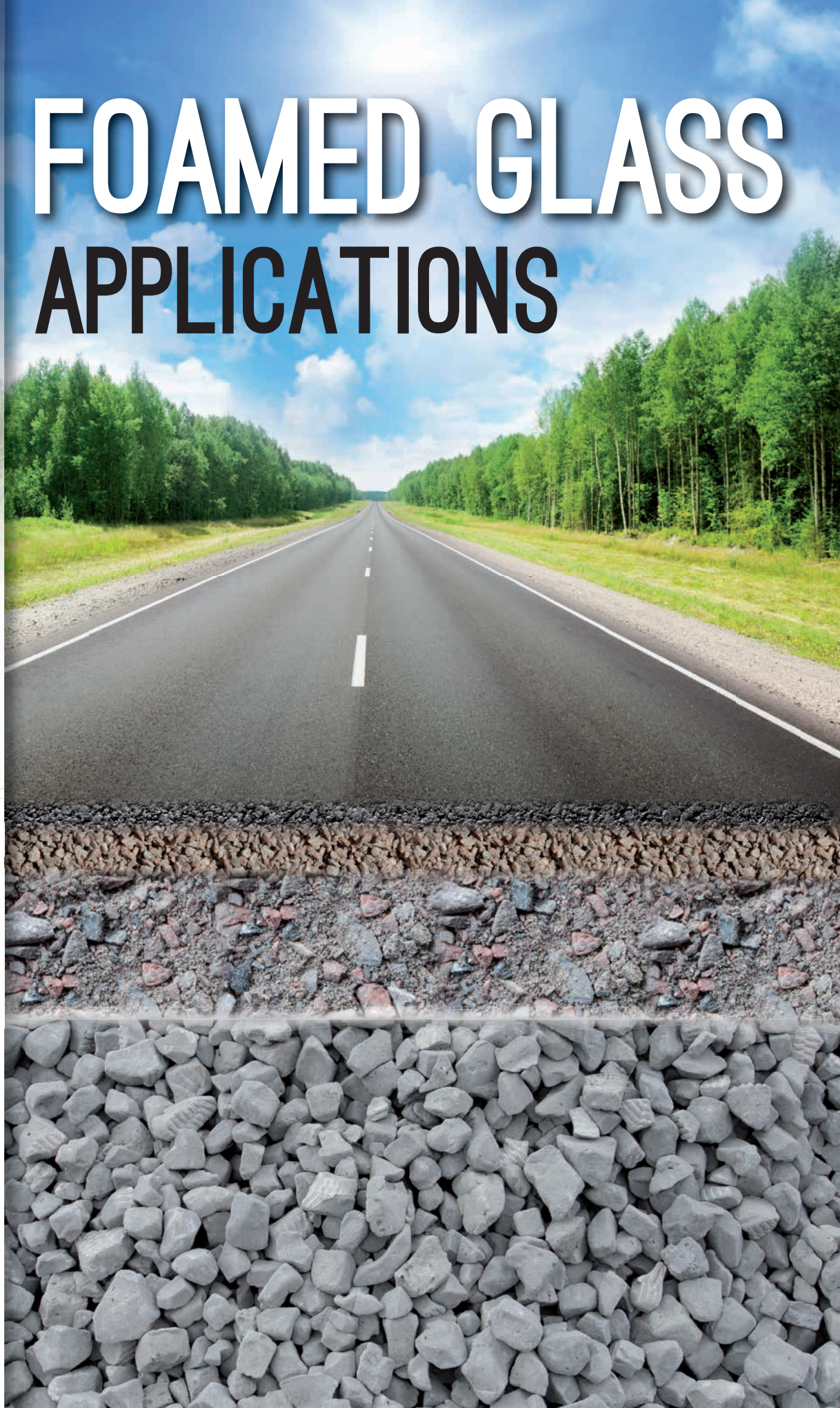
FOAMED GLASS
APPLICATIONS



Foamit®

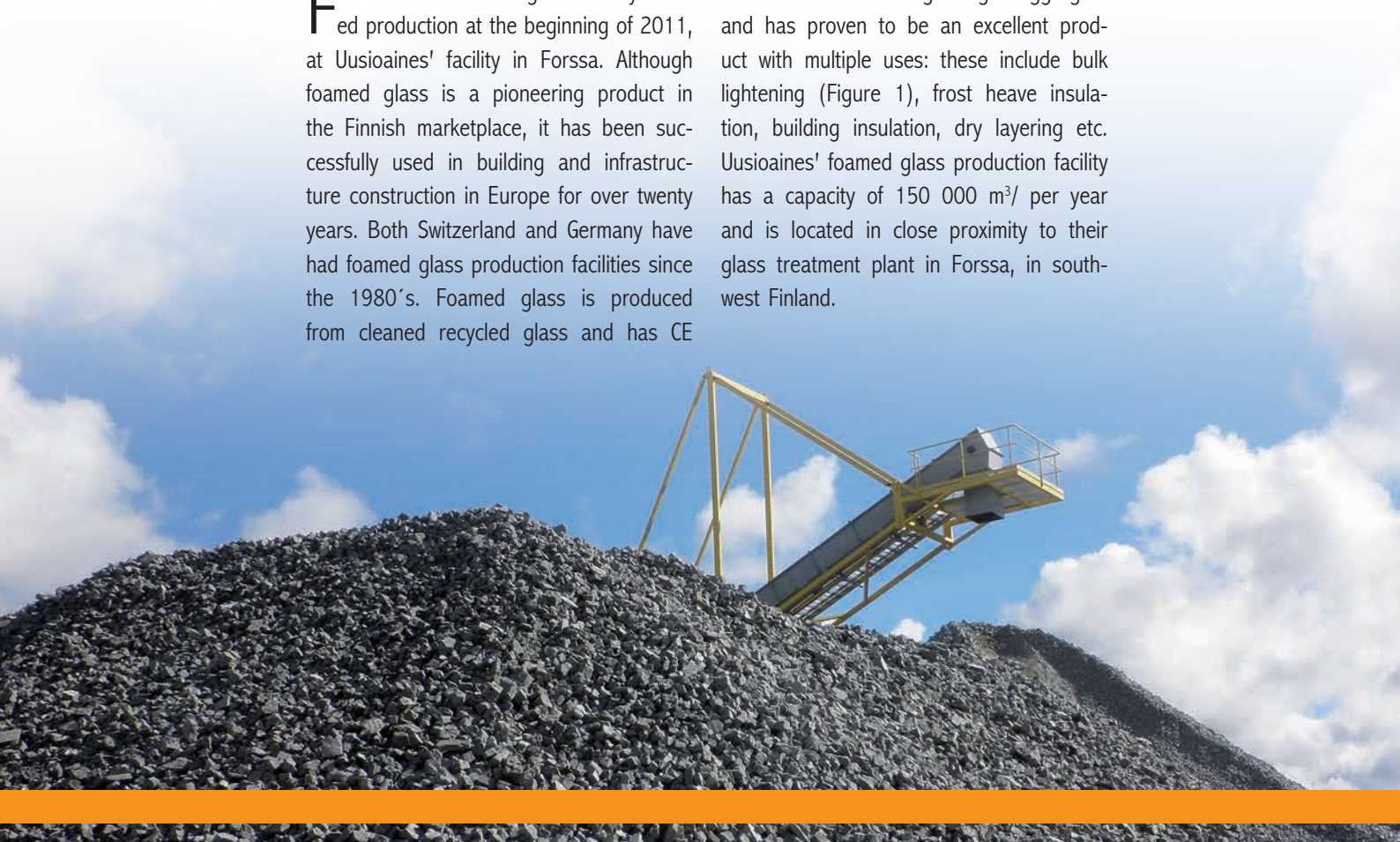
Foamit®, Applications for Civil Engineering and Municipal Construction Projects.

Contents

1.	**Introduction**	**2**
2.	**Foamit -foamed glass in bulk lightening projects**	**3**
2.1	General information	3
2.2	Embankments and transitional structures	3
2.3	Foundations and back-filling for structures	4
2.4	Pipe trenches	4
2.5	Parameters and measurements	5
2.6	Load bearing capacity	5
3.	**Foamit as a frost heave insulator**	**7**
3.1	Overview	7
3.2	General information: frost heave and pipelines	7
4.	**Foamit -building a course of foamed glass**	**8**
5.	**House-building**	**10**
5.1	Passive House construction	10
5.2	Growing media for green roofs	10
6.	**References**	**11**

1. Introduction

Finland´s first foamed glass factory started production at the beginning of 2011, at Uusioaines' facility in Forssa. Although foamed glass is a pioneering product in the Finnish marketplace, it has been successfully used in building and infrastructure construction in Europe for over twenty years. Both Switzerland and Germany have had foamed glass production facilities since the 1980´s. Foamed glass is produced from cleaned recycled glass and has CE certification. It is a lightweight aggregate and has proven to be an excellent product with multiple uses: these include bulk lightening (Figure 1), frost heave insulation, building insulation, dry layering etc. Uusioaines' foamed glass production facility has a capacity of 150 000 m^3/ per year and is located in close proximity to their glass treatment plant in Forssa, in southwest Finland.



2. Foamit® foamed glass aggregate in use in bulk lightening projects

2.1 General information

The purpose of bulk lightening is to reduce load on the subsoil as well as reducing the horizontal load on structures in the vicinity. Foamed glass aggregate is designed to keeps its structural bulk lightening properties for a minimum of fifty years.

Foamed glass aggregate has an angular granular shape and an acute friction angle and these properties make it possible to build on quite steep gradients. Foamed glass aggregate keeps its shape in trenches, which makes repairs or alterations simple for district councils or municipal authorities. Even though foamed glass aggregate is angular its edges are, in the main, rounded (Figure 2). Sharp edges round-off during the period of its handling, spreading and compaction. Any possible remaining sharp edges are rubbed away when the material is installed.

Foamed glass is produced by industrially treating cleaned glass particles. These glass particles are ground into a powder of under 0.1mm and mixed with a foaming agent. The powdered glass is then spread onto a conveyor belt and then slowly passed through a furnace. The furnace heats the powdered glass to a temperature of 900 °C. This causes the glass mass to expand to five times its original size and it subsequently hardens into foamed glass. 92% of foamed glass´s composition is air bubbles. As the foamed glass cools it breaks up into pieces and forms foamed glass aggregate.

2.2 Embankments and transitional structures

Foamed glass aggregate is used as a bulk lightener in traffic infrastructure construction, providing bulk filling material for

Figure 1. Foamed glass being spread on a worksite

embankments (e.g. in pavements, roads, harbour areas, bridge embankments, ramps and culvert foundation work).

It is possible to construct very high embankments using a layer of foamed glass aggregate many metres thick. A typical example of a road embankment built with foamed glass aggregate is the bulk lightening project shown in Figure 3.

Foamed glass aggregate´s internal friction angle can be compared to traditional aggregate. Lightening ramps can be built up to a gradient of 1:1 or less depending on the height of the embankment, the load on the top of the embankment and the bearing capacity of the subsoil. During the construction phase the layer of foamed glass aggregate does not necessarily need a supporting embankment. However a support embankment can lessen the spread of the embankment itself, as it is compacted, as well as ensuring that the outermost edges are sufficiently compacted. The ramp is then spread with a layer of foamed glass (which can then be covered with a geotextile membrane) and a minimum 0.5m thick layer of soil. If the soil is impermeable and used on a gradient then it is necessary to construct drainage holes every thirty metres. It is necessary to calculate the effects of the level of the surrounding ground water on the foamed glass layer (for possible lift). A transforming area of foamed glass can even out differential pressure in the event that the ground conditions , loads on the subsoil or the foundation building method, change significantly in a short period (i.e. the transfer of clay to bearing soil, the deep underground stabilisation of ground mounted embankments, concrete piles). Also it should be ensured that the thickest end of the bulk-lightened wedge does not undergo settlement. The principal of building a foamed glass displacement platform for a transitional structure is shown in Figure 4.

2.3 Foundations and back-filling for structures

The construction of a retaining wall using foamed glass as a back-filler reduces horizontal load. It makes it possible to construct both a lighter retaining wall as well as making it possible to use the space more effectively. When foamed glass is used as a back-filler the horizontal load is only around 15-45% of that of mineral aggregate filler, depending on the thickness of the aggregate layer, the friction angle of the aggregate, as well as the surface load. Foamed glass used for bulk lightening as back filler for a retaining wall is shown in Figure 5. In the embankment it reduces vertical compression from the road and in the foundations it functions as a bulk lightener to reduce horizontal load.

2.4 Pipe Trenches

The use of foamed glass in pipe trenches evens out compression and reduces the need for maintenance work as well as increasing the structure´s operational life. Foamed glass can be used when building roads during the construction of urban areas and the pipe network. In cases where a zinc-coated pipe is employed a geotextile or other type of membrane should be used in between the pipe and the foamed glass. If foamed glass is used as primary filler around pipes then a smaller particle size of Foamit should be chosen. In Figure 6 a layer of foamed glass is used as bulk filler in a pipe trench. The corners of foamed glass are mainly rounded off and any possible sharp corners break off when the foamed glass is spread and compacted.

Figure 2. Foamit- foamed glass aggregate's typical granular shape

Foamed glass can be used as bulk filler in pipe trenches in the same way as mineral gravel.

2.5 Parameters and Measurements

The required measurements and technical properties of foamed glass used in bulk lightening projects are listed in Table 1. If needed, the material´s measurement values can be verified with the manufacturer.

When the foamed glass is compacted its granules are refined and smoothed. The compaction also results in the removal of any residual sharp angles as they are rounded off during the process. The typical Foamit foamed glass particle size is 0-60mm. Only a small percentage is under 10mm.

The permeability of foamed glass can be compared to that of crushed aggregate or gravel as well as having a similar shape and scale of grain sizes. Permeability to water is estimated at around $k \geq 10^{-1}$ m/s.

Foamed glass´s geotechnical measurements should be utilized according to the intended end use of the foamed glass. For general safety, codes, laws and guidelines from the country where the product is to be used should be adhered to.

Foamed glass´s load bearing and frost prevention measurements should be calculated according to the intended usage of the product and according to the guidelines for the country of usage. Measurements for usage of the foamed glass should also take into consideration any special features of the job site to gauge the material´s suitability and this should be undertaken during the planning stage.

2.6 Load Bearing Capacity

To accurately calculate the loadbearing capacity, source data is needed, such as: the target bearing capacity, the thickness of the covering layer as well as the bearing capacity of the subsoil or the supporting embankment. The bearing capacity of roads, pavements and yard structures should be calculated on a case by case basis.

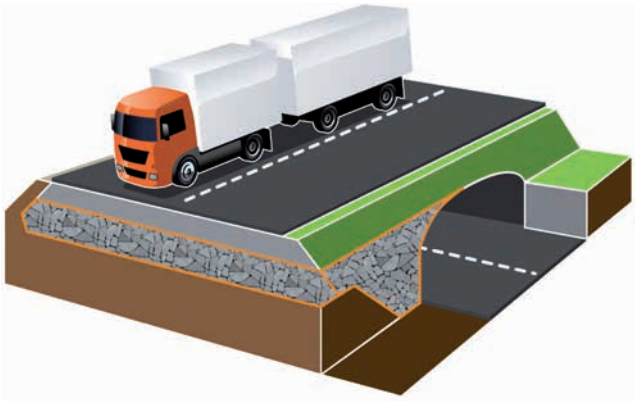


Figure 3. Foamed glass used in an embankment and for the bulk lightening of foundations for a bridge.

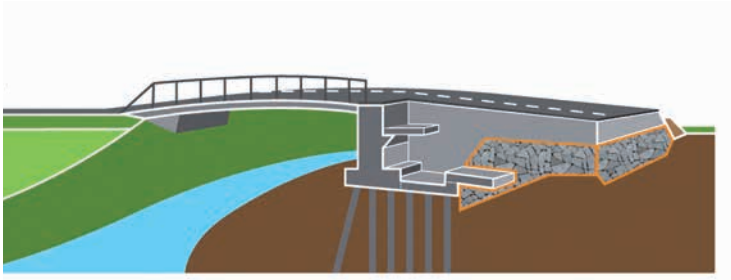


Figure 4. Foamed glass in use as a bulk lightener for both the embankment of a bridge's approach-ramp and the transitional structure.

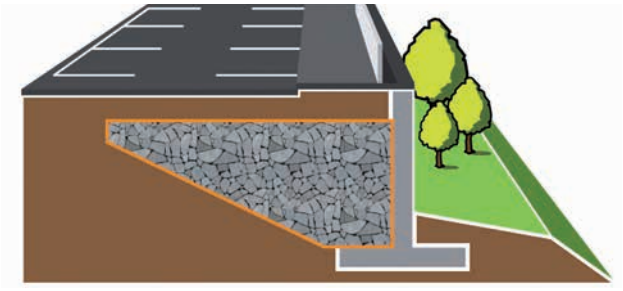


Figure 5. Foamed glass used as back filler for a retaining wall

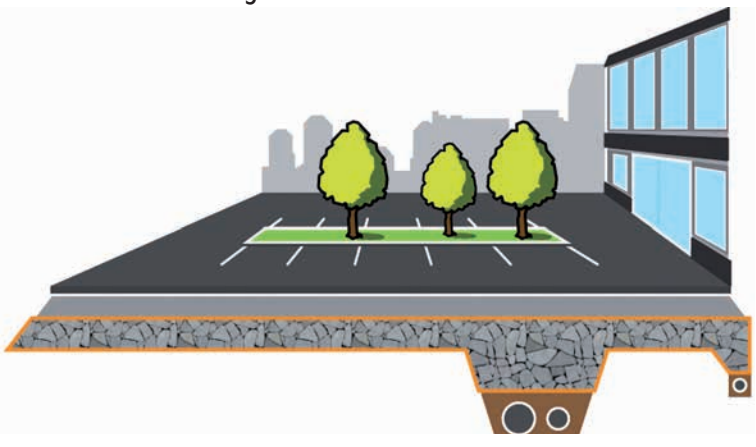


Figure 6. Foamed glass used as bulk filler in a pipe trench

Table 1. The technical properties of foamed glass (A) and its loadbearing properties (b)

a) Properties	Variations recorded in technical literature	FOAMIT® Measurement values
Granular size	10-50 / 10-60 mm	10-60 mm
Density (dry bulk)	180…230 kg/m^3	210 ± 15 %
Density (dry compacted)*	225…290 kg/m^3	220…280 kg/m^3
Density (moist, in a long-term road structure)	270…530 kg/m^3	350 kg/m^3
Density, long-term underwater (<1 year)		600 kg/m^3
Density, permanently underwater		1000 kg/m^3
Bulk density (measurements of lift)		3.5 kN/m^3
Bulk density (permanently underwater)		10 kN/m^3
Friction angle	36…45°	36…45°
pH-value		10
Sealant layer		1.15…1.25
Water absorption**		
Short-term (4 weeks)	30…60 weight-%	≈ 60 weight-%
Long-term (1 year)	40…116 weight-%	≈ 100 weight-% ***
Compression strength		
10 % amount of compression		0.3…0.4 MPa
20 % amount of compression	0.77…0.92 MPa	> 0.9 MPa

b)	Modular	Analytical method
E-module	55…70 MPa *,	**
	thin…thick superstructure	
Resilient-moduuli Mr	≥ 75 MPa, average principle stress 40 kPa	Cyclical 3-axial test
	≥ 150 MPa, average principle stress 100 kPa	

* Foamed glass modular structure´s increasing factors are a thick superstructure, good bearing capacity for subsoil as well as support embankments

** Values for the Odemark formula

The parameters have been defined/evaluated on the basis of the following publications, reports and memorandum : Byggforsk [2005]; the Finnish Transport Agency [2011a]; Ramboll [2012 and previous laboratory tests]; Ramboll [2011a]; Ramboll [2010]; SGI [2008]; Sintef [2010]; Statens vegvesen [2008]; TTY [2012].

3. Foamit® foamed glass as a frost heave insulator

3.1 Overview

Foamed glass is a material that prevents frost heave and is thus an excellent insulator. Foamed glass is suitable for use as a frost heave insulator in road and pavement construction as well as in sports fields and yards. Foamed glass works in a thinner than average layer which means that when it is used as a frost heave insulator the amount of excavated soil is reduced as well as the use of mineral aggregate, both of which speed up the building process. The upper structural layer´s thickness can also be significantly decreased by up to half that of a structure without thermal insulation properties.

When foamed glass is used as a frost heave insulator in roads, yards and parking areas it reduces maintenance costs as it decreases frost heave damage and delays the need for resurfacing. Foamed glass is able to withstand the effects of repeated freezing and melting without breakage. Trials have shown that the freezing and melting process does not increase foamed glass´s permeability or decrease its compressive strength.

A layer of foamed glass does not normally need a separate dry drainage course to be constructed (e.g. of sand) as do other types of insulation such as expanded polystyrene. Foamed glass aggregate acts as a capillary blocker and prevents water from being absorbed from the subsoil structure. When foamed glass is used for frost heave prevention a drainage course, of sand or aggregate (a minimum of 0.2m thick), may also be constructed underneath. This is appropriate if the structure is not to permit any frost heave whatsoever. The drainage course can also be compensated for by using a double thickness of foamed glass (a minimum of +0.15m).

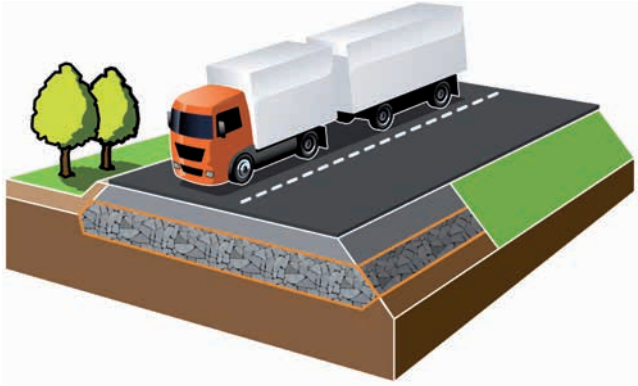


Figure 8. Foamed glass for frost heave insulation in road construction.

Foamed glass used for frost heave insulation in road construction is shown in Figure 8.

3.2 General information relating to frost heave and pipelines

The insulation of pipes in frost heave conditions should adhere to the guidelines and directives of the country of use. The planning of pipeline insulation should take into account the uneven nature of possible frost heave rise, though this can be counteracted by the use of transitional structures. Nomograms and general principles should be adhered to when planning the thickness of the insulation layer and attention should be paid to the trenches and their frost heave insulation requirements.

Table 2. Foamed glass´s technical properties

Properties	Range of variation in technical literature	FOAMIT® Measurement Values
Granual size	10–50 tai 10–60 mm	10-60 mm
Thermal conductivity		
- dry	0.10…0.11 W/mK	0.11 W/mK
- moist	0.13…0.15 W/mK *	0.15 W/mK
Equivalence in terms of insulation **	-	$a_i = 4$
Capillary rise	120…175 mm	200 mm

* Moisture content 25 weight-%, Dry density 210…280 kg/m^3 ** Foamed glass´s equivalence in terms of insulation in comparison to sand (ai)

4. Foamit® –building a course of foamed glass

Foamed glass is an extremely easy material to work with on a jobsite as, although it is angular, its corners are in the main rounded off and any remaining sharp edges are rounded off during the handling, spreading and compaction of the material (see Figure 2). Dry foamed glass does produce small amounts of dust but this can be prevented by dampening the material. Foamed glass is spread and compacted using ordinary plant equipment. It can be spread, for example, using a standard excavator with tracks. Pre-sealing compaction can be carried out with the excavator tracks or with a vibratory plate compactor.

This pre-compaction should be carefully carried out to ensure that the top layer of Foamit is evenly spread. After this pre-compaction the top layer of foamed glass may suffer some small areas of breakage. This is not detrimental to the structure of the material. The surface is sufficiently pre-compacted when it is evenly spread and the excavator tracks have not made any pressure marks in the foamed glass layer.

Next the sealant layer of mineral gravel can be evenly spread and finally compacted with a roller as shown in Figure 10.

In our experience, it is not advisable for a vibratory soil compacter to be driven directly over a layer of foamed glass and pre-compaction should be undertaken beforehand.

Table 3. Foamed glass sealant layer pre-compaction

	Maximum layer thickness (before compaction)	**Amount of times it is recommended to be driven over**
Excavator with tracks	0.6 m	≥ 2
(base pressure 30…50 kPa)	(0.9 m*)	
Vibratory plate compactor (50…200 kg)	0.4 m*	≥ 2

* In structures with weak bearing subsoil the lowest layers of compacted foamed glass material should be a maximum of 0.9m so as to not cause possible subsoil disturbance.

It should be taken into consideration that during the compaction stage the material will be compressed. This can be compensated for by adding an extra layer of foamed glass at the same time as the main bulk of the Foamit is spread. This extra layer should be around 10-25% of the thickness of the main bulk to be spread on the site. In cases where this extra layer is not used, the structure´s bulk lightening properties will be reduced.

The final compaction of the sealant layer is carried out with a c.150-200mm thick layer of mineral aggregate which is driven over by a vibratory soil compactor (1- or 2-rollers). The choice of compaction machinery, as well as the number of times the structure should be driven over, is dependent on the thickness of the structure's layers as well as the bearing capacity of the subsoil.

Figure 9. The unloading of foamed glass aggregate from the delivery vehicle as well as the spreading and pre-compaction of the material.

Figure 10. The final compaction over a 150-200mm layer of mineral aggregate.

5. House-building

5.1 Passive House construction

Foamed glass aggregate is well-suited for the construction of the foundations of an energy-saving Passive House. Due to its high performance as an insulation material, combined with its resistance to moisture penetration as a capillary blocker, the use of Foamit foam glass aggregate reduces material and labour costs. One building phase may be eliminated, removing the need for an extra layer of alternative insulating materials such as expanded polystyrene. In addition, Foamit's steep friction angle facilitates the construction of Passive Houses on gradients and in difficult terrain. The reduction of a building phase coupled with Foamit's high spreadability also reduces the number of passes necessary for heavy machinery on such gradients and problematic terrain.

Foamit foamed glass aggregate's properties as a lightweight bulk filler also minimise the overall load on the subsoil. Even though Foamit is an extremely lightweight material its bearing capacity is well-proven. In situations where the subsoil has a poor bearing capacity the use of foamed glass aggregate can be considered.

5.2 Growing media for green roofs

Foamit is well-suited as a component for the growing medium, planted over a waterproofing membrane, that is partially or completely covered with vegetation and soil, and constitutes the green roof of a building. With its lightweight properties, good permeability and strong insulation credentials it has significant advantages over mineral alternatives such as mineral aggregates and sand.

6. References

- Byggforsk 2005. Hasopor, European Technical Approval No. ETA-05/0187. 13 s.
- Finnish Transport Agency 2011a*. Bulk lightening plans. Guidelines for road foundation construction 05/2011. 9.3.2011. 48 s.
- Ramboll 2012*. FOAMIT foamed glass laboratory tests; Technical report. 3.2.2012. 6 s.
- Ramboll 2011a*. FOAMIT foamed glass compaction test, Forssa. 28.6.2011
- Ramboll 2010*. FOAMIT foamed glass, performance in a groundwater area, Risk assessment. 53 s.
- SGI 2008**. Manual for Foam Glass in soil and road construction. The Swedish Geotechnical Institute (SGI). 44 s.
- Sintef 2010. European Technical Approval No. ETA-10/0297. 13 s.
- Statens vegvesen 2008***. Ground reinforcement, embankments and slopes.
- Handbook 274 Norwegian Public Roads Administration-Technology Department. Oslo. 326 s.
- TTY 2012*. Foamed glass, three-axial cyclic tests. Test description MPR/269/2011. 5 s.

* Currently only available as a Finnish language version

** Currently only available as a Swedish language version

*** Currently only available as a Norwegian language version

Uusioaines Oy

www.uusioaines.com

www.foamit.fi