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# 5th International Conference on Geofoam Blocks in Construction Applications

## Proceedings of EPS 2018

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# Geofoam Blocks in Civil Engineering Applications

**Roald Aabøe, Steven Floyd Bartlett, Milan Duškov, Tor Erik Frydenlund, Jnanendra Nath Mandal, Dawit Negussey, Abdullah Tolga Özer, Hideki Tsukamoto and Jan Vaslestad**

**Abstract** In Norway the use of Geofoam blocks in road construction applications started in 1972. Excessive settlements of a road embankment adjoining a bridge abutment founded on piles to firm ground was then successfully halted by replacing a 1 m layer of road aggregate with blocks of Expanded Polystyrene (EPS). Boards of EPS had previously been successfully tested in road structures over several years in a major research project related to Frost Action in Soils. The use of Geofoam blocks for lightweight fill purposes, reduced earth pressure and several other applications for a variety of Civil Engineering purposes, has since been adopted and further developed in many countries worldwide. In this article the state of the art regarding various applications of Geofoam blocks are shown based on available information supplied by the authors.

**Keywords** Geofoam blocks · Lightweight · Stability · Bearing capacity Settlements

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## 1 Introduction

Geofoam blocks are made of Expanded Polystyrene (EPS) initially produced for packaging and insulation purposes. The material is extremely light and can be produced in many shapes and densities, typical density $\rho = 20\ \text{kg/m}^3$. Geofoam blocks for civil engineering applications have typically dimensions $0.5 \times 1.0 \times 2.5$–$3.0$ m weighing some 25–30 kg. Material strength properties varies relatively linearly with density and a 20 $\text{kg/m}^3$ material may typically have a compressive strength of $\sigma = 100$ kPa at 10% strain. Geofoam blocks are produced in wide ranges of densities and strength characteristics. The term Geofoam is also used in connection with Extruded Polystyrene (XPS), but this production process limits the products to board formats.

When Geofoam blocks were first used as a lightweight fill material for road construction purposes in Norway in 1972 [1] it had already been demonstrated by a research project on Frost Action in Soils that boards of EPS could sustain the repetitive loads in a road pavement and that material properties did not deteriorate with time. When excessive settlements ($\sim$20 cm/year) occurred in a road embankment adjacent to a bridge founded on piles to firm ground, it was decided to replace 1 m of ordinary embankment materials with EPS blocks placed in two layers each with a thickness of 0.5 m. The embankment rested on 3 m of peat overlaying 10 m of soft clay deposits and due to repetitive adjustments of the road level, the embankment load on the subsoil increased resulting in accelerated settlements and risk of embankment failure. By replacing 1 m of embankment aggregate with Geofoam blocks, being nearly 100 times lighter than the replaced embankment material, the settlements were successfully halted.

The use of Geofoam blocks in civil engineering applications has since been adopted as a general practice in many countries and for a multitude of purposes. International conferences have been instrumental in the dissemination of information related to the properties and use of Geofoam blocks. The first conference was held in Oslo, Norway in 1985 attended by 150 participants from 11 countries [2]. With a strong Japanese engagement in using and further developing the method the second conference was held in Tokyo, Japan in 1996 where 300 participants from 15 countries attended [3]. Similarly, with an increased focus on the use of the method in the U.S. the third conference was held in Salt Lake City, Utah in 2001 [4]. The fourth conference was held in Lillestrøm, Norway in 2011 [5]. The present conference is in this respect a further landmark in disseminating information on the use of Geofoam blocks in civil engineering applications.

In addition to international conferences seminars and local arrangements on a national level have also further promoted the use of Geofoam blocks in addition to bilateral agreements between government agencies and private organizations in various countries and by direct contacts on a personal level.

Today projects using Geofoam blocks are known to have been completed in many European countries: Czech Republic, Denmark, Finland, France, Germany, Greece, Ireland, Netherlands, Norway, Poland, Russia, Serbia, Sweden and the UK, but other European countries may also have adopted the method. In Asia the major user is Japan (Figs. 1 and 2), but China, Malaysia, Thailand, The Philippines, South Korea and Taiwan are also known to have used Geofoam blocks. India has recently shown an interest and several other Asian countries are likely potential users. The first road embankment with Geofoam blocks was recently completed in Turkey [6, 7]. In America the method is adopted in the US and Canada as well as in Argentina, and Columbia. Civil engineering projects involving Geofoam blocks have been reported from Victoria, New South Wales and Queensland in Australia. No African projects are known so far but situations where the use of Geofoam blocks may have an advantageous potential, are likely to exist there too.

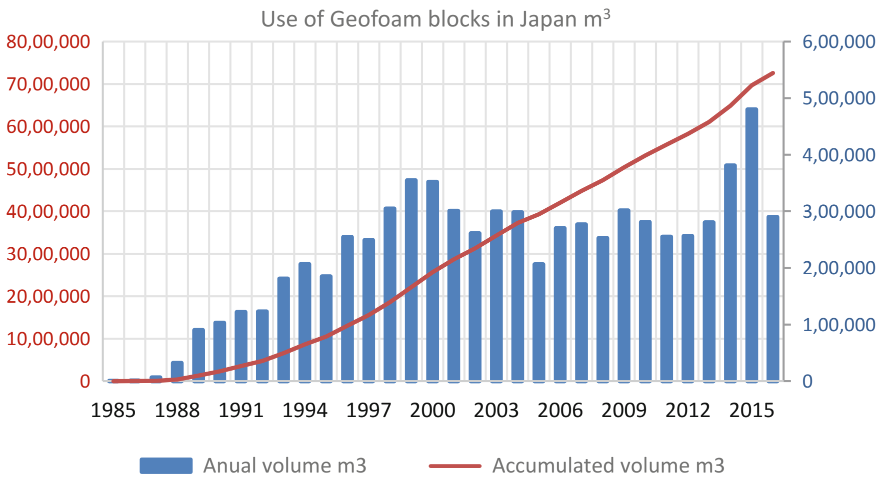
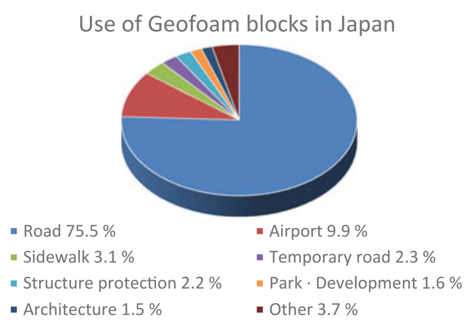



**Fig. 1** Use of geofoam blocks for civil engineering purposes in Japan (EDO)

**Fig. 2** Use of geofoam blocks in Japan by purpose (EDO)



# 2 Applications

## *2.1 Lightweight Fill*

The major use of Geofoam blocks has so far been as a lightweight fill material, mainly for road construction purposes [8–17] but also for railroads [18, 19], airfields and other construction projects. The blocks may be applied to reduce the construction load on soft subsoils for both stability and settlement reasons. A typical road cross section with inclined and/or vertical side slopes may be as shown in Fig. 3. Normally the pavement structure above the Geofoam blocks will consist of a sparsely reinforced concrete slab of 10–15 cm thickness with a minimum bearing course (some 35 cm) above topped with an asphalt wearing course. In cases where the load on the Geofoam blocks is not critical, a normal pavement structure may be applied but a membrane is then usually added above the Geofoam blocks.

As indicated the Geofoam fill may also be terminated with a vertical face on one or both sides. In such cases some form of protective casing should be added to the vertical face. Materials used for such purposes have been aluminum and steel sheets, concrete panels, wooden planks and sprayed concrete. In a landslide area on the Yamagata Expressway in Japan a 16 m high road structure was constructed with vertical walls on both sides, the same design was used to widen the road as shown in Fig. 4 [20, 21].

Here 10 cm thick sparsely reinforced concrete slabs were cast for every 3 m height of EPS block fill in order to bind the structure together and even out possible minor level differences when placing the blocks. Also, a form of sliding connections were introduced to allow for possible differential vertical movements.

When widening existing normal roads, it may also be advantageous to use Geofoam in the widened road structure in order to improve stability conditions and avoid differential settlements [22] between the old and the new road structure (Fig. 5).

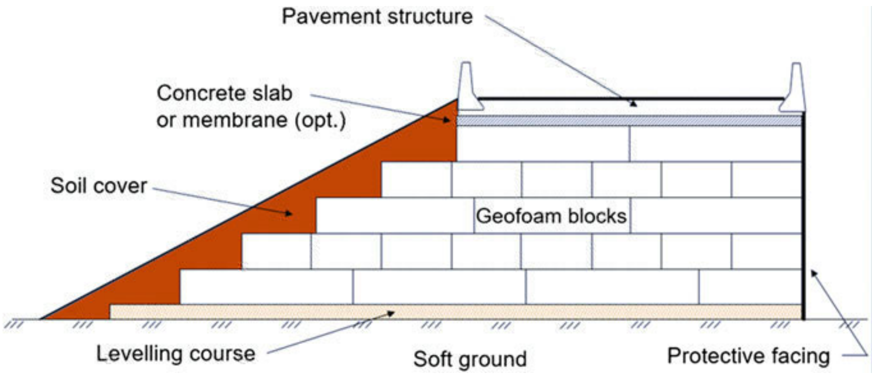



**Fig. 3** Cross section of road embankment with geofoam blocks

Fig. 4 Yamagata Expressway, Japan with vertical side walls (EDO)

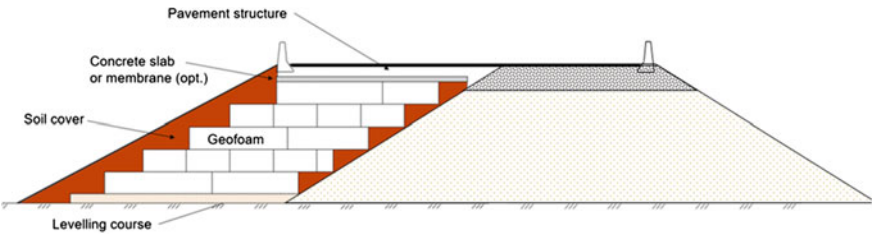



Fig. 5 Road widening application using geofoam blocks

When widening or constructing roads on steep side slopes, Geofoam blocks with vertical side termination may be a favourable solution (Fig. 6). On slopes, particularly where high fills are involved, the need for proper anchorage should then be analyzed separately. The anchorage should provide support for horizontal forces from soil pressure on the structure and vehicles hitting guard rails or side barriers.

On the Otari Road in Nagano Prefecture, Japan a 1.2 km road section was constructed (Fig. 7) [21]. The maximum height of the road structure was 17 m and volume of Geofoam blocks used 30,000 $m^3$ (Fig. 5).

With a properly designed ballast layer and load distribution slab (if required) above Geofoam blocks of sufficient strength, the method may also be used for

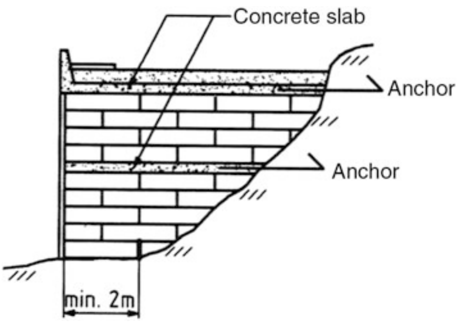



Fig. 6 Cross section of high embankment on slope (NPRA)

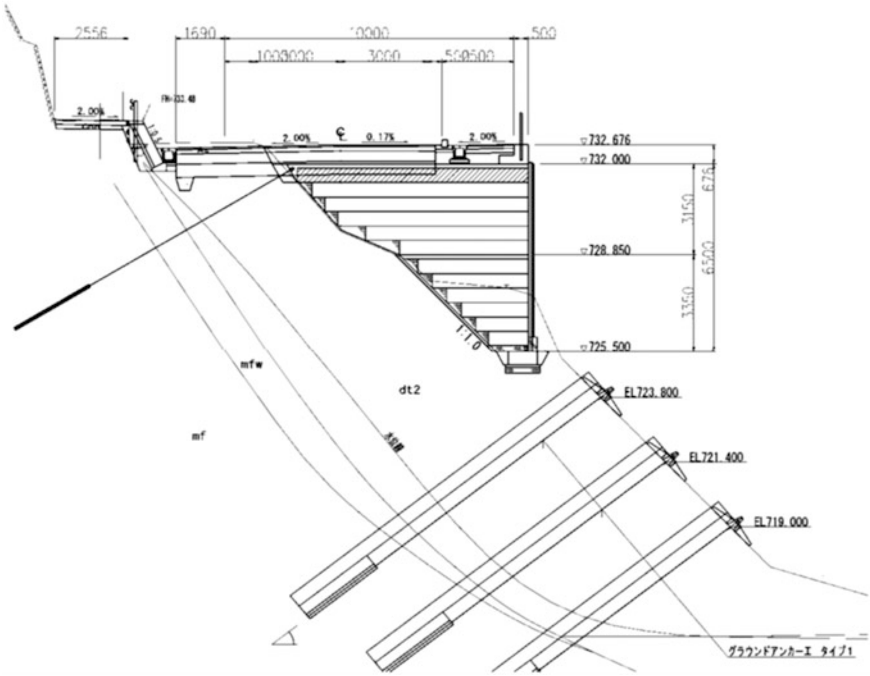



Fig. 7 Design cross section of Otari Road in Nagano Prefecture, Japan (EDO)

railroads and several such projects have been completed in Norway, the UK, Japan, U.S. and possibly in other countries.

The Utah Transit Authority (UTA) in Salt Lake City has constructed EPS bridge approach fills for its light-rail and commuter rail systems. The dynamic deflection performance of these systems under train loadings has been monitored [19]. Dynamic accelerations were obtained via accelerometer arrays placed on the rail sleepers for these systems. Dynamic deflections estimated from these measurements based on a double integration of the acceleration data suggest that the dynamic deflections are acceptable and comparable to those measured on earthen embankment.

The same applies for airfields whether on taxiways or runways as it is only a question of making an adequate design in order for the structure to sustain the wheel loads from landing or taxying aircrafts. The New Orleans Airport East/West runway rehabilitation project included the removal of existing damaged pavement and the construction of new taxiways. EPS geofoam was used under the new pavements to control settlement on the highly compressible and saturated subsoils and to prevent differential settlements at the intersection of new and existing pavements.

Geofoam blocks may also be used for stability improvement purposes in terrain with potential slide hazards and for slope failure mitigation in areas where slides have occurred (Fig. 8). In order to reduce the driving forces, here a volume of high density natural soil is replaced with Geofoam blocks. Proper drainage is also provided in order to prevent hydrostatic pressure building up within the soil/ Geofoam structure. Recent studies were conducted to understand the behavior of slopes under seepage forces and corresponding remedial block configurations tested in a laboratory bench scale models [23–26].

Geofoam blocks may also be used as a compensating foundation for buildings in order to reduce the load on underlying compressible soils and minimize building settlement along with solving potential bearing capacity problems. At the building site existing soil is excavated and replaced by Geofoam blocks in order to reduce the net applied load to the soil by the new structure. If the amount of soil excavated equals the total load applied by the new structure, a fully compensated foundation is obtained, i.e. no increased load is applied to the subsoil by the structure.

Similarly, Geofoam blocks may also be used as a lightweight fill material for landscaping purposes. This may be particularly useful when creating undulating terrain features close to existing buildings where normal soil aggregate used for the

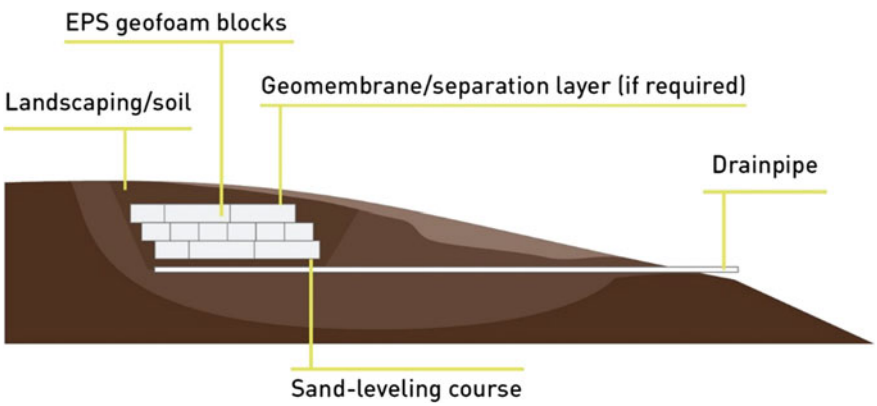



**Fig. 8** Schematic drawing of geofoam block placement in a slide area [27]

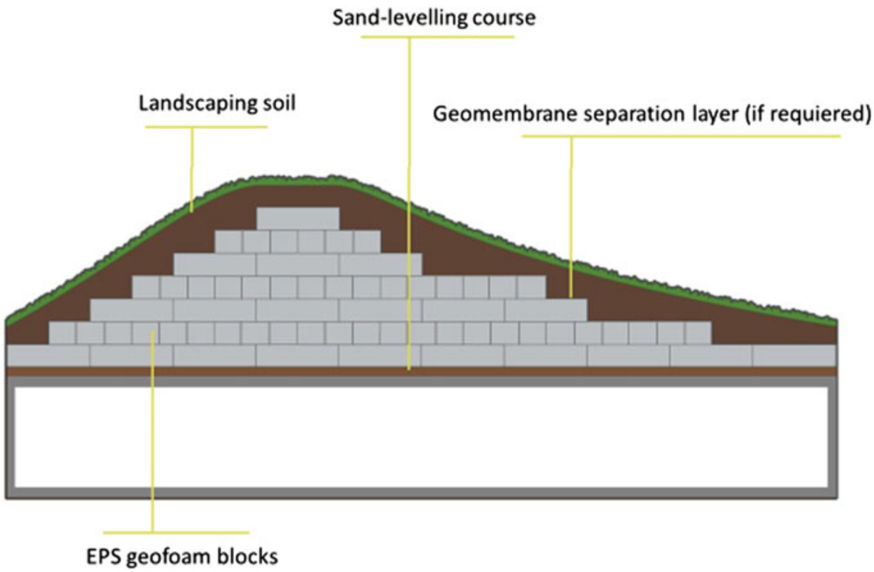



**Fig. 9** Schematic drawing of vegetative roof on building [27]

same purpose could create settlement problems for the building foundations. Some examples of this application include creating roof gardens for urban buildings (Fig. 9). For the same reasons Geofoam blocks may also be used to construct sound barriers to protect roadside residents from noise pollution (Fig. 10).

When excessive settlements occur in levees and repair must be initiated to cope with expected flood levels, the use of Geofoam blocks may provide a favourable solution. If ordinary fill material is used to raise the embankment height, this will result in further subsidence. By replacing part of the embankment soil with Geofoam blocks, further subsidence may be halted. With the extremely low density of Geofoam, caution must, however, be observed to prevent the Geofoam blocks from becoming buoyant. The buoyancy potential must be considered based on expected flood levels and the volume of Geofoam blocks used and their position relative to the flood level. The uplift tendency may also be countered to some extent by providing anchorage (Fig. 11).

It is of course possible to utilise the buoyancy effect of Geofoam blocks directly for floating piers and similar harbour and marina arrangements. This effect has been taken advantage of for a long time, and in Vancouver, British Columbia, Canada Geofoam blocks are used to support a floating helicopter pad (Fig. 12).

A similar use of the buoyancy effect has been introduced in the Netherlands where a floating garden built on Geofoam blocks are seen on one of the canals in Amsterdam (Fig. 13).

Some special forms of Geofoam blocks have also been designed to accommodate rising water levels without introducing the full buoyancy forces that a solid Geofoam block would cause [28]. This is obtained by making hollow blocks with

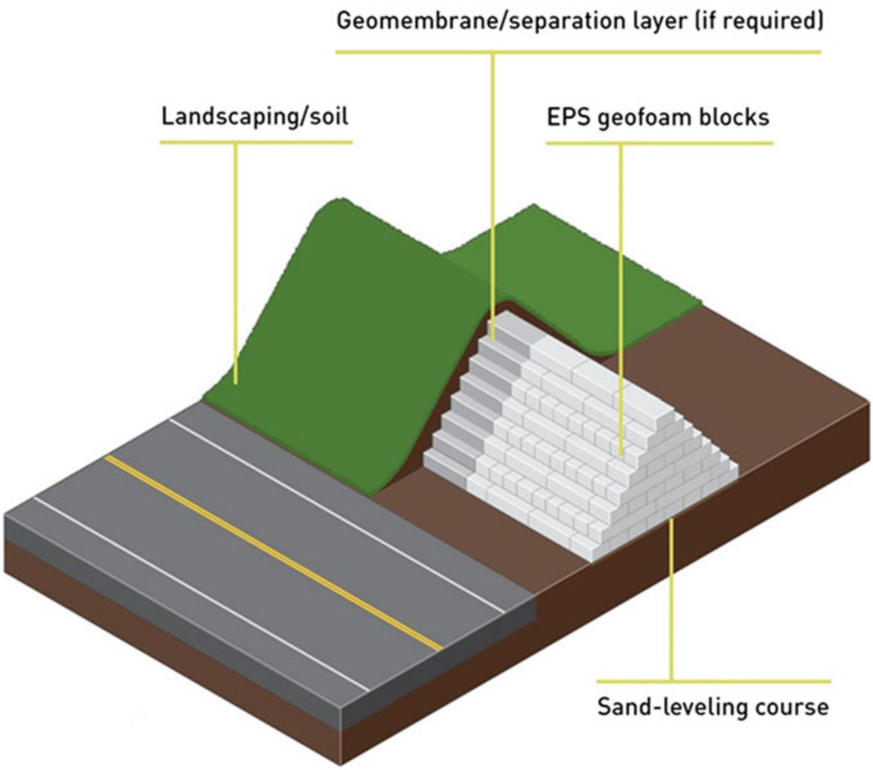



**Fig. 10** Geofoam blocks used in noise barrier [27]

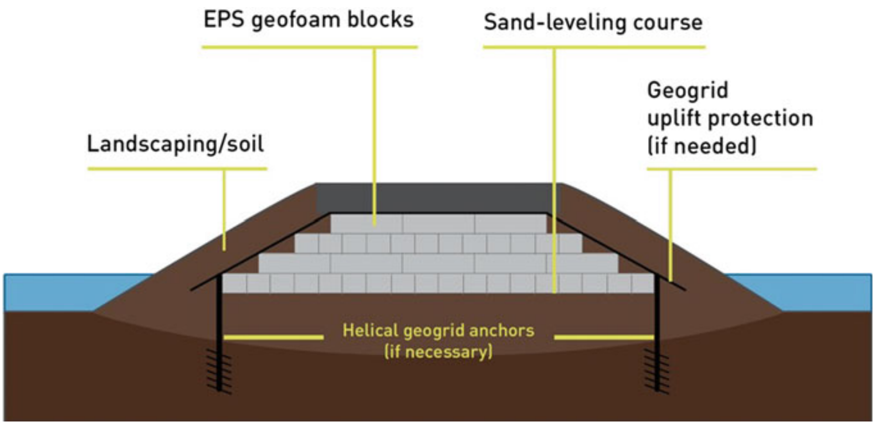



**Fig. 11** Cross section showing levee repair using geofoam blocks [27]

**Fig. 12** Floating helipad supported by geofoam blocks in Vancouver, Canada (www.mansonvilleplastics.com)

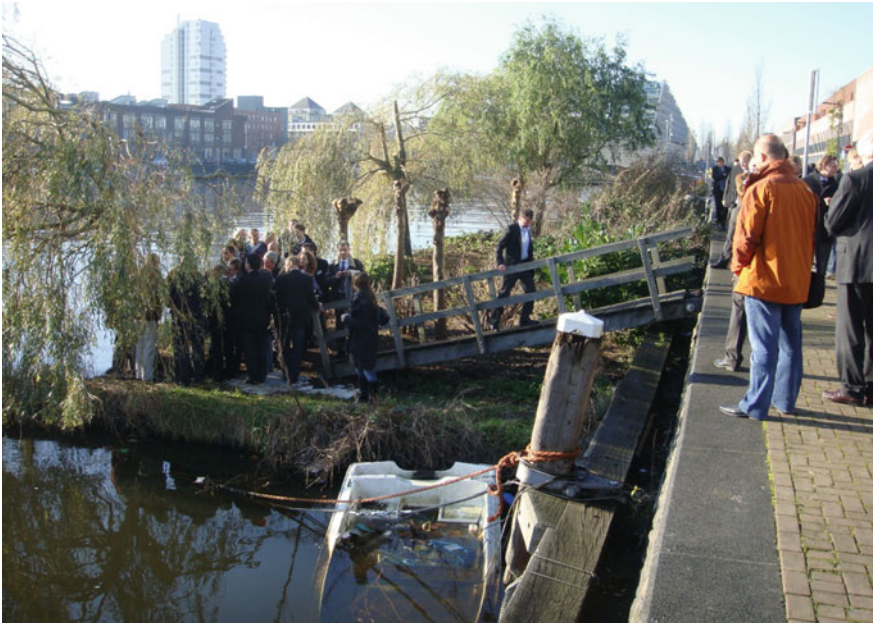


**Fig. 13** Floating garden on one of the canals in Amsterdam, The Netherlands (T. Özer)

slits on the sides allowing water to enter without introducing the full buoyancy force of a solid block (Fig. 14).

Geofoam blocks may also be used to form tiered seating in locations such as auditoriums, movie theaters, gymnasiums and churches. The high compressive resistance and light weight of Geofoam make it well suited to both new construction and renovation projects. Stacked Geofoam blocks before a protective concrete layer is added and seats, bleachers and other attachments and finishes are installed to complete the project (Fig. 15).

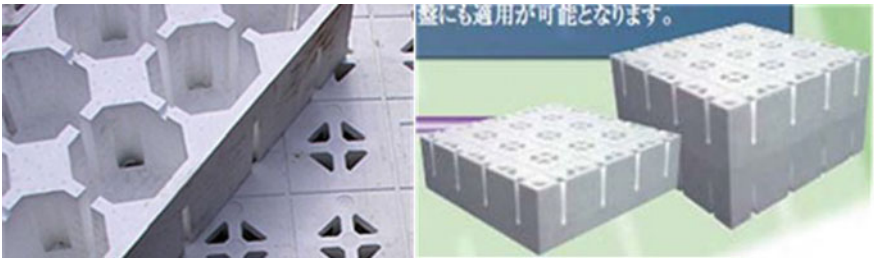



**Fig. 14** Design of EPS block with reduced buoyancy effect (EDO)

**Fig. 15** Stacked Geofoam blocks for seating arrangements (http://blog.achfoam.com/?p=2455)

## 2.2 Load Reduction

Particularly when encountering soft ground conditions with inferior bearing capacity but also in general when subsoil bearing capacity may be a problem due to heavy loads, Geofoam blocks may be used to improve both bearing capacity and settlement conditions. Since the material density of Geofaom blocks is much less than ordinary mineral soils, the load on the subsoil may be substantially reduced by replacing some amount of ordinary soil with EPS. This was the case for the first application of Geofaom blocks in a roadfill in Norway in 1972. By balancing the loads removed by soil excavation with the loads applied to the subsoil by the completed structure, both satisfactory bearing capacity and settlement conditions may be achieved.

Depending on the structure loads and foundation area the compressive strength of the Geofoam blocks must be adjusted accordingly, but the difference in material density of various EPS strength qualities are small compared to the density of the mineral soil to be replaced.

In several projects, particularly in Europa and the US, this principle has also been applied in connection with the design of bridges where bridge abutments have been supported directly on Geofoam blocks. Such an example is shown where the foundations for a temporary Acrow type steel bridge is founded directly on some 5 m high Geofoam fills resting on soft and quick clay in Norway (Fig. 16) [29]. Similar solutions have also been applied for permanent concrete bridges (Fig. 17).

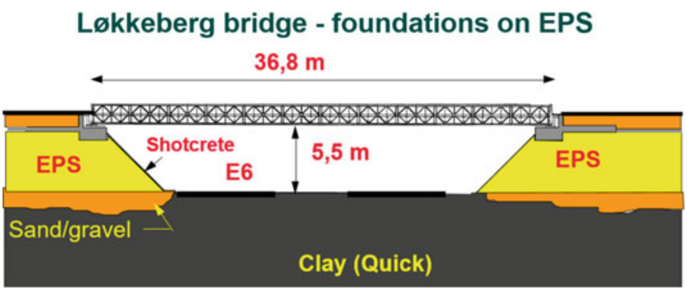



**Fig. 16** Bridge abutment founded directly on geofoam blocks (NPRA)

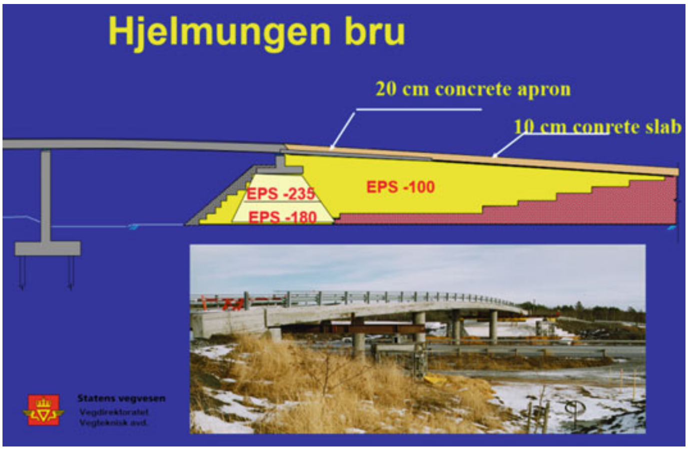



**Fig. 17** Abutment for multispan concrete bridge founded directly on geofoam blocks with varying compressive strength (NPRA)

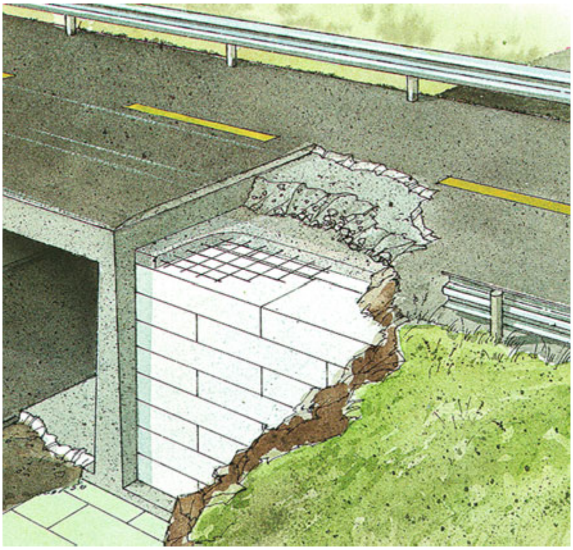


**Fig. 18** Backfill of geofoam blocks against bridge abutment (NPRA)

Furthermore, since fills with geofoam blocks may be terminated with vertical walls, no or only minimal horizontal forces will be transmitted to any structure adjacent to or connecting to the fill. This effect will significantly simplify the design of bridge abutments and retaining walls related to accommodating horizontal forces (Fig. 18).

Another type of load reduction application associated with bridges is a simplified design (Fig. 19). The sheet piles may be driven from the river shores without polluting the water or interfering with fish activities. Scaffolding for casting the bridge deck is connected to the sheet piles or precast bridge deck slabs may be used.

Geofoam has been used to provide an alternative foundation system for replacing a single span steel girder bridge in Upstate New York [30]. The site is in a wide valley of deep soft sediments. The replaced bridge was supported on a shallow foundation and had settled excessively. The span and width of the replacement bridge was increased to provide more flow capacity and sidewalk. The precast concrete box girder replacement bridge and stub abutment system is heavier than the replaced bridge. Conventional deep pile foundations would have required end bearing at depths greater than 30 m. The alternative foundation system used for the replacement bridge consists of a sheet pile cell that surrounds each abutment foot print. Soil within the sheet pile cell enclosure was excavated and the water level was lowered by sump pumping. The volume of the excavated soil was replaced by EPS geofoam blocks to compensate for the weight of the bridge and foundation system (Fig. 20). The steel reinforcement for a 0.5 m load distribution cap and stub abutment over the geofoam backfill is welded to the top of the sheet pile enclosure. The precast concrete box girders rest on neoprene bearing pads over the stub abutments. While in service, the EPS geofoam blocks become fully submerged during high flood periods. The sheet pile wall friction resistance functions to

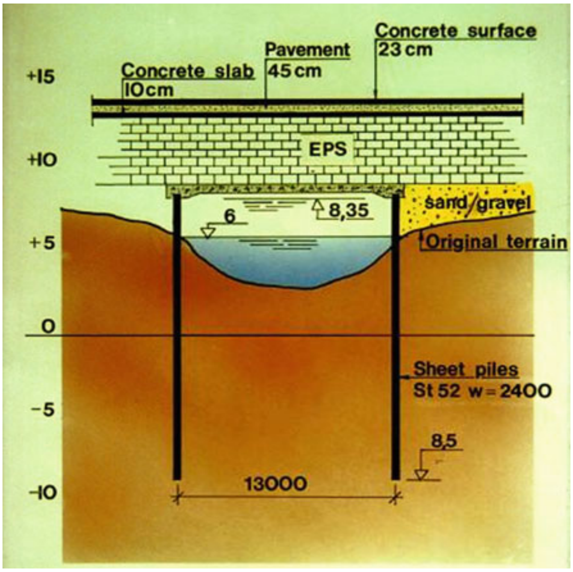



Fig. 19 Simplified bridge design (NPRA)

Fig. 20 Geofoam placement within the sheet pile cell (30)

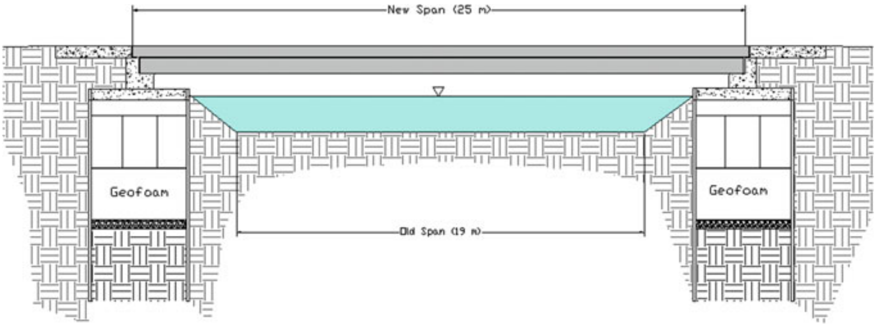



**Fig. 21** Schematic section of the geofoam supported bridge (30)

provide additional capacity to both downward loading and uplift due to buoyancy at low and high flood stages. The completed geofoam supported bridge (Fig. 21) is regularly inspected and continues to receive top rating.

The magnitude and distribution of earth pressure on buried culverts depend on the overburden thickness and the relative stiffness of culvert and soil with varying load distribution along the culvert perimeter. Normally the vertical pressure will be higher than the horizontal pressure. By introducing a compressible layer above the culvert, a more evenly distributed pressure system may be obtained around the culvert. This is a well-known method (often called the induced trench or imperfect ditch method) and various types of compressible materials have been applied for such purposes. EPS is a material well suited for this type of application as the stiffness of the EPS material and layer thickness may be selected to suit a particular project. As the embankment is constructed above the culvert, the EPS layer will deform creating arching effects in the soil above that will redistribute more vertical load to the side of the culvert and hence increase the horizontal pressure. Such effects have been monitored on many culvert projects proving theoretical effects (Fig. 22) [31].

For EPS fills where the blocks are subjected to lateral forces from behind the fill or from traffic and seismic loads, a similar effect by placing deformable EPS blocks against bridge abutments and non-yielding retaining walls, may be utilized to reduce lateral pressure against the wall or abutment [32–35].

For EPS fills with sufficient internal stability terminated in a vertical wall there is no need for a retaining wall as mentioned in Sect. 2.1, only some mechanical protection of the outer blocks. For bridge abutments it has also been demonstrated that leaving a small gap between a stable EPS fill and an abutment wall will prevent transmission of lateral forces on to the abutment from the EPS fill. Monitoring the abutment some 7 years after its completion showed that the EPS fill remained stable and that no measurable movement of EPS blocks had occurred [36].

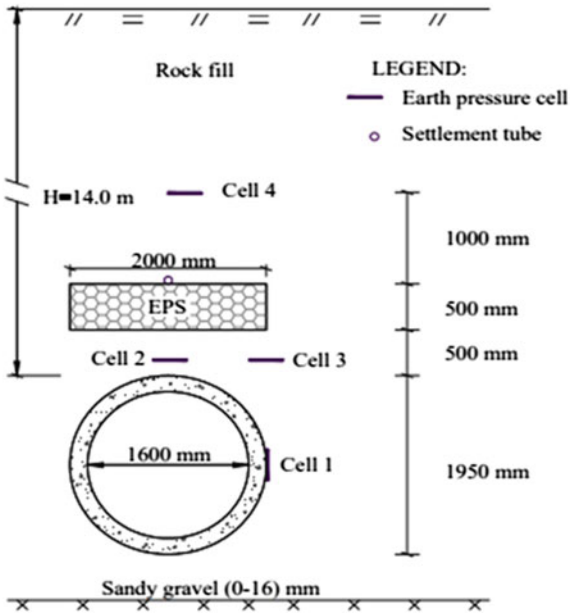



**Fig. 22** Example of monitoring pressure distribution on a culvert with a deforming EPS layer above (NPRA)

## 2.3 *Energy Absorption*

For protecting road users from avalanche hazards in mountainous areas avalanche sheds are sometimes constructed on road sections with frequent avalanche activities. Such sheds will normally have a cover of soil material on the shed roof to absorb some of the impact forces from falling rocks. In order to further reduce the impact loads, Geofoam blocks may be placed on the shed roof with a concrete slab and soil cover on top. When large boulders or rocks hit the structure, the EPS material will deform and absorb a major part of the dynamic energy thus substantially reducing the dynamic loads transferred to the shed (Fig. 23). This idea was first introduced and tested in Japan [37], The method may also be applied for protecting other types of structures from dynamic impacts.

## 2.4 *Seismic Effects on EPS Fills*

From the start some concerns have been raised regarding the behavior and stability of EPS embankments subjected to seismic loads. This problem has been thoroughly addressed particularly in Japan [38] and the USA [39] both from a theoretical approach as well as in small- and full-scale experiments. This includes both the stability of normal EPS embankments, embankments on slopes and free-standing EPS structures terminated with vertical walls as well as fills adjacent to bridge abutments and retaining walls. Figure 24 shows a test setup of reduced scale

**Fig. 23** Geofoam blocks applied for energy absorption on rock fall protection tunnel in Turkey (Curtesy of EPSDER, Turkey)

shaking table and Fig. 25 shows a test setup of a Geofoam structure on a large shaking table in Japan. The general picture is that the EPS material has a positive effect on the type of structures analysed during seismic loading and in Japan no special seismic design considerations are required for fills with heights less than 6 m and a height to breadth ratio <0.8. For higher fills such considerations are recommended. Secondary seismic effects after an earthquake like tsunamis, land-slides etc. may, however, damage EPS fills, but no serious damage was reported for EPS structures during the earthquake or the following tsunami effects from the 2011 Tohoku earthquake in Japan. During the 2016 Kumamoto earthquake large ground deformations occurred and an EPS embankment under construction deformed somewhat. The fill was, however, completed without adjustments and the finished road is in normal service.

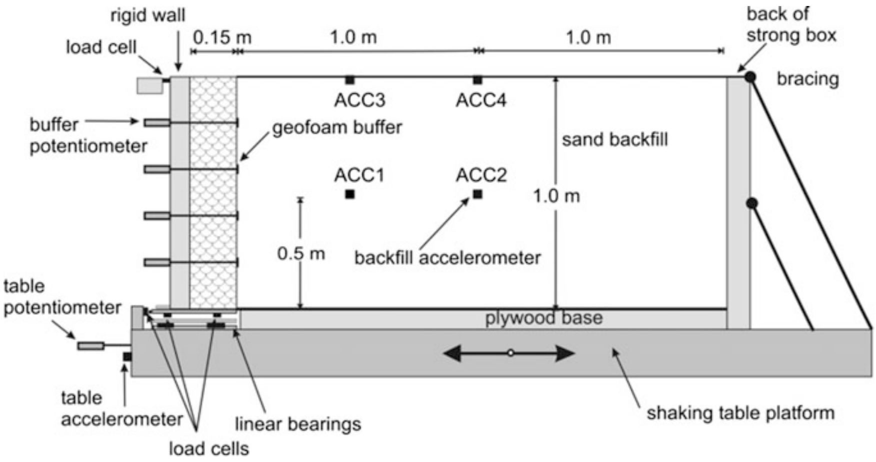



**Fig. 24** Setup for shaking table test on geofoam block structure [32]

**Fig. 25** Full scale seismic loading experiment on shaking table (EDO, Japan)

## *2.5 Speed and Ease of Construction*

For various reasons some construction projects have to be completed within a minimum time span. With the light weight and relatively large volume per block Geofoam blocks may come in handy when construction speed is essential. This has proved the case in several projects [14].

When a high-speed rail service was to be established on the Manchester–Liverpool railway line this involved replacing an old steel bridge from 1899 with a new rail structure [40]. At the same time it was essential to keep the trains running with only a short brake allowed in the railway services for replacing the bridge. The bridge ran across a filled in river channel where various materials had been deposited over a long period of time. The construction method adapted was first to preload the subsoil with a 4.5 m high fill for a period of 9 months starting in 1997. The preload was then removed, and a Geofoam fill constructed up to a level just below the steel bridge with the bridge pillars still intact. Then the bridge was demolished, the height of the EPS fill increased to a level somewhat below the new track level and covered with a levelling layer of granular material. A precast concrete trough was then lifted on to the EPS fill. A HDPE liner, ballast material and rails were added on top of the concrete trough and the whole job was completed within 100 h from the bridge was removed until trains were running again (Fig. 26). The total volume of EPS blocks used with various densities, was 13,000 $m^3$.

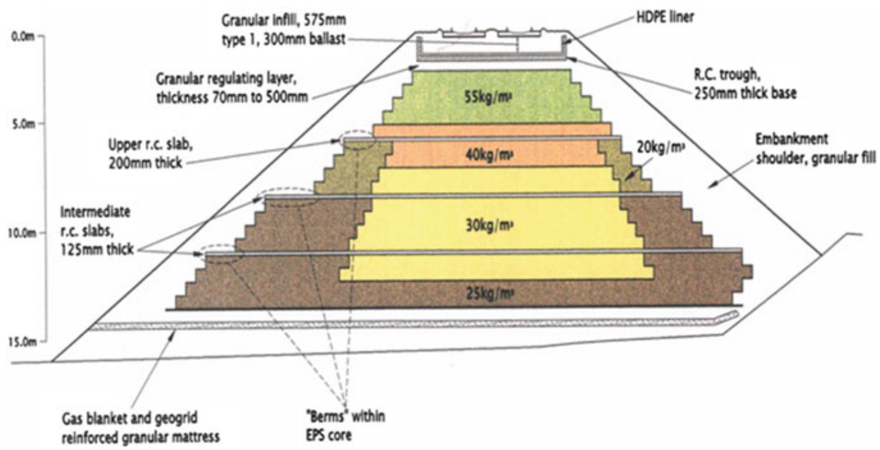



**Fig. 26** Main components of EPS fill design for railway bridge replacement [40]

## 2.6 New Applications

### 2.6.1 Lightweight Culvert Structure

In Dutch road engineering practice, the arching principle is used to design a settlement-free tunnel construction integrated in an EPS embankment without a pile foundation (Figs. 27 and 28). The modular system of corrugated steel sheet elements fulfilled the specific project requirements such as a free space for cyclists and pedestrians, the available cover on the tunnel structure and the construction of the cover layers and pavement structure for the traffic load over the tunnel. In terms of both building costs and construction time reduction, the system offered advantages. The oval tunnel system is based on the load distribution by normal force along the "pressure points" in the steel shell construction. As an alternative to the standard

**Fig. 27** Construction of corrugated steel tunnel in EPS fill (InfraDelft)

**Fig. 28** Finished structure (InfraDelft)

design with compacted sand around the culvert, adequate side support is ensured by a light-weight foamed concrete enclosure combined with stronger EPS blocks. Such a tunnel construction is already in service under the new roundabout of the provincial road N222 near The Hague. There are no technical restrictions regarding either the profile or the traffic load over the considered tunnel system.

### 2.6.2 Seepage Mitigation

Geofoam blocks are used for slope stabilization in Japan and USA [41–44]. The design guideline for using geofoam blocks for slope stabilization and repair projects is based on the recommendation that geofoam slope system incorporate a drainage system for preventing water accumulation above the bottom of the geofoam block configuration [45]. However, the groundwater table may rise due to drainage malfunction. The behavior of geofoam blocks has been studied in Turkey using scaled physical slope experiments [23, 46]. Under the lights of this first study a geofoam block assemblage called this embankment type configuration where the backslope applies overburden along the geofoam block assemblage inside the slope (Fig. 29) was proposed [24]. It has been shown that this embankment type configuration could prevented both deep-seated failures of marginally stable sandy slopes subjected to seepage and hydrostatic sliding along the base of the geofoam block assemblage [24]. Further studies using geofoam blocks with internal drainage system showed that this would further improve the performance of slopes under seepage [25, 26]. However, the results of these laboratory studies can only be used for providing information about the basis to understand the prototype behavior of geofoam blocks in sandy slopes under seepage. It is recommended that the laboratory small scale 1-g model test results must be verified by an instrumented prototype model prior to implementing the recommended block assemblage in projects [22–26].

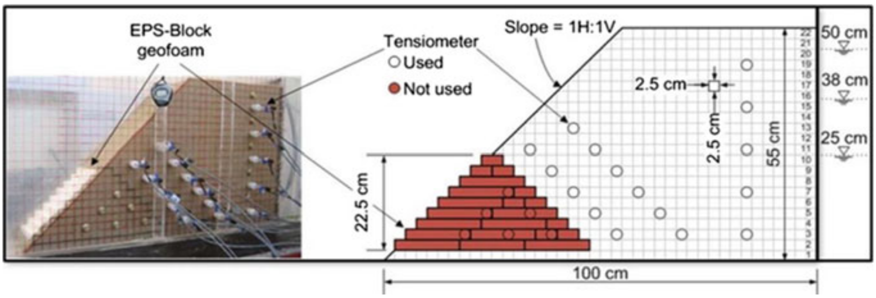



Fig. 29 Embankment type geofoam block configuration [24]

### 2.6.3 Interface Shear Strength

Internal stability analysis of geofoam highway embankments consists of hydrostatic sliding, transition due to wind and seismic stability [10]. The available shear resistance in between the geofoam blocks needs to be evaluated for seismic stability. If this resistance insufficient, additional resistance can be provided by shear key concept where continuous horizontal geofoam block planes are interrupted by installing half blocks periodically in the geofoam block assemblage [39]. In addition, adhesives can also be used to increase interface shear strength [47, 48]. Alternatively, a concept with interlocked geofoam blocks has been proposed [49] where the geofoam blocks have ledges and notches along their tops and bottoms, respectively. Therefore, when they are placed on top of each other, horizontal shear planes in between geofoam blocks are interrupted with interlocked configurations [49]. The interlocking mechanism will increase the interface shear strength of traditional geofoam block to geofoam block surface, and as the number of ledges and notches are increased, the interface shear strength of interlocked blocks approached to the internal shear strength of geofoam blocks [49]. Therefore, this interlocking mechanism can be a viable alternative for the geofoam embankments to be constructed in high seismic activity areas. However, due to the scale effect of the laboratory specimens, conducting large scale shear tests were recommended prior to using the interlocked concept in the field [49].

## 3 Material Specifications

When the first road project with EPS blocks was considered, the Norwegian Public Roads Administration (NPRA) decided to define the compressive strength of the EPS material at 5% strain when testing 50 × 50 × 50 mm cubes in an unconfined compression test apparatus. With the use of EPS blocks for lightweight fill purposes adopted in many countries and the manufacturers showing a higher interest in such uses, more test methods have been introduced and a number of research projects have been carried out on this topic including dynamic loading. Different block shapes have also been tasted (cubes and cylinders) with dimension varying from 50 mm to 100 mm and even full-size blocks. The tensile strength behavior of EPS geofoam has also been investigated [50] and found to depend on density. When strong fill materials with high strengths are required Indian investigations [51] show that expanded polystyrene-based geomaterial with fly ash can be used as a substitute for eps geofoam blocks.

This has resulted in both national and international standards being developed. Within the European Union (EU) a standard EN 14933 “Thermal insulation and light weight fill products for civil engineering applications—Factory made products of expanded polystyrene (EPS)—Specification” came into force in 2009 [52]. Here the strength of EPS material is defined at 10% strain tested on 50 × 50 × 50 mm cubes, but requirements at 2 and 5% strain are added. Unit density is not set as a