0.08-0.17 | 0.34-0.52 | 0.03-0.1 | 0.03-0.6 |
| Tensile Module (N/mm ²) | 1.0-10.0 | 1.0-10.0 | 45.0-70.0 | 1.0-3.0 | 5.0-40.0 |
| Compression Strength (N/mm ²) | 0.10-0.16 | 0.10-0.18 | 0.20-0.70 | 0.08-0.2 | 0.10-0.15 |
| Compression Module (N/mm ²) | 2.3-6.0 | 1.2-3.5 | 15.0-20.0 | 2.0-8.0 | 6.0-15.0 |

2. Thermal Insulation

The thermal conductivity value (λ) is a constant value special to each material. It is the expression of the thermal flow in Watt (W), in cases where the temperature difference between the internal and external surfaces of a material which has a surface of 1 m² and a thickness of 1 m, is 1 Kelvin. The thermal conductivity values of typical insulation materials are given in the following table. Low thermal conductivity value means high thermal insulation performance, so the required performance can be easily achieved with the low insulation material thickness.

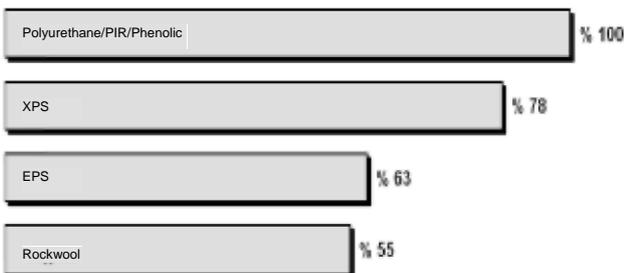
The thermal conductivity value of all insulation materials vary according to the temperature level. However, this relation is generally linear. While the thickness of the material is determined in the calculations, 10 °C temperature in normal applications is taken as basis and the thermal conductivity design values are determined according to this temperature.



The impact of temperature on PUR thermal conductivity

While choosing the optimal thermal insulation material, the initial thermal transmittance value is a very important parameter, however reduction of thermal insulation capacity within time, particularly in plastic foams, must be taken into consideration for the insulation values of the aged material. When the low insulation values are compared and the multi-purposed utilization and long-term performances are considered, PUR/PIR foams may offer the most optimal solution.

The closed cell structure of the plastic foams make it more resistant against water, however the contact of inorganic materials such as Rockwool with water may cause serious reductions such as at 75% rates. at thermal performances



Insulation Efficiency of Core materials

| | PUR/PIR | EPS | XPS | PHENOLIC | ROCKWOOL |
|------------------------------|-------------|-------------|-------------|-------------|-------------|
| Thermal Conductivity (W/m.K) | 0.022-0.028 | 0.034-0.037 | 0.025-0.028 | 0.022-0.028 | 0.034-0.040 |

3. Water Absorption Capacity

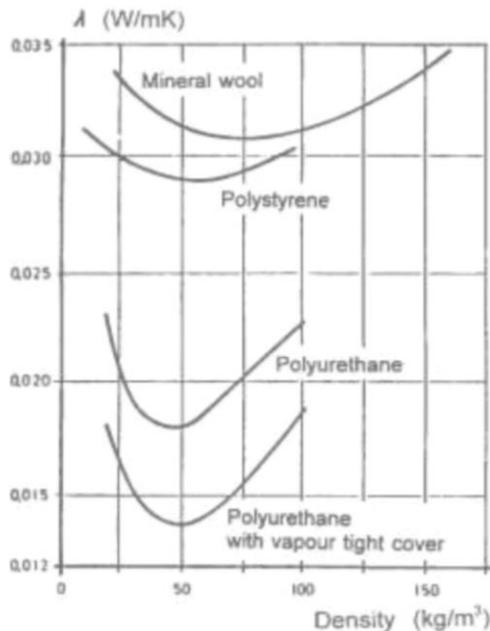
What is required from the insulation material is not to be directly affected by water. Furthermore, the thermal transmittance value must not increase through getting indirectly wet by means of capillarity. In fact, the fibers within the rockwool do not get wet; however the air gaps between fibers are filled in case of contact with water and the wet rockwool becomes unable to perform its insulation duty.

| | PUR/PIR | EPS | XPS | PHENOLIC | ROCKWOOL |
|--------------------------------|---------|-----|-------|----------|----------|
| Water Absorption by Volume (%) | 2-5 | 0-5 | 0-0.5 | | 2.5-10 |

4. Density

When the production costs are taken into consideration, the best performance at lowest density possible is targeted, however the amount of the material to consume may decrease. The density, particularly in the plastic foams have direct impact on the mechanical strength. On the other hand, due to the weight of the sandwich panels produced of rockwool at high density, both the assembly challenges and also the additional loads on the bearing construction occur at the buildings.

The thermal conductivity coefficient depend on various factors that are not related to the time. Closed cell percentage, thickness of the sample, longer expanding period, slower change of thermal conductivity coefficient, cell size, type of foaming material and other factors can be given as an example for these factors. The following chart demonstrates the impact of density on thermal conductivity coefficient.



Impact of density on thermal conductivity value

| | PUR/PIR | EPS | XPS | PHENOLIC | ROCKWOOL |
|------------------------------|---------|-------|-------|----------|----------|
| Density (kg/m ³) | 36-50 | 10-25 | 30-50 | 35-55 | 70-150 |

5. Temperature Strength

It is the temperature level where each thermal insulation material starts to lose its specifications and to be deformed. Therefore, the temperature to be exposed at the application place of the material must be previously determined and the materials appropriate to this temperature must be selected.

| | PUR/PIR | EPS | XPS | PHENOLIC | ROCKWOOL |
|--------------------------------|---------|-----|-----|----------|----------|
| Max. Temperature Strength (°C) | 110 | 80 | 80 | 120 | 850 |

6. Water Vapor Permeability

The water vapor permeability is very important in terms of comfort in the buildings. The water vapor diffusion strength (μ) diffusion and the related thickness (W_d) are two important characteristic values. The water vapor diffusion strength (μ) value is peculiar to the material and it is determined by comparing with the air strength accepted as 1. The water vapor permeability in the sandwich panel systems depend on the density of the material, joint details, production process and type of the metal surface. As the vapor diffusion resistance rises, the amount of vapor to permeate into the material reduces. What is required from the thermal insulation material is high vapor diffusion resistance coefficient.

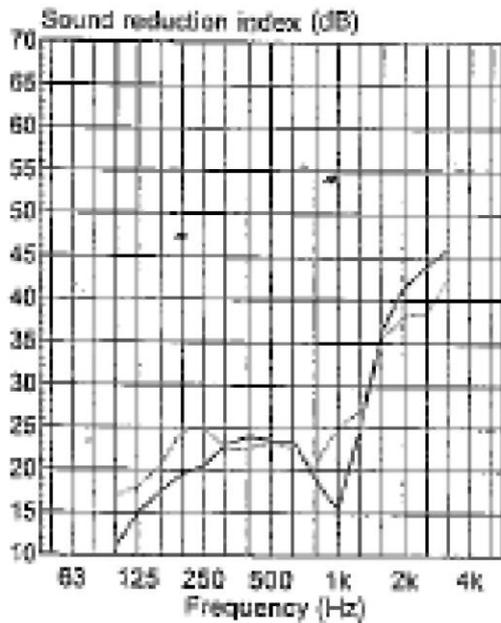
| | PUR/PIR | EPS | XPS | PHENOLIC | ROCKWOOL |
|---|---------|--------|--------|----------|----------|
| Diffusion Resistance Coefficient of Water Vapor (μ) | 30-100 | 20-100 | 90-100 | 10-50 | 1 |

8. Sound Insulation

The parameters required for sound insulation of the roof and wall coatings and the calculation methods can be determined during the design phase. A certain part of sound waves crashing a surface is reflected, some are absorbed and the remaining part is transmitted. Reflection, absorption and transmission rates depend on the shape of the surface, the sound absorption capacity of the material and the frequency of the sound. The closed pored plastic foam materials are in fact thermal insulation materials.

The open pored (glasswool, rockwool, acoustic sponge, etc.) materials are used for the insulation of the airborne sounds. The sound absorbing materials have pores or fiber and they become effective by means of transforming a part of the acoustic energy into heat energy by causing frictional loss through the air penetrating holes in their structure. The rockwool-filled sandwich panels are better when compared to the other panels in terms of its feature of contributing in the sound insulation.

| | PUR/PIR | EPS | ROCKWOOL |
|--|---------|------|----------|
| Sound insulation of sandwich panel system (dB) | ≥ 25 | ≥ 24 | ≥ 34 |



- (b) - - - Profiled sandwich panel with a PUR foam core with thickness 68 mm and weight 14 kg/m^2 , $R_w = 27 \text{ dB}$
- Sandwich panel with a PUR foam core thickness 60 mm and weight 14 kg/m^2 , $R_w = 25 \text{ dB}$

- Sandwich panel with a mineral wool core density 45 kg/m^3 , $R_w = 33 \text{ dB}$
- Sandwich panel with a mineral wool core density 180 kg/m^3 , $R_w = 31 \text{ dB}$

Sound Insulation of PUR and Rockwool-Filled Sandwich Panels

9. Dimensional Stability

The volumes of all the plastic foams are affected by the temperature changes. The temperature increase in the foam causes the pressure of the gases within the cells increase and cause expansion. The contrary situation occurs at sudden cooling cases. There is a possibility of damage on the foam structure due to negative pressure. Due diligence must be paid for the cooling process particularly after the production of PUR foams.

| | PUR/PIR | XPS | EPS | PHENOLIC | ROCKWOOL |
|-------------------------------------|---------|-----|------|----------|----------|
| Dimensional Change (80 °C 48 hours) | 2% | 5% | 1.5% | 1% | 1% |

10. Chemical Strength

Besides their appearance, materials may lose all their functions such as mechanical strength because of the impact of corrosion. All materials of the structure must always be resistant against corrosion or additional precautions must be taken to protect from corrosion. When considered within this perspective, the sandwich panel metal surfaces as well as filling materials must be resistant against corrosion. It can be dissolved by the contact of the aromatic sulphonic acid, which is used as catalyst in the production of phenolic foams, with water. The sulphuric acid that dissolves in phenolic foam resulting from the absorption of high amount of water, and that leaks to the metal surfaces may cause corrosion on the metal.

The chemical strength of the XPS and EPS polystyrene foams are weaker than PUR foams; therefore, due to its sensitivity, the polyurethane-based unsolvable adhesives must be preferred when adding the sandwich panel to metal surfaces.
The rockwool has good chemical strength and does not lead to corrosion.

| | PUR/PIR | XPS/EPS | PHENOLIC | ROCKWOOL |
|-------------------|---------|---------|----------|----------|
| Chemical Strength | Good | Medium | Medium | Good |

11. Fire Performance

Rockwool is classified as an inorganic fireproof material. The best performance for fire-resistant wall, roof or interior partition wall applications is yielded by the rockwool-filled sandwich panels. Fire resistance of the rockwool-filled sandwich panel may vary between 30 to 120 minutes depending on the type, thickness and joint type of the rockwool when the fire resistance of rockwool-filled sandwich panel with 100 mm thickness is taken into consideration. On the other hand, the polyurethane-based adhesives enabling the sandwich panel system to be affixed on the metal surfaces with rockwool, exhibit equal behavior with the PUR-filled panels during the first phases of the fire.

All plastic foams are organic, therefore all of them are flammable. Their behaviors against fire vary widely according to the raw material preference, foaming process, fire retardant additives and contained inorganic components. The general characteristics of plastic foam are as following;

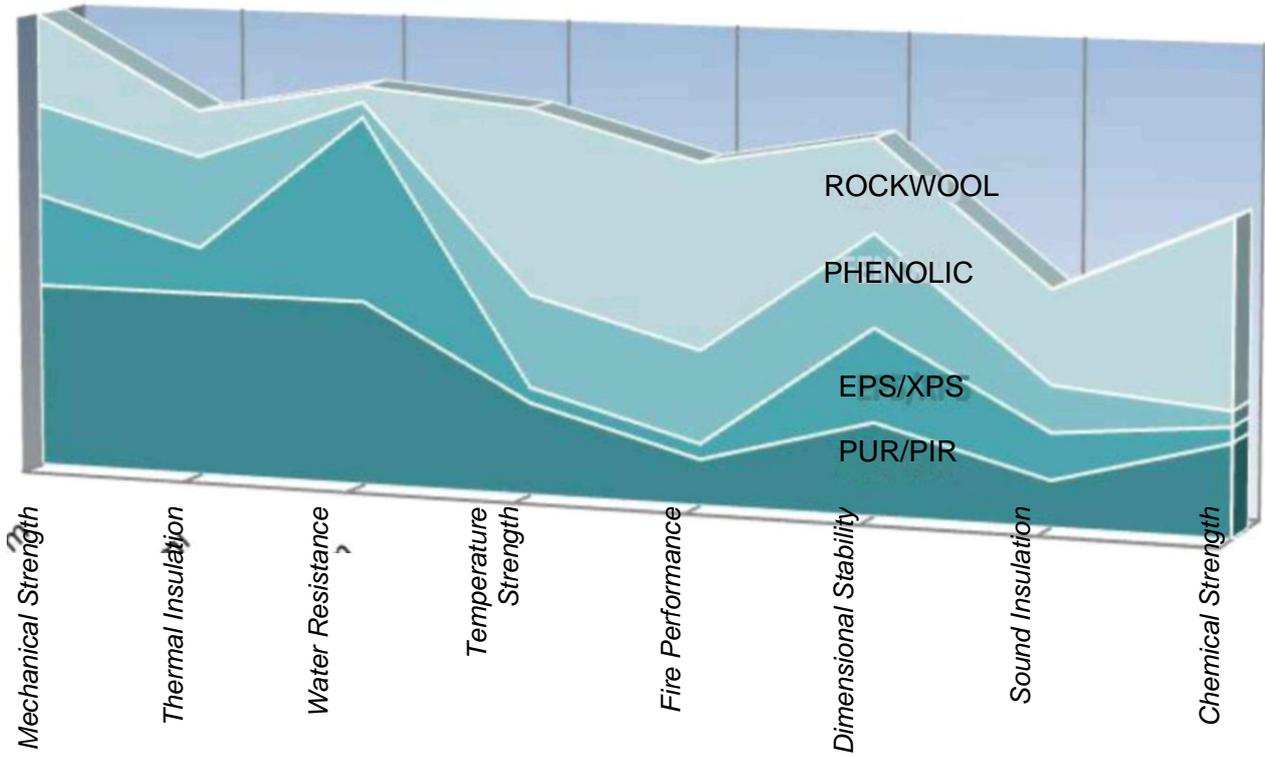
PUR/PIR: Right chemical formulation offers advantages at plastic foams in terms of fire performance. High isocyanate rates and fire-retardant additive are decisive in the performance of polyurethanes. As pure material, causes disperse at 150-200 °C, burning and smoke release over 300 °C. As an example, the performed tests show that the polyurethane foam with a thickness of 60 mm can reach to critical fire resistance duration of 30 minutes.

XPS/EPS: Both expanded polystyrene (EPS) and extruded polystyrene (XPS) are plastic foams with lowest fire resistance. At 100°C, they start to melt and form fire droplets.

PHENOLIC: With its phenolic polymeric structure, it presents a better performance against fire when compared with PUR/PIR foams. Furthermore, low smoke level equal to the levels of PUR/PIR are released. On the other hand, the phenolic that has been developed for the purpose of improving the fire resistance of the plastic foams has some disadvantages. Particularly the acid in the production process, it has low mechanical strength, fragility and relatively low thermal insulation performance.

| | PUR | PIR | EPS/XPS | PHENOLIC | ROCKWOOL |
|---|---------|--------|---------|----------|-----------|
| Temperature at which Dimensional Stability is lost (°C) | ~200 | ~200 | ~90-100 | >250 | |
| Ignition Temperature (°C) | 285-310 | 415 | 245-345 | 490 | |
| Fire Performance | Medium | Medium | Poor | Good | Very Good |

Filling Materials Performance Comparison Table:



| | PUR/PIR | EPS/XPS | PHENOLIC | ROCKWOOL |
|-----------------------|---------|---------|----------|----------|
| Mechanical Strength | ***** | **** | **** | **** |
| Thermal Insulation | ***** | *** | **** | *** |
| Water Resistance | ***** | ***** | ** | ** |
| Temperature Strength | **** | ** | **** | ***** |
| Fire Performance | *** | ** | **** | ***** |
| Dimensional Stability | **** | **** | **** | **** |
| Sound Insulation | *** | *** | *** | **** |
| Chemical Strength | **** | ** | ** | ***** |

Very good ***** - Good **** - Medium *** - Poor ** - Insufficient *

Assan Panel reserves the right to make changes in this file that has been issued for informative purposes.

Reference: 1. Assan Panel Studies 2. TSE EN 14509 /08.01.2009 3. Lightweight Sandwich Construction, J.M. Davies 4. Sandwich Panel Construction, Rolf Koschade 5. Practical Guide to EN 14509, Klaus Berner 6. Durability Assessment of Sandwich Panel Construction, Dr. Lars Pfeiffer 7. TSE EN 13501-1 / December 2003 8. Ode Teknik Yayınlar – 1999 9. TSE 825 / April 1999 10. Heat loss: John Bradley, School of the Built Environment, Leeds Metropolitan University 11. STO Publications "Building with conscience" 12. Eleventh International IBPSA Conference -2009, Uncertainty in The Thermal Conductivity of Insulation Materials 13. The European XPS Associations, Exiba Publications 14. Knauf Insulation Publications 15. EPS Product Solutions, Plasti-Fab Publications 16. J-RAK Consulting for The Alliance for Fire and Smoke Containment-2004, Technical Buyer's Guide 17. Isopa, Fire Performance of Polyurethane Steel Deck Roofing 18. CPS, Composite Panel Services Ltd Publications 19. Alternatives to Glass Mineral Wool, 2004, Mott MacDonald 19. Optimum Design of Composite Cladding Panels, J.M. Davies