Norwegian Public Roads Administration, Directorate of Public Roads
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USE OF EXPANDED POLYSTYRENE IN ROAD EMBANKMENTS

- DESIGN, CONSTRUCTION AND QUALITY ASSURANCE -

1. Various applications of EPS

Blocks of Expanded Polystyrene (EPS) may be used as a light fill material in road embankments or behind retaining structures in order to solve both stability and settlement problems due to soft subsoil conditions. Applications so far have been:

- Reduction in load on subsoil
- Reduction of lateral soil pressure and differential settlements related to bridge abutment and retaining walls
- Repair of landslide areas
- Reduction of construction space required
- Utilization of buoyancy effects
- Compensated foundation design

EPS is a chemically stable compound under normal conditions and not subjected to biological decomposition (rotting etc.).

EPS does not contain ozone-destroying gases (Freon or similar).

2. Material requirements

a) Compressive strength

The compressive strength should be at least 100 kN/m^2 if not otherwise specified (see clause 3.b). The average value for tested blocks should not be less than 100 kN/m^2. The average value for individual blocks (minimum 6 samples) should not be less than 90 kN/m^2 and no single test result should be less than 80 kN/m^2.

If higher strength EPS is required, the average value for tested blocks should at least be equal to the design compressive strength. The average value for individual blocks (minimum 6 samples) should not be less than 90 % of the design strength and no single test result should be less than 80 % of the design strength.

The compressive strength is defined as the stress at 5 % strain measured in an unconfined compression apparatus. Tests should be made on samples of size 50 x 50 x 50 mm. The number of blocks to be tested is given in table no. 2.

b) Dimensions

The shortest side of any block should at least be 0.5 m if not otherwise specified. The block length should at least be 2.5 m. Block sides should be plane and at right angles to each other. Tolerance levels for given dimensions (length, width, height) should be within $^{+}/_{-}$ 1 %. Block surfaces should not deviate from a plane surface with more than 5 mm measured with a 3 m straightedge. For test frequency see clause 6.a.
Differences in heights between adjacent blocks in the same layer should not exceed 5 mm. Particular care should be taken if the blocks are delivered from different producers.

c) Flammability

EPS is produced in two different qualities with regard to flammability, i.e. standard quality and a self extinguishing quality (SE quality). In general, the standard quality will meet requirements for use in road embankments. The SE-quality may be considered in special cases, e.g.:

- Embankments in excess of 1500 m^3
- Embankments where the blocks are left exposed for a long period of time
- Embankments adjacent to structures that may be damaged by a fire
- Embankments in urban areas

The need for SE quality should be considered in view of other measures to reduce the risk of EPS-blocks being ignited, i.e.:

- Providing guards on the storage or construction site and/or combined with working several shifts (will reduce construction time and the time the blocks are exposed)
- Providing fences or other means for restricting access to the site and the fill
- Restrict the use of torch-cutting and welding equipment on site

SE quality blocks should have an oxygen index > 25 as described in ASTM D-2863, or grading B1 according to

DIN specifications.

3. Design specifications

a) General requirements

Road embankments with EPS fill should be designed in such a way that acceptable stability and settlement conditions are achieved. The factor of safety against bearing capacity failure should be as required for ordinary fills.

b) Design strength

The design compressive strength should not be less than 100 kN/m^2. For special structures and structures where the permanent load on the EPS-blocks is in excess of 30 kN/m^2, the need for a higher design compressive strength should be considered. The maximum permissible permanent stress level should not exceed 30 % of the compressive strength of the material at 5 % strain.

Normally, three different strength categories are specified, i.e. 100 kN/m^2, 140 kN/m^2 or 180 kN/m^2. Other strength requirements may also be specified.

c) Settlement and stability calculations

For settlement and stability calculations a nominal unit weight of γ_d= 1 kN/m^3 should be applied.

d) Buoyancy

Submerged EPS-blocks may become buoyant depending on the water level and the weight of the pavement structure on top of the blocks. The factor of safety against uplift must therefore be considered. Normally, EPS-blocks are placed in a drained condition above the ground water table. For buoyancy calculations a nominal unit weight of γ_d= 0.2 kN/m^3 should be applied and the corresponding factor of safety against uplift should be $\gamma_m \geq 1{,}3$ based on the highest probable water level with a return period of 100 years.

e) Horizontal forces, anchorage, drainage

Where horizontal forces are acting, proper anchorage should be considered and provided. For calculation of friction forces between blocks and between blocks and the subsoil (intermediate layer of friction material) a coefficient of friction μ = 0.7 may be used.

Sufficient drainage must be provided in order to prevent ponding of water and resulting horizontal forces, particularly on slopes. For high embankments, wind forces must also be considered, both during the construction stage and for the completed structure.

On slopes, particularly where high fills are involved, the need for proper anchorage should be analyzed separately. The anchorage should provide support for horizontal forces from vehicles hitting guard rails or side barriers and soil pressure on the structure. Anchorage systems may consist of:

- Anchored concrete slabs
- Extended concrete slabs (friction plates)

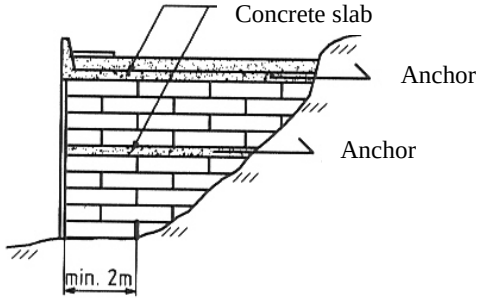

Fig. 1. Cross section of embankment on slope

When EPS is used as fill adjacent to bridge abutments, retaining walls etc. the ratio between horizontal and vertical stress on the structure may be considered as σ_h/σ_v= 0.1. This implies that the ordinary fill adjacent to the EPS fill is terminated with a stable slope so that no soil pressure is exerted on the EPS fill.

4. Construction of EPS fill

a) Evenness requirements

Standard specifications for road construction (Ref. No. 1) specifies requirements regarding levels and evenness of the subsoil stratum.

Blocks should not be placed on frozen subsoil. Before placing the bottom layer, the subsoil should be leveled according to the tolerances +/- 50 mm. Deviations in the subsoil stratum from an even surface should be 10 mm or less measured with a 3 m straightedge. Required evenness of the subsoil stratum may be achieved by pulling a straightedge across the subsoil surface (eg. a heavy ladder pulled by hand).

When placing the EPS-blocks, a continuous check should be kept to ensure that the evenness of the blocks is satisfactory in each layer. The importance of this factor increases with the height of the fill.

In EPS-fills subjected to normal loads (weight of concrete slab and bearing course layers) deformations of the order of 1 % of the fill height have been observed after the load has been applied.

b) Placing and adjusting the blocks

When more than one layer is applied, the EPS-blocks in different layers should be placed at right angles to each other in order to avoid continuous vertical joints (fig. 2).

The shape of the blocks may easily be adjusted by hand- or chainsaw in order to accommodate for the shape of structures like drainage pipes, bridge abutments etc. Small gaps (less than 2-3 cm) may be accepted in such cases and when blocks are placed at different angles (i.e. in curves).

Larger gaps should be filled with sand or light expanded clay aggregate ("Leca"). However, gaps larger than 5 cm are not permitted.

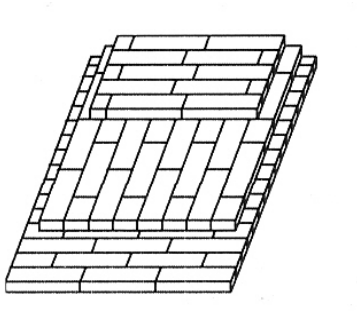

Fig. 2. View showing alignment of blocks in different layers.

c) End adjustments and varying slopes

The different layers in an EPS fill should be parallel to the bearing courses. Sloping end adjustments along the road should be accomplished by leveling terraces in the subsoil in accordance with the block thickness. End adjustments using EPS chips or thin boards should not occur.

If the road surface is designed to have a two-way (roof type) cross fall, the EPS fill should still be placed in parallel layers. The specified cross fall is achieved by adjusting the thickness of the pavement structure accordingly.

d) Anchorage between blocks

In general anchorage between blocks is not required when considering the vertical load on the blocks from the completed road structure. In order to prevent blocks from moving out of position during the construction process, timber fasteners may be used between layers (eg. two timber fasteners, 95 mm Buldog or equivalent, per block). In areas subjected to strong winds, additional anchorage may be required in order to prevent the blocks from being blown away.

e) Side slopes/coverage

For fills with normal side slopes of 1:1.5 or 1:2, the side slope of the EPS fill should not be steeper than 2:1, see fig. 3. For very soft subsoils less steep side slopes should be considered in order to reduce loads on the subsoil and prevent excessive settlements.

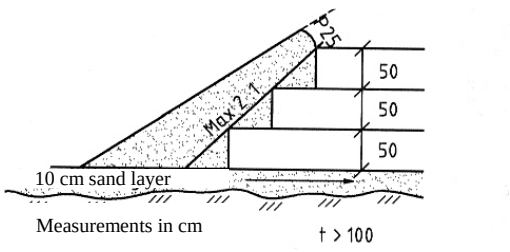

Fig. 3. Side slope for EPS fill

All types of fill material may be used on side slopes. The minimum thickness should be at least 0.25 m. If the EPS-blocks are protected by polyethylene foil/membrane or equivalent, the foil/membrane should be placed in contact with the block surface and covered with a geotextile cloth before applying the covering material. Clay or well graded, fine grained, non-cohesive material (no stones) should then be used next to the geotextile.

f) Vertical termination

The EPS fill may also be terminated in a vertical wall covered by e.g.:

- corrugated steel or aluminum plates
- wood panels (should not be used if exposed to possible fire hazards, e.g. grass fires, forest fires)
- shotcrete
- prefabricated concrete slabs

g) Protection against solvents

EPS will dissolve if subjected to petrol and some other chemicals. The fill may, however, be protected from damage caused for example by petrol from an overturned tanker truck by casting a concrete slab on top of the EPS - or if the concrete slab is omitted - by using a membrane (polyethylene sheet/foil) between the EPS and the bearing course material. When crushed material is used in the bearing course, the membrane should be protected by a layer of sand/gravel or some other suitable material.

Damage from petrol percolating into the EPS fill through the side slopes, may also be prevented by covering the side slopes of the EPS fill with a membrane and geotextile before placing the side slope material.

The membrane should have a thickness of at least 0.3 mm and be inert to petrol and other solving agents.

h) Crash barriers

Crash barriers may be anchored in the concrete slab above the EPS-blocks (if the slab design solution is used). For fills terminated in a vertical cross section, the crash barrier may be anchored in a reinforced concrete slab. For design of crash barriers, see separate code of practice "Vegrekkverk" (Guardrails), 1992.

i) Bridge aprons

Special concrete aprons may be used in the transition zone between the EPS fill and bridge abutments or culverts in order to reduce settlement differences. The concrete apron may be 20 cm thick and 3 - 6 m long (in the direction of the road). The concrete mix should be designed for quality C 45 or better. A joint should be provided between the apron and the concrete slab above the EPS-blocks if a slab is used

5. Pavement structure

a) Concrete slab

It is normal to cast a min. 10 cm reinforced concrete slab directly on the the EPS-blocks. The slab may be omitted if

a load increase on the subsoil is acceptable. The concrete slab directly above the EPS-blocks may also be omitted if the road is provided with a concrete top layer.

The final design of the pavement structure depends to a great extent on whether or not a concrete slab is used.

b) Design of concrete slab

The concrete mix should be designed for a strength of C 25 or better. A welded steel reinforcement grid should be placed in the middle of the slab. Reinforcing bars of the grid should have a diameter of 5 mm placed at 15 cm c/c. The grids should be produced in sizes 2 x 5 m and placed with overlap according to NS 3473 (Norwegian Standard 3473).

c) Pavement structure design

The necessary thickness of the subbase, base and pavement layers is determined by conventional design, taking into consideration th subsoil conditions and the traffic volume, e.g. as given in tables in the standard specifications for road construction, chapter 5.1 (Ref. No. 1). The EPS layer is considered as a subsoil in bearing capacity group 6. For the concrete slab a load distribution coefficient of 3.0 is applied.
The load distribution coefficient for bearing course gravel is 1.0. This implies that the total pavement thickness must be increased by 20 cm if the concrete slab above the EPS is omitted (i.e. 30 cm of bearing course gravel substitutes 10 cm of concrete).

In order to reduce the risk of "black ice" at unfavourable temperature and weather conditions (especially during autumn and spring periods), the total thickness of the pavement structure above the EPS should at least be as shown in table 1. The given minimum thickness will ensure that the icing conditions on the EPS fill will not differ to any great extent from that on the adjacent road sections. This requires that the bearing courses above the concrete slab mainly consists of gravelly material.

Probability of icing on adjacent road	*Min. thickness of roadbase above EPS [1])*		
	AADT <1500	*AADT 1500-15000*	*AADT >15000*
High	*[2])*	*[2])*	*[2])*
Medium	*40*	*50*	*60*
Small	*50*	*60*	*70*
Very small	*60*	*70*	*80*

[1]) Min. thickness of road base layers must always be satisfied according to design table.

[2]) Values stated in the design table are to be used directly. If due to traffic loads or other conditions the roadbase is to be composed of crushed aggregate or bituminous materials, the increase in icing hazards may be compensated by increasing the subbase by 10 cm.

Table 1. Minimum thickness of roadbase above EPS when icing conditions are critical

6. Quality assurance

a) Quality control

Selection of blocks for quality control should be made at random, but evenly distributed among any set of blocks. The frequency when testing for material strength should be as shown in table 2. Block dimensions and evenness should be checked on one in every 25 blocks. Requirements regarding evenness and level of subsoil surface below the EPS should be checked in a cross section profile for every 10 m of road.

Size of fill	*No. of blocks to be tested*
< 500 m^3	*Min. 3 blocks*
500-1000 m^3	*Min. 5 blocks*
> 1000 m^3	*Min. 5 blocks per 1000 m^3*

Table 2. Frequency for testing material strength

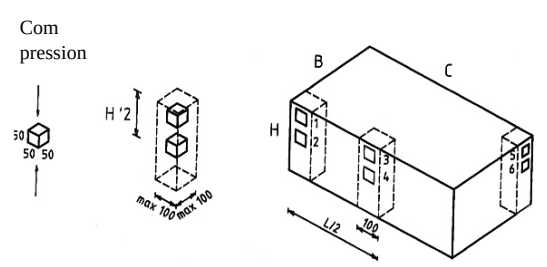

Fig. 4 Sample pattern for testing material strength

b) Documentation of quality from producer

A producer of EPS-blocks should at the latest when a tender for delivery is opened, produce documents giving details of the quality assurance system applied in the production process. Quality certificates should be submitted for blocks delivered on site. The Directorate of Public Roads may specify detailed requirements for such documentation. Sampling should be performed according to clause 6.a. by the authorities in charge of construction before the blocks are placed in the fill.

7. References

1 - Statens vegvesen (1992): Vegbygging. Håndbok 018. *(Standard specifications for road construction, handbook 018)*

2 - Statens vegvesen (1990): Geoteknikk i vegbygging. Håndbok 016. *(Code of practice on soil mechanics in road construction, handbook 016)*

3 - Statens vegvesen (1991): Materialkrav for ekspandert polystyren til vegfyllinger. Blankett 483. *(Material*

requirements for EPS for road fills, form 483)
4 - Statens vegvesen (1991): Kvalitetskontroll av ekspandert polystyren til vegfyllinger. Blankett 484 *(Quality control of EPS for road fills, Form 484)*