BASF Plastics
key to your success

Styropor®

Expandable Polystyrene (EPS)

Construction with Styropor

BASF

Fig. 1:
The pitched roof as a striking architectural element. Here roof insulating systems made from Styropor offer enduring thermal insulation – both in summer and in winter.

Thermal insulation in the construction industry

By virtue of its properties expanded foam made from Styropor has secured a firm position for itself as an insulating material in the construction sector for almost 50 years.

Styropor is the expandable polystyrene from BASF. It is supplied to foamed plastic producers in the form of bead-like granules.

BASF has a total of 12 plants around the world where it produces Styropor, the raw material for a diversity of application areas, insulating and building materials for the construction industry being uppermost.

Foamed plastics from Styropor

The production of Styropor foamed plastics takes place in three stages: preexpansion, intermediate aging and moulding. First of all, the granules are preexpanded and thus foamed by heating. The blowing agent contained in the raw material inflates the particles up to about fifty times their original volume to form closed-cell foam particles. This is followed by an intermediate aging time, during which air diffuses into the material and blowing agent partially diffuses out of the material.

Finally, the preexpanded particles are filled into molds and undergo final foaming, the foam particles expanding once again and fusing together. A rigid foamed plastic with a high air content is produced, which is trapped in a large number of small cells and brings about excellent long-lasting thermal insulation!

The special production process makes it possible to vary the apparent density of the Styropor foamed plastics within a wide range. As the properties of the foam depend substantially on the apparent density, foamed plastics can be produced with a variety of qualities suited to particular applications ranging from insulating boards to lightweight structural units.

Construction today and in the future is and will be characterized substantially by requirements for energy saving, noise and environmental protection.

Virtually all industrialized countries today have statutory minimum requirements for the constructional thermal insulation of heated and air-conditioned buildings.

By now, even in countries with moderate to tropical climates, a comparatively high level of constructional thermal insulation is prescribed, as is the case in countries with relatively low winter temperatures. This is due to the fact that in these countries summer thermal insulation – namely the energy lost in the air-conditioning of buildings – is a relatively significant factor in energy calculations, as is winter thermal insulation in other countries. This is so because the energy loss in the air-conditioning of a building on hot summer days is greater than that in the heating of buildings with cold outside temperatures in winter.

Being forced to use additional insulating layers today means for architects and building contractors on the one hand a considerable intervention into the amount of freedom they have in planning and structural design. On the other hand, this intervention has a beneficial effect on the development of new, innovative system solutions. Here, Styropor as a material for the insulation of complete compound units has for a number of years and in many countries held a significant place in practical construction on account of its excellent material properties.

Construction with Styropor

By using Styropor rigid foam, architects and construction engineers today are also at the same time making use of the opportunity presented by system solutions and incorporate them in their plans appropriately for the functions concerned. The trend is clearly toward specific insulation systems, such as external wall and roof insulation systems, underfloor heating systems etc.

Such systems give the owner of a building under construction not only considerable cost/benefit advantages but also reduce the risk of technical errors in the planning and execution of work.

The examples on the following pages show how Styropor is used as a system on a structure. They are current practical examples from internationally known construction applications.

They provide interesting insights into the unique versatility of foamed plastics from Styropor as system materials. Of course, this “practical exhibition” cannot cover all possible construction applications because there are so many. Even today, 4 decades after its invention, Styropor has lost nothing of its attractiveness and is more a part of today’s construction industry than ever.

Roof constructions with Styropor

From the viewpoint of construction physics, the roof, no matter of what design, is the most highly stressed part of a building. Heat and cold, dryness and wetness, storms and snow act from the outside, internal relative humidity acts from inside, either alternately or both at the same time. Roof designs and materials have to be adapted to these conditions if the roof is to fulfill its protective function. Plastics play a significant part in this connection, as insulating layers, waterproofing membranes, vapor barriers, underlays, gutters, downpipes and many other functional elements.

Whether a flat roof or a pitched roof, whether someone's home or an office building, on factories, workshops or warehouses, whether a roof garden or an underground garage: Styropor foamed plastics are always involved because they have outstanding insulation and offer economical answers as insulating systems.

Flat roofs

Flat roof insulation is an important field of application for Styropor foamed plastics. Depending on the roof design, the insulating material is laid loosely, fixed by hot or cold adhesive or mechanically fastened to the underlying surface.

The insulation of a nonventilated flat roof is performed simply and economically by means of insulating units of Styropor which have been precoated with roofing felt. The lamination with roofing felt protects the insulating layers when the hot bitumen is applied to fix the roof seal (Fig. 2). In the case of rollable insulating sheets, the lamination already counts as the first roof sealing layer.

Unlaminated rigid foam boards are used on what are known as tarpaulin roofs (Fig. 3). In this case, the insulating boards and the plastic tarpaulin sealing are loosely laid and provided with a ballast (eg gravel) or are fixed with special dowels.

Fig. 2:
Rollable insulating sheet

Fig. 3:
Tarpaulin roof

Pitched roofs

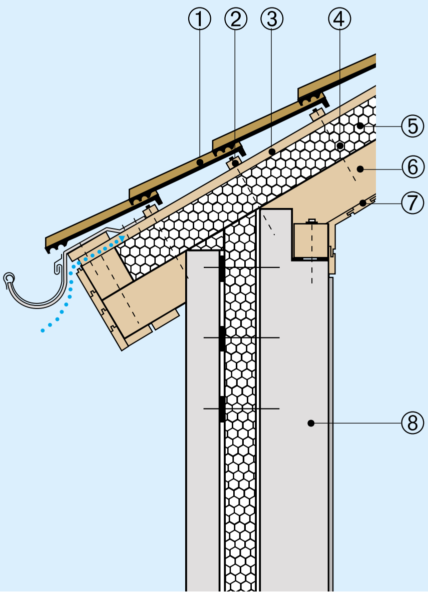
In many countries, use of the roof space for living purposes is already a consideration during the planning of a building. Even on existing buildings, roof space is increasingly being developed as additional living areas for guest rooms, play rooms or hobby rooms. Adequate thermal insulation of the roof surface – as the area bounding indoors from outdoors – must be provided. Making the insulating layer adequately thick is also worthwhile with regard to the effect of sunlight in the summer.

Suitable for use as insulation in pitched roofs are Styropor rigid foams in the form of filler insulating boards between the rafters, laid on the rafters (Figs. 4 – 6) or in the form of thermally insulating structural composite units. Such insulation systems make economical construction work possible and offer lasting thermal protection.

Fig. 4:
Construction and insulation with Styropor rigid foam

Fig. 5:
A Laying system:

1 = Tile roofing
2 = Roof battens
3 = Underlying battens (for ventilation)
4 = Nailing through the Styropor insulation
5 = Styropor laying system
6 = Rafters
7 = Formwork
8 = External wall with, for example, core insulation



One example of this offers advantages in particular in the case of a subsequently installed roof insulation: foam moulded boards with underlying vapour barrier are laid on the existing roof battens. The tiles are then re-laid on the profiled insulating units (Fig. 7).

Fig. 6:
Nailing the bearing battens

Fig. 7:
Foam moulded insulating boards

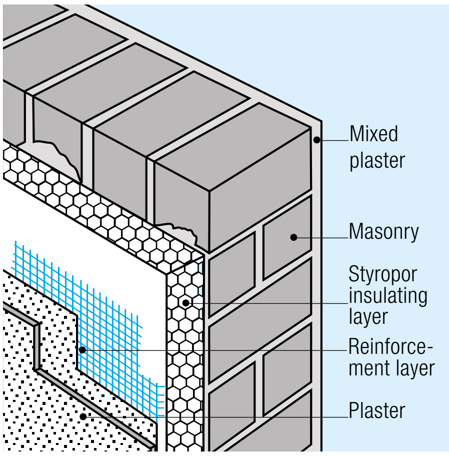
Wall constructions with Styropor

A wall is both a load-bearing and a protective building unit. It protects the surrounded space against the effects of temperature and weather and against noise. Nowadays, the thermal insulation function is assumed by modern insulating materials, such as Styropor foamed plastics.

In what is the optimum type of external insulation from a construction physics viewpoint, the Styropor insulating layer is applied on the outside of the load-bearing masonry and weather-protected either by a reinforced special plaster or by a ventilated facing layer. Another effective type of external insulation is an insulating plaster with foamed Styropor particles as lightweight aggregate, applied as a continuous layer. But composite Styropor/plasterboard units are also used to achieve thermal insulation to today's requirements by insulating external walls from the inside, for example by subsequent interior insulation on existing buildings.

A method widely used in Europe is that of external insulation with Styropor boards and fabric-reinforced plaster coating. In this method, the insulating boards are fixed to the masonry by bonding mortar and subsequently covered with a fabric-reinforced dispersion plaster (Figs. 8 and 9). The reinforcement of the plaster layer with alkaliresistant glass fibre sheets is necessary to absorb the material and temperature – dependent stresses in the plaster layer occurring on the insulated facade as the result of temperature fluctuations.

Figs. 8 and 9:
External wall insulation with the composite thermal insuiation system



The production of lightweight large-panel wall units with a plastercoated external insulation is particularly widespread in the USA. The supporting board is mounted on a sectional steel frame and provided with the insulation and fabric-reinforced plaster coating (Fig. 10). The easy-toassemble compound units give the impression of a solid external wall.

Another system of thermal insulation which is likewise widespread – is the use of mouldings from Styropor for the external walls of buildings. The mouldings are placed dry and then filled with concrete.

Walls and floors are produced "in one" when Styropor formwork elements are used for the production of reinforced concrete ribbed floors. The formwork elements are easy to lay and produce an even, thermally insulated ceiling which can subsequently be plastered or lined (Fig. 11).

Fig. 10 (above):
Installation

Fig. 11 (below):
Floor formwork elements

Fig. 12:
Wall construction system

There is an extremely wide variety of variations of wall moulding systems: large wall units, produced on continuous moulding machines and, for example, mouldings of Styropor with stainless steel connecting elements (Fig. 12) or wall formwork elements already provided with a pre-coating for plaster bonding.

In the case of a cavity wall, the insulating layer is provided between load-bearing wall and weather-resistant facing masonry. The closed-cell boards, rebated all around, make it possible to dispense with the otherwise customary air gap between insulation and facing masonry. The cavity between the two wall skins can be fully utilized for insulation (Fig. 13).

For the insulation of an already existing cavity wall, there is likewise an economical method: foamed particles are blown into the cavity between the two masonry skins. For this purpose, holes are drilled into the skin and closed again after the filling operation. Foamed beads are delivered in special silo vehicles.

A method of construction which is as simple as it is economical is the use of special masonry blocks in which the Styropor insulation has already been introduced into the cross-section of the block. This may be performed by the insulating boards being pushed manually into corresponding block cavities or already molded-in during block production.

Another method is to fill the block cavities with preexpanded beads and then foam them with steam.

This economical production method makes possible an integrated insulation and thus a substantially improved thermal insulation capacity of the hollow blocks.

To reduce heat loss through the mortared joints, a light masonry mortar is generally used.

Fig. 13:
Core insulation

Insulating plaster

A further possibility of improving the thermal insulation of external walls is to coat them with a thermally insulating lightweight plaster. In this case, small, foamed Styropor particles are added to the plastering mortar mix, substantially reducing the apparent density of the plaster and thus increasing its thermal insulation.

The dry mix is delivered to the construction site in sacks or containers and is prepared ready-for-use just by adding water.

Such lightweight Styropor plasters can be mechanically processed and sprayed on up to a thickness of 6 cm in a single operation (Fig. 14).

3 to 5 days after applying the layer of insulating plaster, a mineral plaster is added for surface protection.

Depending on the plaster thickness, profiling and surface coating, unconventional facade designs are also possible (Fig. 15).

Fig. 15:
Insulating plaster facade
Building: Les Grottes, Geneva

Fig. 14:
Insulating plaster

Lightweight concrete

Foamed Styropor beads are not only suitable for lightweight plasters, but also for the production of lightweight concrete and porous bricks. The possible applications of Styropor concrete as a thermally insulating, lightweight construction material have already been investigated by BASF years ago and formulations for various apparent density ranges with different concrete properties developed.

From the point of view of structural thermal insulation and economical processing, Styropor concrete is of particular interest in the low, very light apparent density range: for example as a special prefabricated system in which the tubular cavities in the lightweight Styropor concrete wall units are later filled with normal concrete, which undertakes loadbearing and reinforcing functions. Recesses or openings can be cut out simply by using a saw (Fig. 16).

Or for the production of domed houses, using a blown-up shell on which the Styropor concrete is mechanically sprayed.

Fig. 16:
Styropor concrete
wall units

Prefabricated Systems

The use of Styropor foamed plastic boards as thermal insulation in large-format facade units of normal concrete (sandwich construction) has long since proven successful (Fig. 17).

The high mechanical load-bearing capacity and dimensional stability of Styropor rigid foam also make possible a trouble-free production of largepanel lightweight units which can be covered with various materials depending on the intended application (Fig. 18, see page 12).

– Such as sheeting with wood or chipboards as load-bearing wall or roof unit in prefabricated home construction: an economical dry insulation technique which is used particularly in North America, where it has been recognized that houses made from prefabricated Styropor units make possible far more cost-effective construction and energy-saving living than conventional building methods.

Fig. 17:
Prefabricated concrete
unit

– Such as sandwich units covered with fibrated concrete slabs, as infill, thermal-insulating facade units.

– Such as large-format wall and roof units with metal coating as systems for industrial constructions and cold stores. Such structural systems are preferred in particular in countries where there is a high demand for cold rooms or cold storage houses, such as South America and Australia. In this application, as in the insulation of refrigerant lines, the good thermal insulation and dimensional stability of Styropor foamed plastics prove effective even at low temperatures.

The lightweight, prefabricated composite units can be transported costeffectively over large distances. They are therefore also used as a structural system in the construction of houses and housing estates, in particular in locations where living quarters have to be created under difficult climatic and constructional conditions. Whether in the cold of the Antarctic or in the heat of dry desert regions: Styropor composite units make economical construction possible and offer pleasant living conditions (Figs. 19 and 20).

Fig. 18:
Detail of Styropor composite unit

Fig. 19:
This region in West Australia suffers from cyclones and summer temperatures of 45 °C (113 °F). All the buildings of this settlement were constructed using the Styropor sandwich technique. The 50 mm to 75 mm thick sheet steelcoated panels were brought 1600 km for this project.

Fig. 20:
Australian research center in the Antarctic. The building consists of 100 mm to 150 mm thick Styropor sandwich units which have to withstand temperatures down to 40 °C (– 40 °F) and wind speeds of up to 280 km/h (174 miles/h).

Floor constructions with Styropor

Footfall sound insulation

In some countries, structural sound insulation is even today only of secondary importance; nevertheless, in the meantime noise pollution has become so great everywhere, especially in large conurbations, that adequate sound insulation is becoming ever more important. As well as limiting sound transmission through external compound units, impact sound insulation is of great importance. To achieve effective impact sound insulation, the sound which is made by walking on a floor must be prevented from being transmitted to other compounds units. For instance, a thick carpet may be laid on a concrete floor. However, this is only a temporary solution, as the carpet wears out or may be taken up. Another possibility is to increase the weight of the floor and thus reduce the sound transmission. However, this is only possible to a limited extent for financial and technical reasons. All of these considerations finally led to the development of what is known as the "floating floor system", a flooring structure common in particular in Germany and a number of other European countries (Fig. 21).

A floating floor is a flooring (for example cement screed) which is laid on a flexible insulating layer and can freely oscillate, thus acting as a spring-mass system. This substantially prevents the penetration of structure-borne sound into the floor structure.

Special Styropor foamed plastic boards, which are elasticized by special subsequent treatment, have proven their value for impact sound insulation. Such boards have a low dynamic rigidity (comparable with an air cushion) and are nevertheless sufficiently compression-resistant to bear the load of the floor permanently.

Floor heating

Impact sound insulation is often combined with underfloor heating. To avoid downward heat loss, an insulating layer of Styropor rigid foam is laid between the underfloor heating and the impact sound insulation. Boards with moulded-in grooves or elevations on the upper side are used for this to permit easy laying of flexible polyethylene hot water pipes (Fig. 22).

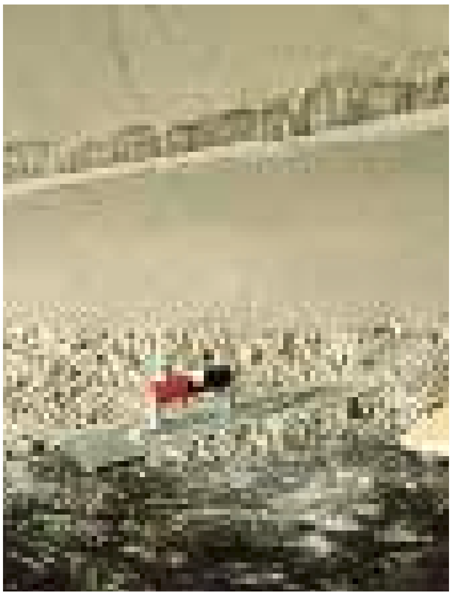


Fig. 21:
Structure of floating floor

Fig. 22:
Floor heating

Fig. 23:
Laying moulded Styropor elements for the thermal insulation of the normal floor construction in Japan

Styropor: miscellaneous uses in construction

As well as applications in the area of thermal and impact sound insulation, Styropor foamed plastics perform a wide variety of other functions in construction.

Drainage boards

Drainage boards of Styropor consist of foamed Styropor beads which are interconnected in such a way that the voids produce a large continuous pore volume. As a vertical filter layer in front of cellar walls or retaining walls, drainage boards prevent seepage water accumulating in the ground until it exerts hydrostatic pressure. They form a path of seepage from the overlying ground to the drain tile at the foundation of the wall (Fig. 24).

Drainage boards of Styropor have also proven particularly suitable for the drainage of roof gardens. The advantages here are the additional thermal insulation and the low weight in comparison with a drainage layer of gravel.

Permanent formwork

To reduce the weight per unit area of large-span concrete floors, in particular in the case of ribbed floors and coffered ceilings, Styropor formwork elements are used. Depending on requirements, such formwork elements are cut from the block or produced as a foam moulded unit (Fig. 25).

Large-format wall and floor formwork with foamed plastic boards are produced by pushing the board sections into a correspondingly designed structure of galvanized steel wires. After assembly of the formwork elements, concrete is cast in the cavity. The thermally insulating Styropor formwork is subsequently plastered or lined, the outer steel mats offering a good anchorage (Fig. 26).

For making concrete facades, Styropor textured formwork is used. To create an artistic design on a concrete wall, the image relief may be cut in the foam, for example with a hot wire, and the foam then used as concrete formwork.

Fig. 24:
Drainage

Fig. 26:
Wall formwork system

Fig. 25:
Floor formwork

Foundation engineering

Especially in northern countries with severe winters and deep ground frosts, Styropor rigid foam has proven very successful as an insulating material for protection against frost damage to foundations and buried pipelines (Fig. 27).

The special properties of the closed-cell foamed plastic, such as stability and durability, the immunity to moisture and ground bacteria and also the good thermal insulation have resulted in rigid foam boards being used as a frost protecting layer in road and railroad construction. The practical experience of this since 1968 – in particular in Scandinavian countries – provided the basis for a new method of construction, which has been developed since 1972 in Norway and in the meantime is also put into use in other countries: the use of Styropor blocks as a loaddistributing substructure for road and bridge approach ramps in areas with poor loading-bearing soil conditions. In such regions, major settlement of the pavement structure have occurred over the years, necessitating expensive renovation work. Solving the problem was possible with Styropor rigid foam blocks which, assuming an apparent density of at least 20 kg/m^3 (1.25 pcf), have the strength properties necessary for this application. The high bending and shear strength of the lightweight block foam made a good pressure distribution possible on the muddy ground. The low weight of such a substructure permanently prevents sinking of the road structure.

The rigid foam blocks are secured against slipping by claw plates and stacked up to a height of 10 m. Then a 10 cm (3.94 in.) thick layer of concrete with steel mesh reinforcement is applied before laying the bituminous pavement (Fig. 28).

Fig. 28:
Styropor as a load-distributing substructure

Fig. 27:
Foundation formwork

Characteristics of Styropor foamed plastic

Thermal properties

There is virtually no lower temperature limit for the application of Styropor rigid foam in the construction industry. Wherever a thermally induced volume contraction requires such a limit (for example in cold store construction), this is to be taken into account in design. If the rigid foam is subjected to elevated temperatures, the maximum permissible temperature depends on the duration of temperature exposure and the mechanical loading of the foam (see Table 2 on Page 18).

In the case of brief exposure (fixing with hot bitumen), Styropor rigid foam may also be subjected to higher temperatures. Under prolonged temperature exposure above 100 °C (212 °F), the foam structure begins to soften and to sinter.

Fire behavior

Like many other construction materials, Styropor foamed plastics are combustible. When assessing their fire behaviour, it must be taken into account that this depends to a substantial extent not only on material-related effects but also on application conditions. Of considerable importance in particular is the combination with other construction materials and the often necessary or desired arrangement of protective and covering layers.

With regard to the material-related effects, a distinction has to be made between foamed plastics from Styropor P and -F grades. The latter include a flame-retardant additive which distinctly reduces ignitability and flame progagation. They achieve the best possible classification for combustible construction materials specified by various national regulations.

While foamed plastics of Styropor P grades are to be classified as highly flammable, construction material class B3, when tested in accordance with DIN 4102, Part 1 (May 1981) and therefore inadmissible in Germany as construction materials, foamed plastics of Styropor F grades meet the requirements specified in this standard for flame resistant construction materials, construction material class B 1. As proof of this, the test mark PA-III 2.1001 has been issued. The test certificate also reveals that these foamed plastics are to be classified as non-dripping when they burn.

Therefore, in most cases the use of foamed plastics of Styropor F grades for constructional applications may be permitted, though in each case the respective national building regulations are to be observed.

As biological investigations have shown, if Styropor rigid foam is involved in a fire, the toxicity of the gasses from burning and carbonization is lower than that of the same amounts of wood.

Biological properties

Foamed plastics from Styropor have no nourishing value to animals. They do not rot, are not water soluble and do not give off any water-soluble substances which could contaminate ground water. If relevant local regulations are observed, they may be dumped together with household refuse.

Foamed plastics from Styropor have been in production and use for several decades. No harmful effects on health have been discovered in this time. The health-safety of the application of rigid foam boards of Styropor is also evidenced by the fact that Styropor is used as food packaging.

Table 1: **Resistance of Styropor rigid foam to chemicals**			
Active agents	Styropor® P	Styropor® F	Styropor® FH
Salt solutions (seawater)	+	+	+
Soaps and wetting agent solutions	+	+	+
Bleaching lyes, such as hypochlorite, chlorine water, hydrogen peroxide solutions	+	+	+
Dilute acids	+	+	+
35 % hydrochloric acid, up to 50 % nitric acid	+	+	+
Anhydrous acids, for example fuming sulfuric acid, glacial acetic acid, 100 % formic acid	–	–	–
Sodium hydroxide, potassium hydroxide, ammonia solution	+	+	+
Organic solvents, such as acetone, ethyl acetate, benzene, xylene, paint thinner	–	–	–
Saturated aliphatic hydrocarbons, surgical spirit, test benzene	– (+ –)	– (+ –)	– (+ –)
Paraffin oil, vaseline	+ – (+)	+ – (+)	+ – (+)
Diesel oil	– (+)	– (+)	– (+)
Motor fuel (normal and super gasoline)	–	–	–
Alcohols, for example methanol, ethanol	+ –	+ –	+ –
Silicone oil	+	+	+

\+ Resistant: the foam plastic is not destroyed even after prolonged exposure.

\+ – Conditionally resistant: the foamed plastic may shrink or suffer attack to the surface after prolonged exposure.

– Unresistant: the foamed plastic shrinks at a greater or lesser rate or is dissolved.

Table 2: **Physical data for foams made from Styropor® for construction**

Properties [1]		**Test standard**	**Unit**	**Test result**		
Quality assured types		GSH quality conditions		PS 15 SE	PS 20 SE	PS 30 SE
Application types		DIN 18164, Part 1		W	WD	WS + WD
Minimum bulk density		EN ISO 845	kg/m³	15	20	30
Building material class		DIN 4102		B1, Poorly flammable	B1, Poorly flammable	B1, Poorly flammable
Thermal conductivity	Measured value at +10 °C	DIN 52612	mW/(m · K)	36 – 38	33 – 35	31 – 34
	Calculated value according to	DIN 4108	mW/(m · K)	40	40	35
Compressive stress at 10 % compressive strain		EN 826	kPa	65 – 100	110 – 140	200 – 250
Resistance to sustained compressive loads at < 2 % strain after 50 years		ISO 785	kPa	20 – 30	35 – 50	70 – 90
Flexural strength		EN 12089	kPa	150 – 230	250 – 310	430 – 490
Shear strength		DIN 53427	kPa	80 – 130	120 – 170	210 – 260
Tensile strength		DIN 53430	kPa	160 – 260	230 – 330	380 – 480
Modulus of elasticity (compressive test)		EN 826	MPa	1.0 – 4.0	3.5 – 4.5	7.5 – 11.0
Heat deformation temperature	short-term	based on DIN 53424	°C	100	100	100
	long-term at 50 kPa		°C	75	80	80
	long-term at 20 kPa		°C	75	80	80
Coefficient of linear expansion			1/K	$5 – 7 \cdot 10^{-5}$	$5 – 7 \cdot 10^{-5}$	$5 – 7 \cdot 10^{-5}$
Specific heat capacity		DIN 53765	J/(kg · K)	1210	1210	1210
Water absorption when submerged (by volume)	after 7 days	EN 12087	Vol. %	0.5 – 1.5	0.5 – 1.5	0.5 – 1.5
	after 28 days		Vol. %	1.0 – 3.0	1.0 – 3.0	1.0 – 3.0
Water vapor diffusion rate		DIN 52 615				
Water vapor diffusion resistance factor		Calculated according to DIN 4108, Part 4	1	20/50	30/70	40/100

[1] corresponding to Test Norm

1 N/mm² = 1000 KN/m² = 1 MPa = 1000 kPa

Further information

This brochure could only give a broad outline of the many fields of application of Styropor foamed plastics. Details on application techniques, structural engineering and construction physics are contained in the “Technical Information” publications by BASF.

Photo credits

Figure 11:
Rhodius – Chemie-Systeme GmbH

Figures 19 and 20:
BONDOR PTY LTD, Australia

Figure 22:
Felix Schuh & Co. GmbH

Figure 27:
ISORA OY, Finland

Figure 28:
ISO Bouw, The Netherlands

Note

The information submitted in this publication is based on our current knowledge and experience. In view of the many factors that may affect processing and application, these data do not relieve processors of the responsibility of carrying out their own tests and experiments; neither do they imply any legally binding assurance of certain properties or of suitability for a specific purpose. It is the responsibility of those to whom we supply our products to ensure that any proprietary rights and existing laws and legislation are observed.

Note:
You will find more information on Styropor in the Technical Information leaflets available on CD-ROM.
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