USE OF WASTE MATERIALS FOR LIGHTWEIGHT FILLS

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ABSTRACT

In Norway the 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/m$^3$ depending on the compaction machinery and compaction efforts. On a recent road project deformations and possible variations in moisture content, unit density and grain size distribution will be monitored. This paper presents results from this monitoring programme.

KEYWORDS

Waste materials, lightweight fill, foamglass, field monitoring

INTRODUCTION

Sawdust and bark residue

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. Some 50 years back sawdust, a waste material from sawmills, was used as a lightweight filling material. The unit density employed for design purposes was 10 kN/m$^3$. Similarly when the timber industry started to strip trees of bark at centrally located barking stations in the 1960ties, vast amounts of bark residue were accumulated. In both cases this waste material could be obtained at practically no cost except for the cost of transportation from the waste dumps to the construction sites. The bark was classified according to degree of decomposition and the less decomposed material was used in road construction on secondary roads with a design density equal to saw dust, i.e. 10 kN/m$^3$. As long as the saw dust or bark was kept moist in a submerged position or covered by layers of clay, no appreciable decay or road subsidence were observed. However, when the timber industry started to make use of saw dust and bark as a combustible material for drying newly cut planks at the saw mills, the cost aspect changed dramatically and these types of lightweight filling materials could no longer compete with alternative material having emerged in the meantime.

Foamed concrete materials

Such materials were waste from the production of cellular concrete blocks or slabs for house building purposes, in this country sold under the trade name of Siporex or Ytong. Again being a waste product these materials could be obtained at fairly low cost. Being a rather weak material, several tests were performed regarding compressive strength and unit density including the affinity to absorb water. Also monitoring programmes were initiated testing for possible changes in particle sizes due to crushing during placement and repetitive loading in a road structure, and also changes in water content when stored in the ground for some appreciable period of time. From the result of these monitoring programmes a design unit weight for design purposes was established at 10 kN/m$^3$. When the demand for such materials in the building industry receded also the amount of available waste materials diminished and today such materials are seldom used.
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 a 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/m$^3$ when positioned in a drained condition in the fill or 7 kN/m$^3$ 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.

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 worldwide 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. As the use of EPS as a filling material now has a fairly broad literature coverage internationally, most recently in the proceedings from the EPS Geofoam Conference in Salt Lake City December 2001, further information on this topic may be obtained here.

Other waste materials in Norway

Another waste material of some concern 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 a pile of whole tyres at the core.

In this country attempts have also been made to produce a lightweight insulation and filling material by foaming common household garbage and industrial waste. This requires various processes like sorting, grinding, kneading, cleaning and purification prior to foaming and drying. Small scale testing is presently being performed in order to evaluate the production procedures and resulting material qualities. No further information can therefore be given at this stage.

FOAMGLASS

Concept

In the western hemisphere vast heaps of glass products are also 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. 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. The resulting product is a lightweight foamglass material and it has been given the trade name of Hasopor. This product has 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. Hasopor 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 m$^3$ of Hasopor.

**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 grind ed glass powder from different glass sources mixed with an activator like silica carbide into glassfoam. 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 solid 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.

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 material confirming that possible leaching products from a fill will have toxic contents well below normal environmental requirements (see figure 2.).

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: 180 kg/m$^3$ and 225 kg/m$^3$.
- High thermal insulation qualities
- High material strength, 60 – 120 kN/m$^2$
- Low moisture absorption
- Chemically and thermally stable

These material qualities have been measured in laboratory tests performed by certified laboratories.

*Figure 1. Typical foamglass particle*

The production process may be visualised as indicated in figure 2.
Figure 2. Recycling process

USE IN ROAD PROJECTS

National road No 17 - Repair of slope failure

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 foammglas 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 foammglas 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.

Figure 3 Placing of foammglas with excavator

The composition and thickness of the road pavement placed on top of the foammglas fill was equivalent to the pavement on the adjoining road sections.
The slide occurred not far from the processing plant for foamglass in the middle region of Norway and
at the time in question foamglass had already been used in pilot projects for testing its thermal
properties as a frost insulating layer in road structures and other road related properties. Based on the
preliminary experiences from this project a decision to use foamglass to repair the slide area could
quickly be made. Due to the short construction period no on site density tests were performed other
than estimating the compaction ratio based on the delivered volume divided by the theoretical volume.

Experience gained from this project was that foamglass was easy to handle and therefore resulting in a
very short reconstruction period. The internal stability was also satisfactory on sloping subsolil
surfaces. The cost of foamglass delivered on site was $35 per m$^3$ (1999).

Visual observations 2 years after the slope was re-established indicate that the road is performing well
without any pavement cracks or settlement. Test pits are planned for checking grain size distribution
and density in the future.

**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. $\bar{n} = 180$ 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 m$^3$ foamglass was used.

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

![Figure 5. Distributing foamglass material using a crawler mounted excavator (Hitachi EX60, 8 tonnes). For internal transport on site a shovel dozer (CAT 923E) was used](image-url)
For layer thickness less than 2 m compaction may be performed after placing the road base. The thickness of the roadbase layer should then be at least 20 cm.

Field observations

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.

The deformations of the foamglass layer may then be evaluated from the settlement differences of the tubes, see figure 8.

According to the measurements shown in figure 8 the foamglass layer deformed about 12 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.

Design density

The design unit density used for foamglass in this fill was calculated to be $\tilde{n} = 300$ kg/m$^3$ based on the following criteria:

- Dry density (light quality) 200 kg/m$^3$
- Increased due to moisture 15 kg/m$^3$
- Compaction factor 1.3
- Material factor $\tilde{\alpha}_m = 1.1$

*Figure 6. Isometric view of foamglass fill at Lodalen*

*Figure 7. Monitoring long term deformations with tube settlement gauges.*
At two locations a thin walled steel tube with diameter 570 mm was pressed 270 mm into the foamglass fill until the top was level with the top of the foamglass layer. One test site was located in the open and the other underneath a bridge crossing over the foot/cycle-path. The particles contained within the steel tube was 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. Just before the samples were taken, heavy rain occurred.

Results from the two test sites are as follows:
Test site 1: Measured density $\bar{n} = 384 \, \text{kg} / \text{m}^3$ (w = 15.2 %)
Test site 2: Measured density $\bar{n} = 294 \, \text{kg} / \text{m}^3$ (w = 2.8 %)

The test show that the amount of accumulated water is somewhat higher than expected. Test site 2 was located under the bridge and this may explain the difference in water content. Also the material was compacted more than anticipated and the resulting density tend to be somewhat above the design density.

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

A total volume of 3 950 m³ of Hasopor type foamglass, light version with unit density 180 kg/m³ was used in layer thickness up to 3 m. The following procedures were adopted in cooperation with the contractor.

- Placing of separation cloth on subsoil.
- Transport to site by large trucks and internal transport by dumper.
- Distribution and compaction with crawler mounted dozer. (belt pressure 56 kN/m², belt width 61 cm).
- Placement in min 1 m layers.
  Compaction from min 3 passes by dozer.
- Separation cloth used on fill sides and top
- Road sub-base and base placed on top of separating cloth.

Field observations

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. The results from measurements taken so far are shown in figure 13.

Also measurements of density and water content was performed in the same way as described for the Lodalen site. 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 %.

Two test sites were selected, one underneath the tracks of the transport trucks and other traffic on the fill while the other was located towards the edge of the fill less influenced by traffic other than for compaction purposes.

Results from the two test sites are as follows:
Test site 1: Measured density $\bar{n} = 653$ kg / m³  
(w = 17.3 %)
Test site 2: Measured density $\bar{n} = 429$ kg / m³  
(w = 17.0 %)

Again a higher water content than expected was found and also a considerably higher unit density than anticipated was measured.

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 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 14. 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.

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. 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 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.

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.
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