EXPANDED CLAY LIGHTWEIGHT AGGREGATES FOR GEOTECHNICAL APPLICATIONS

AGREGADOS LEVES DE ARGILA EXPANDIDA PARA APLICAÇÕES EM GEOTECNIA

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ABSTRACT

A number of R&D projects have been carried related to the use of expanded clay lightweight aggregate (expanded clay LWA) in Civil Engineering applications and particularly in Geotechnics. Expanded clay LWA is used as frost insulation material in road pavements, light weight fill for stability improvement, reduction of settlement and reduction of earth pressure, and as drainage material in backfills and drainage ditches. The research projects have focused on verification of material properties and structural behaviour through laboratory and field tests. The projects have verified that expanded clay LWA has physical, mechanical and environmental properties to be largely used as lightweight fill material in roads, railways and other geotechnical construction works.

RESUMO

Têm vindo a ser realizados projectos de I&D relacionados com as utilizações de Agregados Leves de Argila Expandida em aplicações de Engenharia Civil e de Geotecnia em particular. Este material é usado na protecção contra o gelo em pavimentos rodoviários, na execução de aterros leves para aumento da estabilidade, redução de assentamentos e redução de impulsos, e como material drenante no tardoz de estruturas de suporte e em trincheiras drenantes. Os projectos de investigação têm vindo a focar-se na verificação das propriedades do material e no seu comportamento estrutural, através de ensaios em laboratório e em campo. Os projectos verificaram que os agregados leves de argila expandida têm propriedades físicas, mecânicas e ambientais que permitem a sua ampla utilização como material para execução de aterros leves na construção rodoviária, ferroviária e em outras obras geotécnicas.

1. RESEARCH PROJECTS

Expanded Clay LWA has been used as frost insulation material, lightweight fill and drainage material in the Nordic countries for more than 40 years. SINTEF Civil and Environmental Engineering has for several years been working on research and development projects related to the use of expanded clay lightweight clay aggregates in civil engineering applications. SINTEF has been technically responsible of projects which include participants from public authorities, research institutes, universities, consultants, contractors and industry. The projects include activities related to laboratory testing, large scale model tests, theoretical analyses and preparation of requirements and tests methods for verification of material characteristics.

Two of the most comprehensive projects were “MiljøIso”, focusing on physical and mechanical properties of the material, and its a second part, the “Internordic Geoproject”, focusing on the structural solutions, on design and on quality requirements for the material and construction.

2. APPLICATIONS

Some examples of the use of lightweight aggregates are presented in Figure 1.

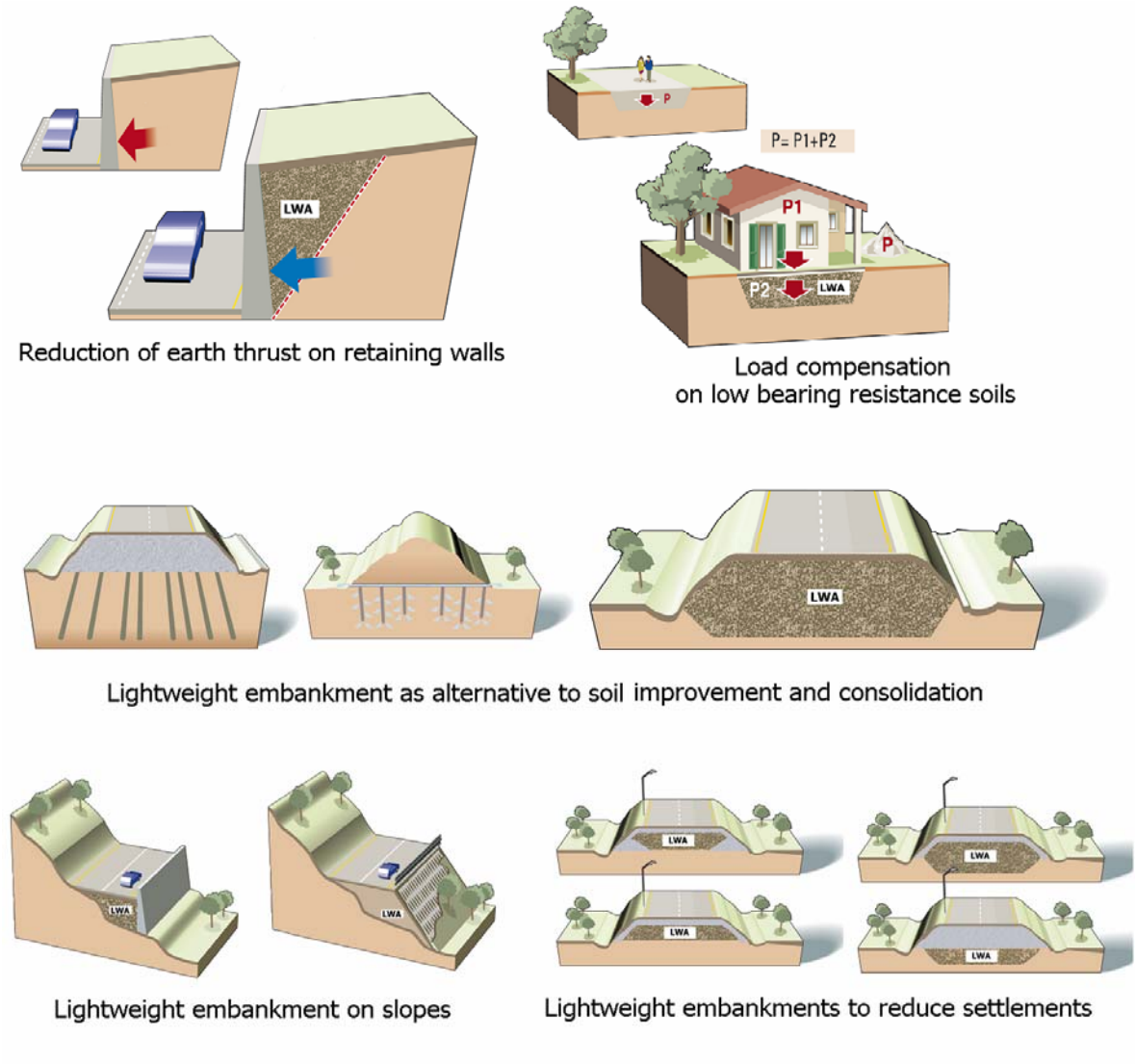

Figure 1 - Expanded clay LWA as lightweight fill for earth pressure reduction

3. TEST METHODS AND RELEVANT MATERIAL PROPERTIES

Physical and mechanical properties of expanded clay LWA are essential to be able to design sound technical solutions. As expanded clay LWA to some extent differ from conventional granular materials the projects also have to evaluate relevant test methods to determine the material properties. Further to current and large scale model laboratory testing, there were performed field investigations on expanded clay LWA in existing fills, and a full scale instrumented field test is currently going on. The project has provided both informations on the relevant material properties and the test methods to determine these properties.

3.1. Physical properties

A summary of the results for physical properties is given in Table 1.

Table 1 - Physical properties of expanded clay LWA

Properties	**Symbol**	**Leca® 10-20**	**Leca® 0-32**	**Comments**
Compact density	ρ_k	**2600 kg/m^3**	**2600 kg/m^3**	Dependent on the raw material
Pellet density	ρ_s	**750 kg/m^3**	**800 kg/m^3**	Mean value for the grading
Internal voids in the pellets	n_i	71%	69%	100 (1-ρ_s / ρ_k)
Dry bulk density before compaction	ρ_d	**280 kg/m^3**	**335 kg/m^3**	Dependent on loading or placing
Volume reduction by compaction	P	**10 %**	**10 %**	Dependent on construction method
Dry density after compaction	$\rho_{d,\,f}$	310 kg/m^3	370 kg/m^3	(1+P/100)ρ_d, used in the formulae bellow
Porosity of the fill	n	54%	49 %	100 (1-$\rho_{d,\,f}$ /ρ_s)
Total porosity (internal + external)	n_{tot}	88%	86%	100 (1-$\rho_{d,\,f}$ /ρ_k)
Water content	**w**	**25%**	**25%**	24 h immersion
Volume % water	w_{vol}	7.8	9.3	w ($\rho_{d,\,f}$ /ρ_w)
Air volume	n_{luft}	80%	77%	$n_{tot} - w_{vol}$
Unit weight	γ	3.75 kN/m^3	4.5 kN/m^3	$\gamma_{d,\,f}$ (1+ w/100)

3.2. Mechanical properties

The laboratory testing of the mechanical properties includes intial tests for preparation and compaction, triaxial tests, cyclic triaxial tests, and large scale oedometer tests. The results have been verified through large scale model tests and instrumented field tests.

Results from oedometer test in terms of idealised modulus curves are given in Figure 2.

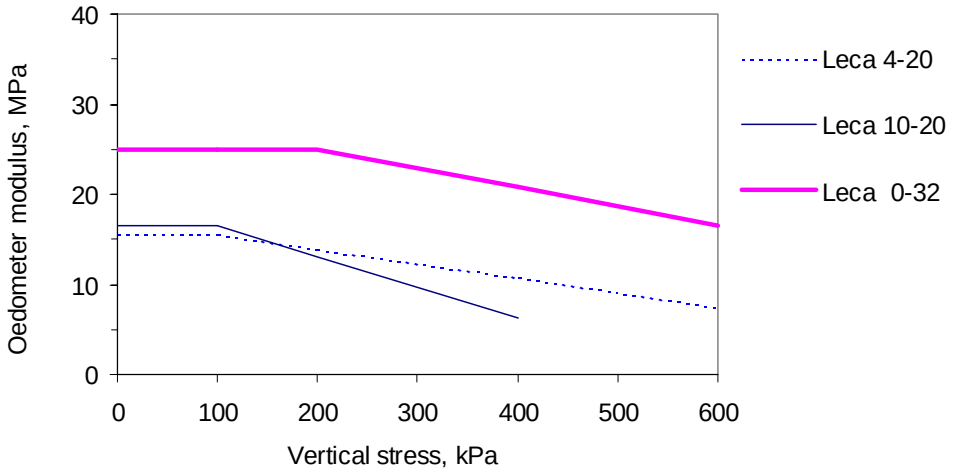

Figure 2 - Idealised modulus curves for compacted expanded clay LWA.

Based on static triaxial tests the effective strength parameters of expanded clay LWA are determined as:

- friction angle (peak) $\tan\varphi_p = 1.02$ $\varphi_p = 45°$
- friction angle (constant volume) $\tan\varphi_{cv} = 0.85$ $\varphi_{cv} = 41°$
- cohesion $c = 0$ kPa

In Figure 3 results from cyclic triaxial test in terms of E-modulus are presented.

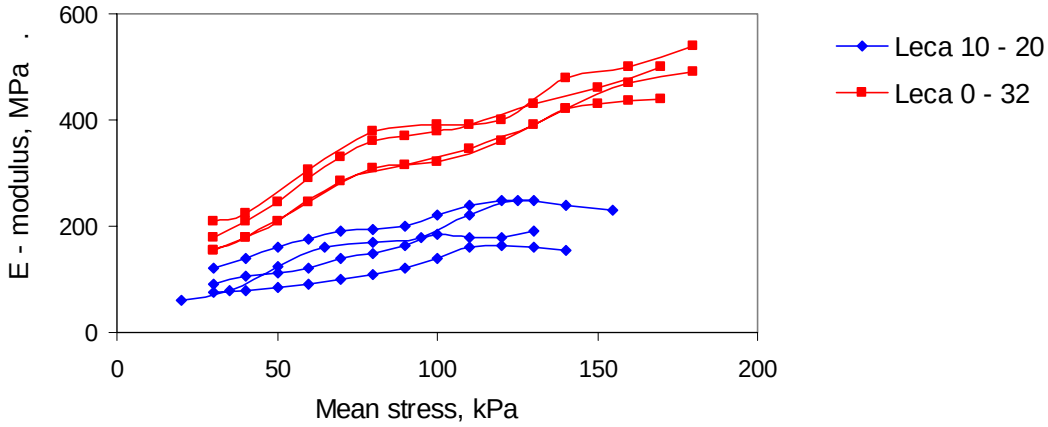

Figure 3 - E-modulus as found from cyclic triaxial tests

The tests have verified that expanded clay LWA has strength and stiffness comparable to conventional granular materials, provided the stress level is not resulting in crushing of the grains. Based on the results it is concluded that the mechanical properties of expanded clay LWA is sufficient for use as part of the sub-base

4. MODEL TESTS AND FULL SCALE FIELD TEST

4.1. Large scale model test

The results from the laboratory and the theoretical analyses are verified from a large scale model test, represented in Figure 4. The model test was run with a repeated loading for nearly 5.000.000 load cycles with a stepwise increased load pressure up to 700 kPa. Some results in terms of plastic deformations of asphalt layer and top of the expanded clay LWA is presented in Figure 5. The loads resulted in fairly small total deformations of the expanded clay LWA layer and the interaction between the expanded clay LWA and the other materials were good. After the test was completed the expanded clay LWA material was in the same condition as before the test. The large-scale test indicates that expanded clay LWA can be used with far less cover than what has previously been recommended.

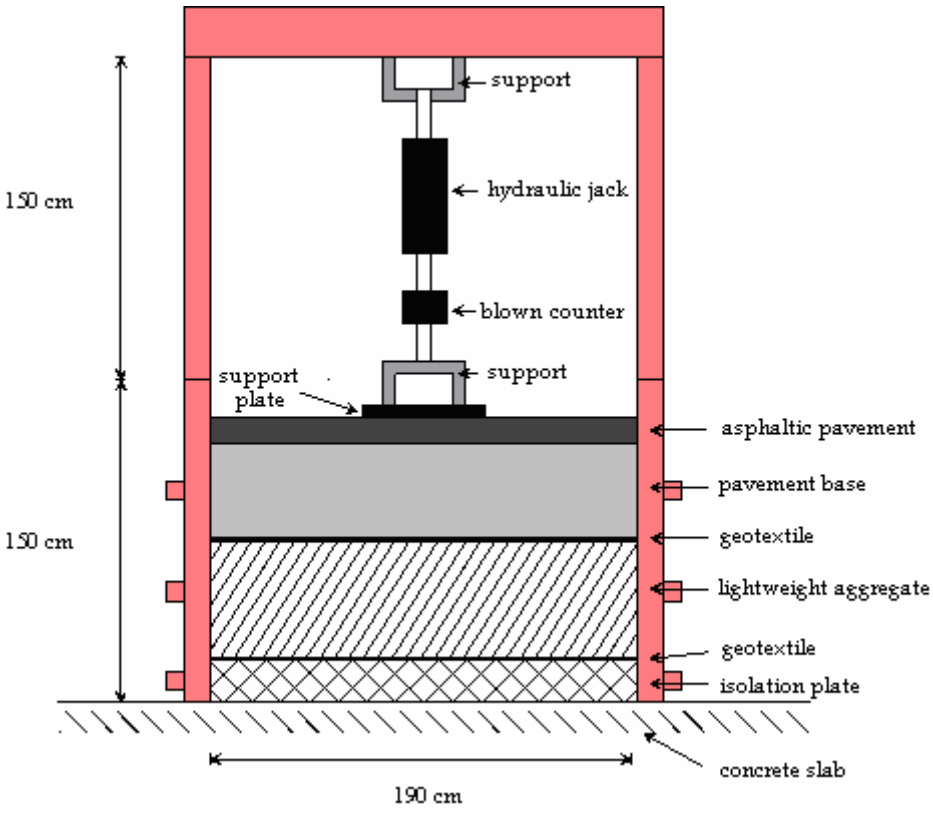

Figure 4 - Large scale model test set up

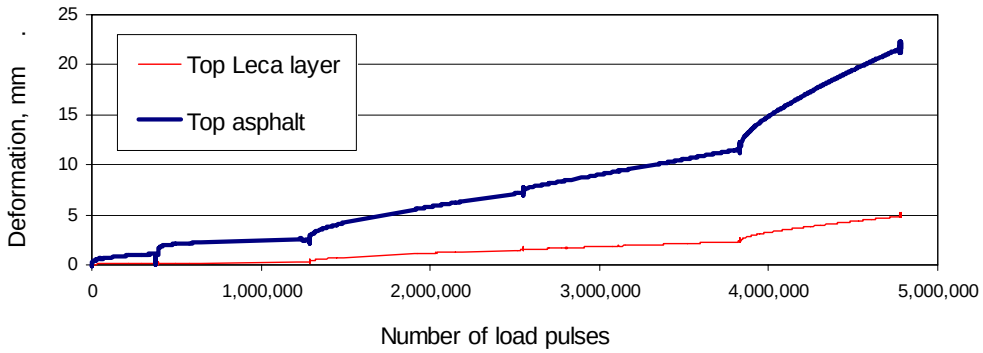

Figure 5 - Permanent deformations in the pavement structure.

4.2. Full scale field test

The results from the laboratory tests and the large-scale model tests were used as basis for planning the full-scale field test, which is currently running. A detail of the lay-out of the field test of Sandmoen is shown in Figure 6.

The measurements include falling weight deflectometer,stress and strain measurements under controlled loading and continuous logging of deformations (Figure 7). Stress measurements were performed at the top and at the bottom of the expanded clay LWA layer with a controlled loading (truck with tyre pressure 700 kPa), as shown in Figure 8.

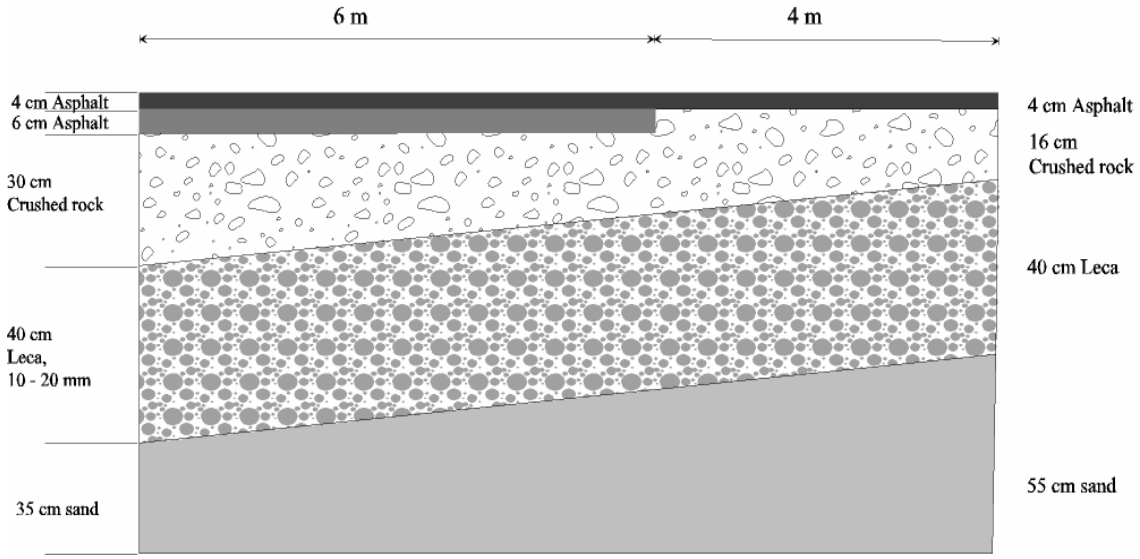

Figure 6 - Lay-out, full scale field test. Sandmoen, Norway.

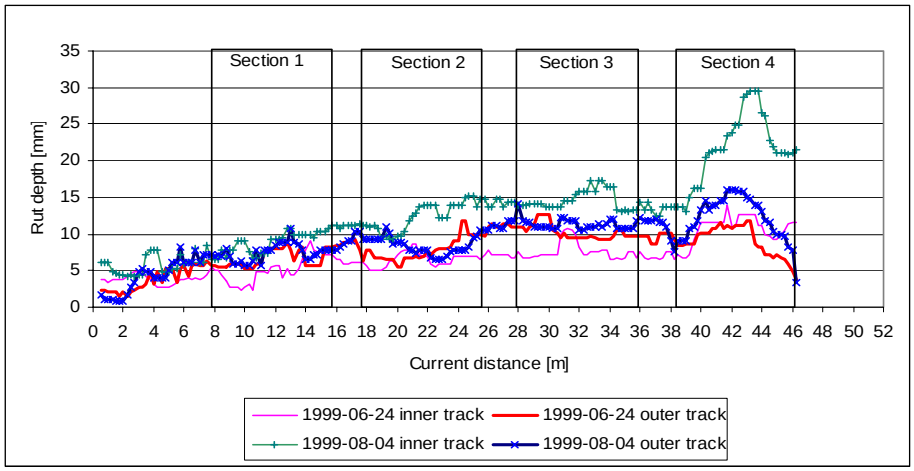

Figure 7 - Accumulated extreme measured rut depth in pavement

Figure 8 - Controlled loading on top of road with stress measurements

The results form the stress measurements are shown in Figure 9.

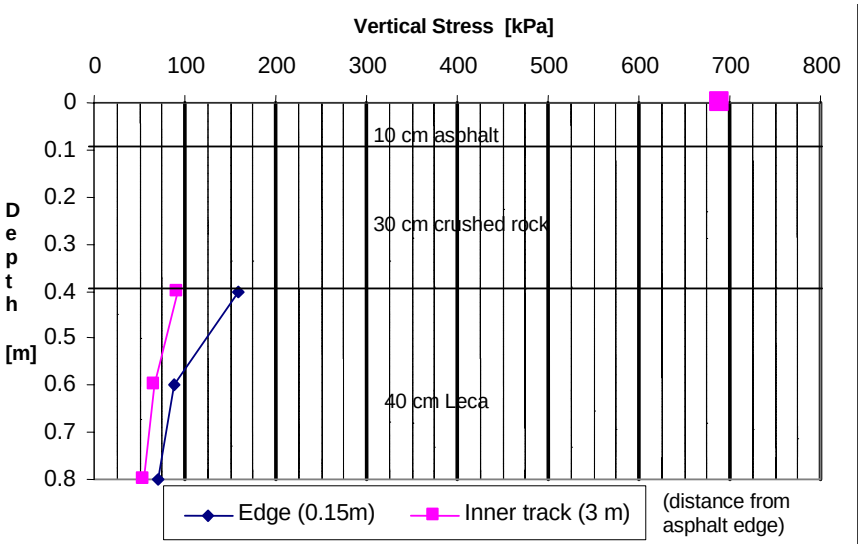

Figure 9 - Stress measurements in expanded clay LWA layer under controlled loading

The stress measurements verify that the vertical stress level is significantly higher at the edge of the road compared to the inner wheel track 3m from edge. The results indicate that the maximum stress level on top of the expanded clay LWA at the inner wheel track is less than 100 kPa, while at a distance 0.15 m from the edge the vertical stress level is more than 160 kPa.

5. QUALITY REQUIREMENTS AND CONSTRUCTION

5.1. Material quality requirements

A proposal for a product standard has been prepared by CEN TC88/WG 20. The draft standard called "prEN 15732 Light weight fill and thermal insulation products for civil engineering applications (CEA)" was completed by the end of 2006 and was sent on national enquiry in 2007. The standard gives the required properties and relevant test methods for material characterization and factory production control for attestation of conformity.

5.2. Brief comments on handling and construction

Expanded clay LWA has low weight and is therefore easily handled. Handling and storage of the material should be done in a way that takes into account the need for reduction of water absorption and also to reduce the risk for crushing of the grains.

Placing the expanded clay LWA by help of machines can be done in several ways:

- dozing
- by help of belt driven excavator
- blown from car up to 40 meters horizontally and up to 20 meters vertically (only for some gradings.)

The slopes of a LWA fill must be covered by other non-organic fill materials. In roads and railways it is recommended that the covering fill is 80 cm thick, measured normal to the fill slope.

6. LITTERATURE LIST

BANVERKET (1996): "Lättfyllning i järnvägsbankar". Håndbok BVH 585.111. (Guidelines for application of plastic materials and expanded clay aggregates as light weight fill materials in railway fills).

Furuberg, T., Hoff, I. and Solheim, O.M. (2000):"MiljøIso-Leca® isolasjon i veg og bane. Sluttrapport for delprosjekt 1: Leca® frostsikring –veg, bane, grøft". Final SINTEF-report in the "MiljøIso"-project.

Länsivaara, T. (2000): "Quality requirements for Light Weight Clay Aggregates. Present status in Finland". Report from SCC VIATEK as part of this project. May, 2000. (In English).

VEGVERKET (1987):"Lättfyllning i järnvägsbankar". Publication 1986:78. (Swedish guidelines for application of expanded clay aggregates as light weight fill materials in roads).