

FOAMGLASS – A NEW VISION IN ROAD CONSTRUCTION

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ABSTRACT

The Norwegian Public Roads Administration has a long tradition in applying various types of lightweight filling materials for road construction purposes. During the last 50 years wooden materials like sawdust and bark residue from the timber industry have been applied for such purposes. Also waste material from the production of cellular concrete blocks and LWA (Light Weight Clay Aggregate) have been widely used. Since 1972 blocks of Expanded Polystyrene have been used extensively in road projects for a variety of applications also including blocks produced from re-circulated EPS material. In this connection monitoring programmes have been initiated in order to investigate the long term performance of these materials. Presently a new option is being investigated involving the use of granulated foamed glass produced by re-circulating waste glass. The maximum grain size will be some 50 mm with angular edges and the material may be produced in various densities. When placed and compacted in a drained fill the unit density of the lightest version will be some 300 – 350 kg/m³ depending on the compaction machinery and compaction efforts. On recent road projects deformations and possible variations in moisture content, unit density and grain size distribution will be monitored. In two projects in particular foamglass used temporarily in a road section will be excavated and reused in another location providing extended possibilities for monitoring material behaviour. This paper presents results from this monitoring programme and gives recommendations regarding design criteria and construction procedures related to foamglass. The application of foamed glass in road construction is also part of a larger programme in order to enhance the use of re-cycled material in road construction in general.

KEY WORDS

Waste materials / lightweight fill / foamglass / field monitoring

1. INTRODUCTION

1.01 Sawdust, bark residue and foamed concrete material

The Norwegian Public Roads Administration has for many years employed various lightweight filling materials to overcome load and settlement problems in connection with road construction on soft subsoils. Initially in the 1950ties and 60ties sawdust and bark residue from the timbre industry were used with a unit density of 10 kN/m³ employed for design purposes. Waste from the production of cellular concrete blocks or slabs for house building purposes was also employed with a design unit density of 10 kN/m³ established from field monitoring tests. The cost aspect and availability of these materials changed, however, dramatically when the timbre industry started using their waste for heating purposes and the demand for cellular concrete materials in the building industry receded.

1.02 Light Weight Clay Aggregate - LWA

Instead the focus was placed on another type of lightweight aggregate, LWA (Light Weight Clay Aggregate). By sintering clay in a special furnace, hard spheres of various sizes are formed (generally 0 – 32 mm). These spheres are used for producing building blocks and slabs. At the start in the late 1950ties waste products from this block production were used as lightweight filling materials, but it was also found suitable to use the LWA grains in fills directly. The unit density of such material based on monitoring programmes has been determined to be 6 kN/m³ when positioned in a drained condition in the fill or 7 kN/m³ when periodically submerged. In addition it has thermal insulation effects and may therefore also act as a frost-insulating layer if having sufficient thickness. LWA material is in common use as a lightweight filling material for road construction in Norway today and will compete with other lightweight materials like Expanded Polystyrene blocks EPS.

1.03 Expanded Polystyrene

Since 1972 when the first road EPS fill was placed in Norway, the use of blocks of EPS as a super light filling material has seen a major increase both in volume and types of application on a world wide scale. Initially blocks were only foamed using fresh raw materials. Incorporation of recycled EPS material has also been introduced in the block production and in some cases whole blocks have been reused in another location. Design unit densities employed for this type of material are 0.5 kN/m³ when placed in a drained condition and 1 kN/m³ when submerged.

1.04 Other light weight waste materials in Norway

Another waste material of interest is used car tyres. Most countries are now accumulating appreciable amounts of used car tyres and one possible reuse of these tyres are in fills as a lightweight material. Various approaches have been made in different countries, but in general shredded tyres are most commonly used for this purpose, but in some cases whole tyres have also been applied. In Norway only a few projects have been completed using shredded tyres including a noise barrier with shredded tires at the core.

1.05 Recycling programme

Ambitious environmental politics, international treaties and agreements, and a general change of attitude and awareness considering generating and handling waste has encouraged the development of national policies, codes, routines and contract clauses that motivate more extensive use of recycled materials. The Norwegian Public Road Administration (NPRA) has in this connection initiated a programme in order to promote the use of recycled material in road structures. This includes incorporating secondary materials in the design guidelines and standards. Environmental issues and concerns need to be addressed during the entire life cycle from the design phase through maintenance and to demolition.

One aspect of this programme is to promote the reuse of foamglass, whole or shredded car tyres, EPS, slag and broken glass as lightweight filling materials. For NPRA it is important to define quality specifications for these materials including environmental considerations and incorporate these in the general design specifications.

2.0 FOAMGLASS

2.01 Concept

In the western hemisphere vast heaps of glass products are accumulating. This comprises various sorts of glass waste originating from light bulbs and other lighting fixtures like mercury lamps, bottles, windowpanes, car windshields etc. and industrial waste. In Europe the average annual glass consumption is some 30 – 40 kg/per inhabitant. At the same time as being a waste product it also constitute a raw material for possible reuse. Some of the glass waste may be used directly in the production of bottles and other products but some of the glass waste also contains toxic materials that need to be removed in the recycling process.

In this connection a production process has been initiated based on the recycling of waste glass in the middle region of Norway. A patented process originating in Switzerland (Misapor) is used in Norway under the trade name of Hasopor. In this process lighting fixtures and other toxic glass waste is treated in order to remove heavy metal components and other environmentally difficult matter. The product has

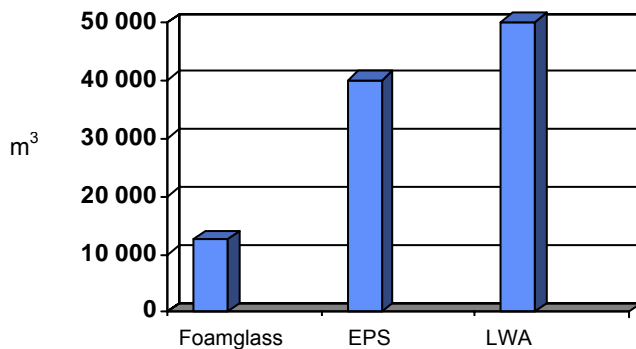


Figure 1 – Annual use of lightweight filling materials for roads in Norway

now been used as a lightweight filling material on some road projects in Norway and the Norwegian Public Roads Administration has initiated a monitoring programme in order to evaluate the material properties and performance in this connection. A similar product is known to have been produced in Switzerland for some time and it is also reported to have been used in road structures. Regarding material quality and behaviour in this connection only sparse information has been obtained.

In Norway about 4 million mercury lamps are used every year and the

aim is to recycle about 40 % amounting to an annual production of some 50 000 m³ of Hasopor.

2.02 Production process

Foamglass is produced using an environmentally friendly recycling technology for contaminated and toxic waste ranging from mercury lamps, industrial slag and flyash, PC- and TV-tubes, and laminated glass to batteries. The process is based on the concept of transforming finely ground glass powder from different glass sources mixed with an activator like silica carbide into glass foam. In the grinding process heavy metals are separated out and recycled to metal melting plants.

The powder is spread on a steel belt conveyor running through high temperature ovens whereby the powder expands above 4 times, to leave the oven as a glass foam material. When the product leaves the oven it will crack and separate into

smaller units due to the temperature shock. Normal grain size will be in the range of 10 – 60 mm (figure 2).



Figure 2 – Typical foamglass particle

material confirming that possible leaching products from a fill will have toxic contents well below normal environmental requirements.

Foamglass generally consists of 8 per cent of glass by volume and 92 per cent gas bobbles. A thin impervious glass wall encloses each bobble.

Material qualities listed by the producer is as follows:

- Low unit bulk density, the product is delivered in two qualities: (Light) 180 kg/m³ and (standard) 225 kg/m³.
- High thermal insulation qualities
- High material strength, 60 – 120 kN/m²
- Low moisture absorption
- Chemically and thermally stable

2.03 Material properties

With its insulating properties and light weight the material may both be used as a lightweight filling material and/or frost insulating layer in roads. Compared to the production parameters used at the start in 1999 the material now has a different pore structure, density and strength today with possible improvements in material properties as a result.

In order to investigate material properties for road construction purposes various monitoring programmes have been initiated both for field and laboratory testing. Data relating to water content and densities measured in the field by the Public Roads Administration is shown in table 1.

The production process is free of dust and any harmful gases and does not need water at any stage.

The principles behind this system is very simple:

- To separate, and
- clean the waste in fractions for further treatment down the process line.

During this process the toxic components are reduced below the detecting limits. In this connection a certificate has been obtained for the

Table 1 – Field tests on foamglass material placed in road structures.

Road project	Mat. type	Year	Field test	Volume m ³	Water cont. %	Density kg/m ³	Fines < 8 mm (%)
Lodalen	Light	2001	2001	1500	3 -18	325	
Rv 120	Light	2001	2001	2900		500	15 - 65
E 6 Mule	Light	2002	2002	550		295	25 - 35
E6 Eggemarka	Std.	2002	2003	1000	15 - 20	345	20
Postterminalen	Std	2000	2000	2750			30
E6 Rosendal	Std	1999	2002	310	18	530	30
E 6 Klemetsrud	Light	2003	2003	1100	0,5	271	5 - 20



Figure 3. – Installing steel tube

On 6 of the existing foamglass fills a thin walled steel tube with diameter 570 mm was pressed / vibrated 270 mm into the foamglass until the top was level with the top of the foamglass layer (Figure 3). The particles contained within the steel tube were removed and the excavated material weighed wet and dry. Also the void left in the tube was lined with a thin plastic sheet and filled with water from a measuring glass in order to determine the excavated volume. The accuracy of this testing method is believed to be fairly good. Errors may occur if the plastic sheet bridges some of the voids within the steel tube and possibly some

compaction may occur when pressing the tube into the material. The overall error is, however, not expected to exceed 1–2 %. The test sites will be monitored with more tests over time in order to observe changes in deformations, water content and density.

Laboratory water absorption tests have also been performed by the Sintef group (The Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology) and the Norwegian Building Research Institute (NBI). The result is shown in table 2.

Table 2 – laboratory tests performed on foamglass by the Sintef group

Material type	Water absorption (2000) % by weight after 22 weeks	Water absorption (2003) % by weight after 50 weeks
Light	76	48
Standard	103	45

From both field and laboratory tests the Sintef group concludes that foamglass of the Hasopor type has favourable insulating and drainage properties and that adjusted production procedures have improved the material properties in particular for the light quality. Due to the angular particles the material also has high internal stability and

flexibility. For use in road structures the material has elastic properties comparable to ordinary gravel commonly used as a roadbase material. It is, however, important that the stress level is kept below a level that will result in crushing and permanent material deformations.

Foamglass may compete with other lightweight filling materials like LWA and EPS. Tests performed so far indicate that unit densities in the range of 300 – 350 kg/m³ may be expected, but for use in roads the Norwegian Public Roads Authorities has not yet made a decision on values to be applied for the light and standard type of Hasopor. Here also construction procedures and type of equipment used will play an important part. Design unit densities will probably have to be linked both to the type of material delivered on site and construction procedures.

Table 3 – Observed deformations in fills

Site	Max height of fill in m	Compaction factor %	Deformations % short term	Deformations % long term	Deformations on slopes %
Lodalen	2	1.25	1.5 – 2.5	+ 0 – 0.5	4
Rv 120	3	1.6	1	+ 0 – 0.5	2 - 3
E 6 Mule	3	1.25			
E6 Eggemarka	4		1	+ 0	1.5
E6 Rosendal	2.5	1.4			
E6 Klemetsrud	3	1.20	1		

The compaction factor is defined as the actual volume placed in a fill divided by the theoretical volume. After being placed in the fill and compacted only small further deformations may be expected from road pavement and live loads, in the short term about 1 % of the layer thickness. Observations over time (3years) indicate that further crushing and deformations tend to be negligible. The content of fines may be checked again when two temporary foamglass fills will be excavated and moved to another location for reuse in 2003 (see chapter 3). On the side slopes deformations tend to be about twice as that in the rest of the fill, but these deformations also occur in the initial stages and no long term effects seem to be present. Due to the angular shape of the foamglass particles the fill may be placed with rather steep side slopes and this is the reason for the larger initial deformations in the outer part of the fill.

2.04 Environmental properties

Reuse of waste material for filling purposes requires a certification that the material is inert and does not leach unwanted matter to the surroundings. For this purpose a series of specifications and guidelines from the Norwegian Pollution Control Authority (SFT) must be considered related to the project in question. A material may be defined as inert provided it does not undergo any appreciable physical, chemical or biological change and any leaching fluid must only contain insignificant amounts of polluting matter.

The composition of the waste material, its leaching effects, environmental properties and the long term behaviour in a deposit must therefore be known before it is deposited. In this connection a technical description of foamglass is prepared by the Norwegian Building Research Institute for the manufacturer of Hasopor. For this

purpose a Common Understanding Assessment Procedure is used as an alternative to the ETA approval of non standardised materials.

3.0 USE IN ROAD PROJECTS

3.01 National road No 17 - Repair of slope failure at Rosendal

Due to erosion along the riverbed a 10 m high road slope failed over a distance of some 30 m. At the river level and in the slope the subsoil consisted of quick clay of medium strength. In order to re-open the road and prevent further erosion along the riverbank and more slides, it was necessary to quickly implement repair measures. Erosion protection was established using blasted rock before filling the slide area with foamglass of the Hasopor type. The material was delivered on site by large trucks and side tipped into slide area. Volumes of up to 100 m³ could be transported in one haul. The foamglass was then distributed and placed in layers of 0.5 m thickness by a 30 tonnes crawler mounted excavator and compacted by 3 – 4 passes by the crawler belts giving a compaction ratio of 1.4. In this way a total volume of 300 m³ was placed within the time span of 4 hours.

The composition and thickness of the road pavement placed on top of the foamglass fill was equivalent to the pavement on the adjoining road sections.

Visual observations and in situ tests for checking density and grain size distribution has been performed 3 years after the slope was re-established (see table 1). The road is performing well without any pavement cracks or settlement.

3.02 Pedestrian/cycle path in Lodalen

In connection with the construction of a pedestrian/cycle path on a slope with low stability against failure, foamglass was used to construct the fill. The lightest quality of foamglass was employed, i.e. $\rho = 180 \text{ kg/m}^3$. Since no additional load could be placed on the slope it was decided to use a fully compensated solution by replacing some of the natural subsoil with foamglass. Totally a volume of 1200 m³ foamglass was used.



Figure 4 – Distributing foamglass using a crawler mounted excavator / shovel dozer

The foamglass was placed in layer thickness up to 2 m. The top surface was levelled off by the excavator and compaction was performed by the crawler belts of the excavator. On the slopes light compaction was performed with the excavator bucket. The natural slope angle for uncompacted foamglass seems to be 45°.

For layer thickness less than 2 m compaction may be performed after

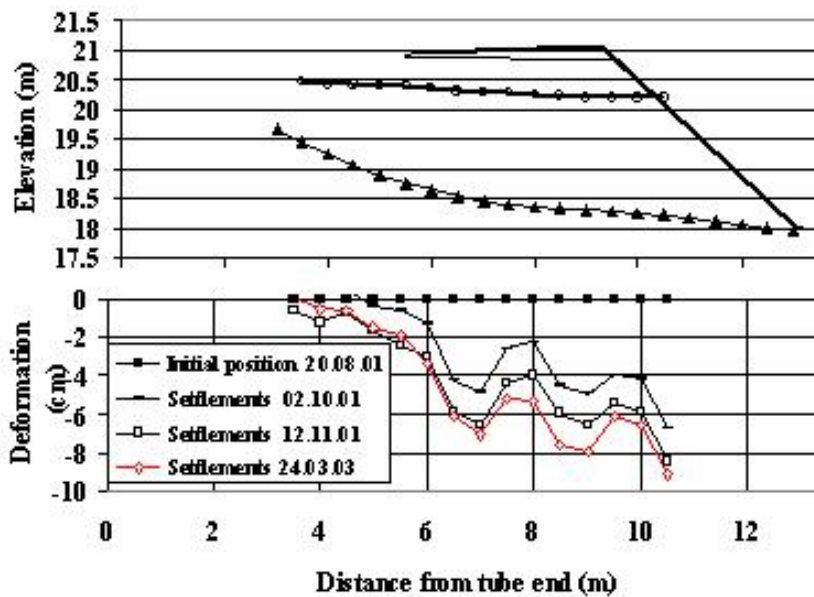


Figure 5 – Observed deformations at Lodalen

placing the road base. The thickness of the roadbase layer should then be at least 20 cm.

In order to monitor deformations in the material, settlement tubes have been installed at the bottom and at the top of the foamglass layer at two sections (figure 5).

The deformations of the foamglass layer may then be evaluated from the settlement differences of the tubes, see figure 5.

According to the measurements shown in figure 5 the foamglass layer deformed about 10 cm after the roadbase materials were placed. It is important to note that the deformations in the outer area occurred immediately after the foamglass layer was loaded.

3.03 Embankment on National highway No 120

In an area some 50 km north of Oslo with subsoils consisting of soft sensitive clay it was decided to use foamglass as a lightweight filling material in competition with LWA. The cross section of the road is in cut on one side and fill on the other. The height of the fill is up to 4 m. No appreciable settlements are expected, but lightweight filling materials were selected due to stability concerns.



Figure 6 - Transport to site in large trucks

A total volume of 3 950 m³ of Hasopor type foamglass, light version with unit density 180 kg/m³ specified by the manufacturer was used in layer thickness up to 3 m. The foamglass was placed in 1 m thick layers and compacted using a crawler mounted dozer with belt pressure 56 kN/m².

As in the previous case at Lodalen settlement tubes have been installed at the bottom and top of the foamglass layer at two locations in order to monitor possible deformations in the material (figure 7).

Measurements of density and water content were performed at two locations; one underneath the tracks of the transport trucks and other traffic on the fill while the

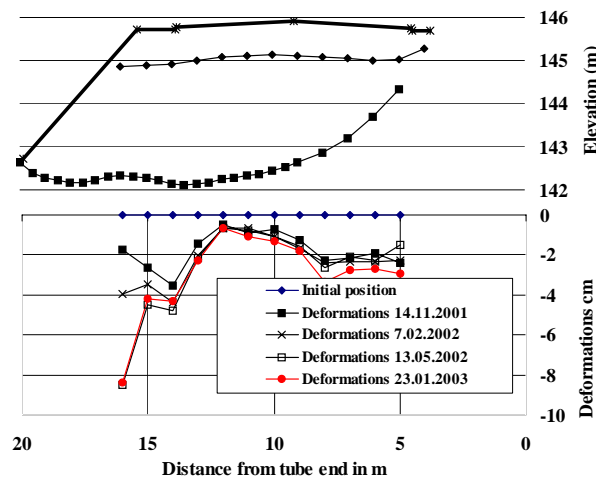


Figure 7. – Observed deformations at NR 120 substantially less crushing was observed.

During construction heavy machinery was used to a great extent for placing and compacting the foamglass and the material was distributed in thin layers. In addition the fill was also used as an access road for the construction site in general. A compaction factor of 1.37 is calculated by the contractor based on actual volume of foamglass delivered on site compared to the theoretical volume.

The results of sieving tests performed on excavated material are shown in figure 8. Here it may be observed that the grain size distribution curves show considerable amount of fines below the typical particle size 10 – 60 mm that results from the production process.

This site will also be followed up with more tests over time in order to monitor possible changes in deformations, water content and density.

With the angular shaped particles the foamglass has a high internal stability facilitating transport with heavy trucks directly on the material. This will, however, cause some breakage and crushing of individual grains resulting in a higher unit density underneath the tracks.

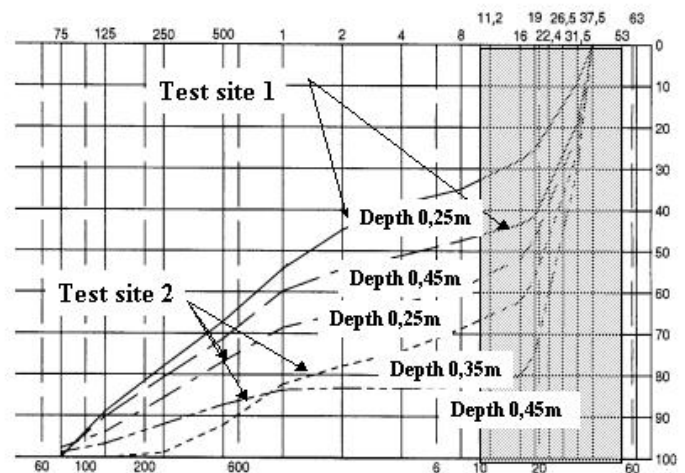


Figure 8 - Grains size distribution of excavated material

3.04 E6 Steinkjer, Eggemarka cut and cover tunnel

In this road project a cut and cover concrete tunnel of some 600 m length joins on to a rock tunnel for Euroroad E 6. The backfill cover above the concrete tunnel is some 25 metre at the highest point. In order to keep traffic running on E 6 during the construction period a temporary diversion road with an embankment height of more than 15 m is needed, with the upper 6 m consisting of lightweight filling materials.

other was located towards the edge of the fill less influenced by traffic other than for compaction purposes.

A higher water content than expected was found and also a considerably higher unit density than anticipated was measured, (see table 1)

Test pits were also excavated below wheel tracks for visual inspection. In this connection clear indications of major crushing were detected down to a depth of 700 mm below the surface. Outside the wheel tracks and in areas with little on site traffic

Here expanded clay aggregate (LWA 9000 m³) and foam glass (Hasopor 1000 m³) are used to reduce the weight on the culvert and to improve stability and reduce

settlement problems. In addition foamglass and LWA will be used for frost insulation purposes on a pedestrian/cycle path. Construction of the embankment started in November 2002 and was completed in February 2003. The diversion road was opened for traffic in March 2003 and is planned to be in service until the construction of the new road is finished in the summer 2004. The lightweight filling materials will then be reused against bridge abutments on other parts of the road projects. This will provide possibilities for comparing the material properties of reused LWA and foamglass.



Figure 9 – Exposed foamglass slopes

The foamglass materials were treated in the following way: A separating geotextile (class 2) was placed above the blasted rockfill material in order to facilitate later removal of the lightweight materials. The foamglass was transported to the site in large volume trucks directly from the factory or from local storage sites with dumper trucks. Placing and compaction was performed in 1 to 1.5 metre thick layers using crawler mounted dozers with track loads $\leq 40 \text{ kN/m}^2$ performing some 3 passes over the area per layer. With this procedure a volume reduction of 25 % was observed. Another 5 % reduction in volume was anticipated due to transport on site from local storage areas. A separating cloth (class 1) was used on top of the foamglass before placing the road base materials. No covering soils were placed on the foamglass slopes on the temporary fill (see figure 9).

In order to monitor field densities similar testing methods as applied on the sites mentioned above was applied. Density measurements were performed throughout the construction period both on loose material delivered on site, and on compacted material in the fill. In the fill 2 samples were taken for every second layer and with 4 layers a total of 8 samples were collected for each material type (LWA and foamglass). Average figures from these tests are given in table 1. Water content was measured on samples when delivered on site and compacted in the fill. Possible changes in water content will be monitored by retrieving further samples for testing after one year in the fill.

Sieving tests were performed both on loose material delivered on site and on compacted material retrieved from the fill. Since use of a sieving machine tends to create additional fines during the sieving process, special care had to be taken when performing sieving tests. Sieving tests were performed on all test samples collected for density measurements (table 1).

In addition plate bearing tests and falling weight measurements were performed both on the outer and inner wheel tracks on the right lane of the road and in the

centre line of the pedestrian/cycle path. So far there seems to be small differences between the rockfill and the light weight material.

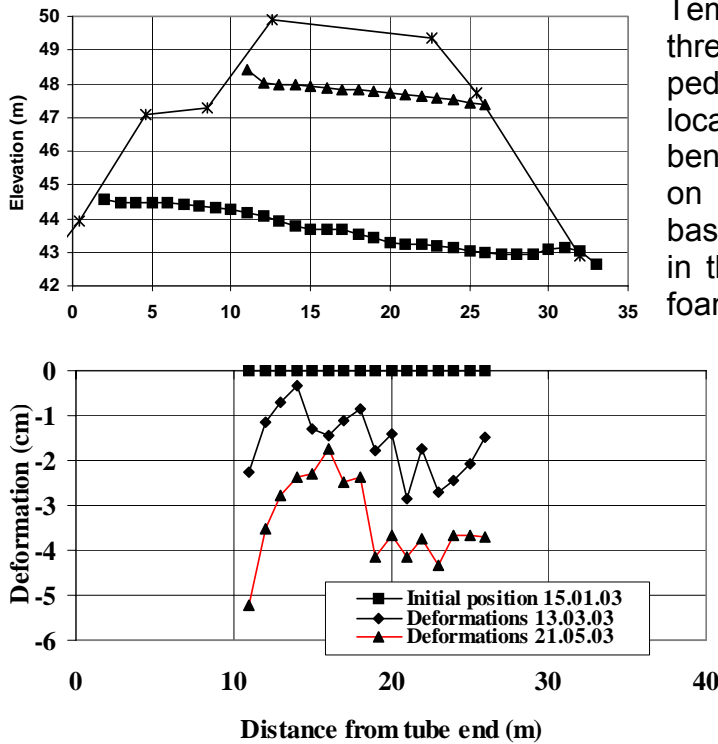


Figure 10 – Observed deformations at Eggemarka

Temperature gauges are installed in three sections on the pedestrian/cycle path centrally located. Gauges are located just beneath the asphalt pavement and on the top and bottom of the road base material as well as on the top, in the middle and the bottom of the foamglass and 20 cm into the materials below. In order to monitor possible icing dangers gauges are also placed in the upper part of the asphalt pavement. Air temperatures are monitored at a location 2 metres above the ground level.

In order to monitor the location of the freezing zone during the winter period frost zone gauges are also installed at the same three sections of the pedestrian /cycle path as mentioned above. Temperature will be monitored during the winter 2003/2004.

Settlements are monitored using settlement tubes placed at two sections, one section with LWA and one section where foamglass is used. At these sections there is one tube on the top and one at the bottom of the lightweight filling layer. Initial measurements were taken when the fills were completed and then again two months later (see figure 10).

3.05 E 6 Klemetsrud



Figure 11- Light compaction of fill on diversion road at Klemetsrud

Construction activities has started in 2003 in section southwards out of Oslo towards Sweden from two lanes to a four lane motorway. In order to keep traffic running during the construction period a short diversion road is needed for a period of about half a year in 2003. On this section foamglass has been employed with layer thickness of up to 4 metres in order to reduce the load and resulting settlements on a water main. The light quality has been used and the material will be reused in connection with a ramp at one of the

intersections with soft ground conditions. The foamglass has been subjected to light compaction activities with a belt pressure of 45 kN/m² in order to reduce particle

crushing. While the diversion road is in operation possible deformations of the road surface and at the top of the foamglass layer will be monitored in order to evaluate if such light compaction is acceptable. The calculated compaction factor is low (1.2). So far the observed deformations at the top of the foamglass layer does not deviate from deformations registered in other foamglass projects. Sieving tests and density measurements were performed when the fill was placed and similar tests will be performed when the material is moved to its future location.

4.0 CONCLUSIONS

Foamglass of the type Hasopor is believed to be an interesting lightweight filling material that may be applied in road construction projects if the price is economically favourable compared to competitive products. The cost of foamglass delivered on site in Norway is at present approx. \$ 35 - 40 per m³. Consisting of glass the material is believed to be fully resistant to possible chemical degrading agents in a road structure. The mechanical strength of the light quality material may require some special handling in order to prevent excessive crushing. Observations so far indicate that fairly light machinery should be used on site for placement, distribution and compaction of this light quality. In this respect the denser quality may in some cases be preferred since the in place unit density of the light quality tend to be at least as high as that to be expected for the denser quality. In this connection both specifications for determining design densities and construction procedures may have to be revised.

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