European Expanded Clay Association, ASBL
Rue Volta 8, Brussels

EXCA Technical report. Draft 2007-09-13:

PRELIMINARY DRAFT

Expanded clay LWA in CEA

Lightweight fill and thermal insulation products for civil engineering applications.
Installation and structural quality control on site

23/09/2011

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European Expanded Clay Association, ASBL
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Foreword

This Technical report has been prepared by TG S&U 02 in EXCA, the European Expanded Clay Association. Chairman of the group has been Oddvar Hyrve, maxit Group Norway, and technical secretary has been Arnstein Watn, SINTEF Norway.

The goal and purpose has been to present the current best practice and recommendations on the European level concerning in-situ quality control to ensure a correct and proper execution of civil engineering applications of Expanded Clay aggregates.

The basic material properties shall be tested and declared as stated in prEN 00088199 Light weight fill and thermal insulation products for civil engineering applications (CEA). Expanded clay lightweight aggregate products (LWA).

This technical report is acknowledged by all the major partners in the European Expanded Clay industry, and thus should be considered as a recommendation from the industry.

The report has no legal status, and instructions and guidance given in the specific projects has to be followed.

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1 Scope

This technical report provides recommendations for the material delivery control on site, storage and handling, construction procedures and quality control of the installed products. The required product characteristics and procedures for testing, marking and labelling of expanded clay LWA for this application is given in prEN 00088199.

This technical report contains 3 annexes:

Annex A (informative) – Installers Declaration

Annex B (informative) – Marking and labelling

Annex C (informative) – Delivery Control

This document covers the use of expanded clay LWA in Civil Engineering Applications excluding the use as thermal insulation in and under buildings which are covered by European Standard EN 14063-1. The technical report intends to cover the use of expanded clay LWA as lightweight fill, drainage and insulation materials in e.g embankments for roads, railways,and other traffic areas, as lightweight backfill e.g for retaining walls, sheet pile quay structures or as foundation for structures and as light weight fill of cavities..

This technical report gives recommendations for quality control of the expanded clay LWA product delivered on site, quality control of the construction work and for quality control of the structure during the construction and after completion.

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2 Terms, definitions, symbols, units and abbreviated terms

2.1 Terms and definitions

For the purposes of this technical report, the following definitions apply.

2.1.1 Expanded clay lightweight aggregate (expanded clay LWA):

Insulation material or product composed of lightweight granular material having a cellular structure formed by expanding clay minerals by heat.

2.1.2 Delivery in bags:

Installing loose-fill expanded clay LWA directly by pouring from the bag or installed directly in the bag.

2.1.3 Delivered loose material:

Loose-fill expanded clay delivered by truckload and installed directly from the truck by tipping or by blown delivery.

2.1.4 Blown (pneumatic) delivery:

Loose-fill expanded clay LWA applied or installed by a pneumatic unit.

2.1.5 Rounded particle:

Material consisting of expanded clay LWA particles with 50% or less of its surface crushed or broken (r).

2.1.6 Crushed or broken material:

Material consisting of expanded clay LWA particles with more than 50% of its surface crushed or broken (c).

2.1.7 Compaction:

The mechanical compression (e.g. by vibrator) of the installed layers, expressed as a percentage of the initial layer thickness.

2.1.8 Long term deformation:

The decrease of installed expanded clay LWA thickness with time, due to e.g external loads, environmental loads or creep, expressed as a percentage of the initial installed thickness.

2.1.9 Level:

The given value, which is the upper or lower limit of a requirement. The level is given by the declared value of the characteristic concerned.

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2.1.10 Design thickness:

Layer thickness after deformation and/or compaction as specified by the designer.

2.1.11 Installed thickness:

Layer thickness as installed by the installer including compaction if prescribed.

Expressions on the structural layers used in this report is presented in Figure 1.

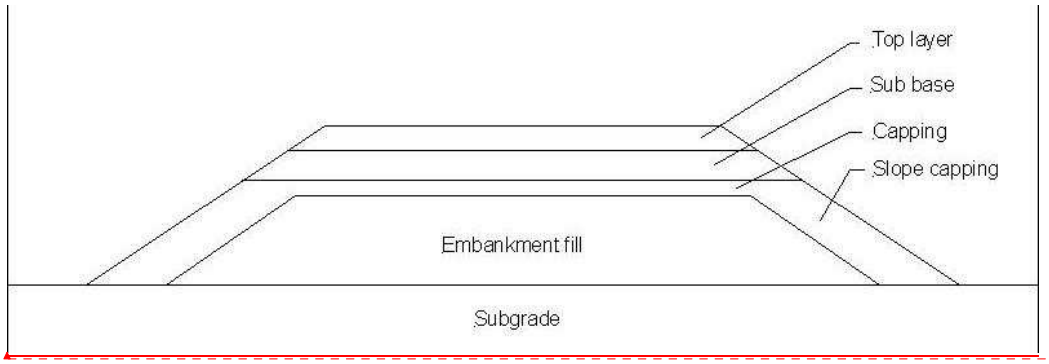

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Figure 1 Expressions on structural layers in expanded clay LWA structures used in this report

3 Applications

Light weight aggregates can be used both for insulation purposes and to reduce settlement and improve stability of fills on soft subsoil. Some examples of the use are presented in Figure 2-8.

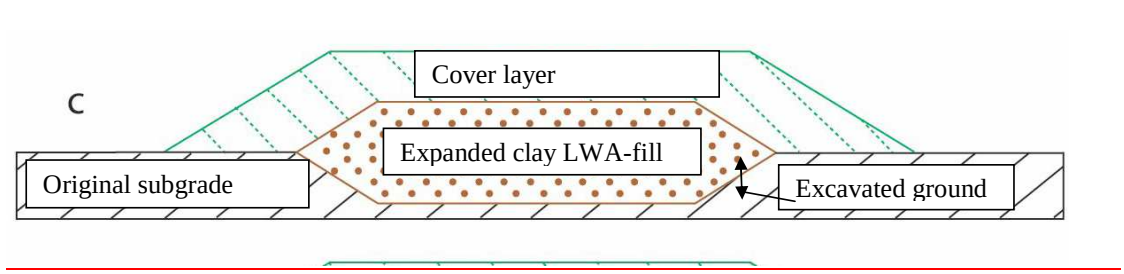

Figure 2 Expanded clay LWA used for load reduction to reduce settlement

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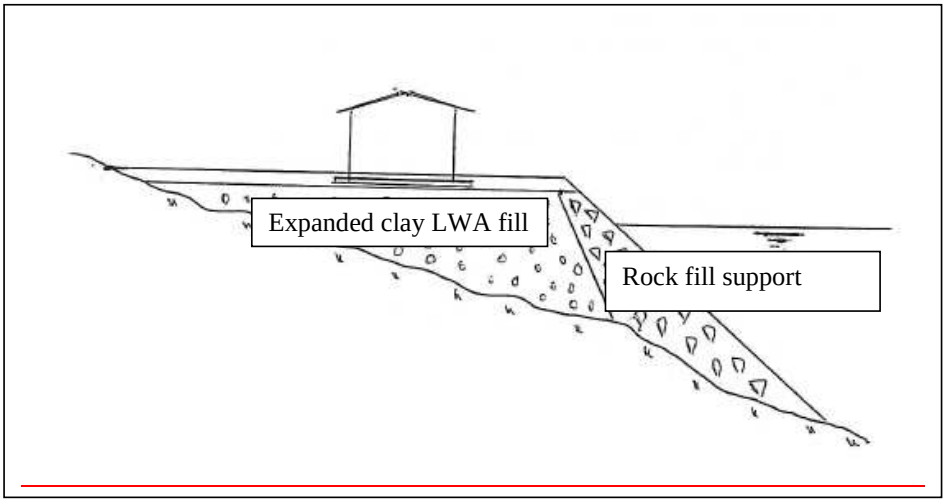

Figure 3 Expanded clay LWA to reduce weight and increase stability for fill in the sea

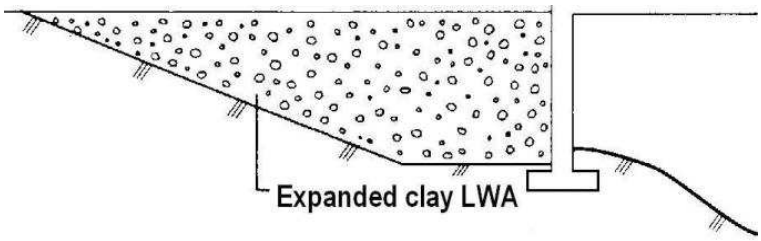

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Figure 4 Expanded clay LWA as lightweight backfill to reduce weight and earth pressure to reduce differential settlement and horizontal load for a bridge foundation

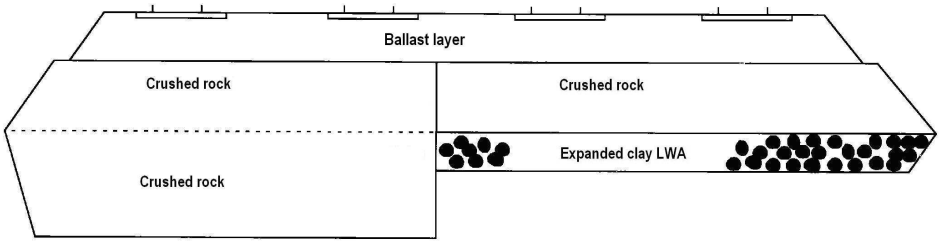

Figure 5 Expanded clay LWA as frost insulation in railroad embankment

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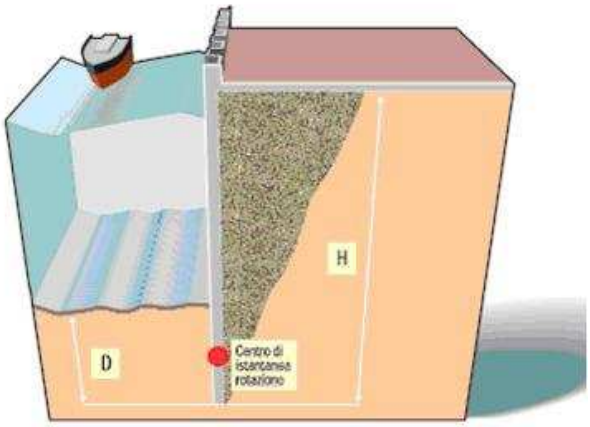

Figure 6 Expanded clay LWA used to reduce earth pressure on sheetpile wall for quay structure

Figure 7 Expanded clay LWA as light weight fill of cavities

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Figure 8 Expanded clay LWA embankment with intermediate geotextile layers

4 Execution and Control

4.1 General

The installer shall use an expanded clay LWA product that complies with prEN 00088199.

The installer shall inspect the construction site etc. in accordance with designers requirements and National Regulations, in order to determine whether it is suitable for application of the product.

4.2 Delivery Control

The purpose of the delivery control is to verify that the material delivered on site is according to the project specifications and the data provided by the manufacturer.

If additional delivery control is requried, including acceptance criteria, it shall be agreed upon before deliverance of expanded clay LWA. This can be done according to appendix C.

4.2.1 Marking and labeling

The marking and labeling of the delivered material shall be checked to verify that the product is in accordance with the project specifications. The marking of the delivered material shall be in accordance with prEN 00088199. An example of marking of the product is shown in appendix B. Accompanying document shall be made available on request and provide the required characteristics in accordance with prEN 00088199.

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4.3 Handling and storage

Handling of the expanded clay LWA can be done using normal construction equipment but care should be taken to avoid excessive impact on the material that may cause crushing of the aggregates. Care should be taken to avoid mixing with other materials during storing and handling. The material can be stored as conventional fill materials.

4.4 Construction

The construction control shall ensure that the material is installed in a proper way without being subjected to treatment that may reduce the intended function in the structure.

4.4.1 Preparatory work

The sub formation does not need levelling beyond the normal requirements for sub formation levelling.

The preparation of the sub formation for expanded clay LWA fills includes normal cleaning of the construction site (removal of e.g tree roots, shrubs and other obstacles). If construction is taking place under winter conditions all snow and ice should be removed from the sub formation. When prescribed a geotextile should be installed as a separator between the subgrade and the expanded clay LWA-fill.

Excess water in the excavation pit should be avoided and pumped out to acceptable levels. A high water level could cause problems with uplift, and reduce the effect of compaction.

NOTE: High water levels in an uncovered expanded clay LWA fill can be dangerous and should be avoided. Floating expanded clay LWA could make the fill surface appear stable, machines or workers going onto the fill may sink down into the water.

4.4.2 Installation

The material can be installed by tipping from the truck or by blowing. When tipping expanded clay LWA directly from the truck driving directly on top of the expanded clay LWA should be avoided. The material can be spread with a back excavator, dozer or other similar equipment. The spreading of the material can also favourably be combined with the compaction procedure (see compaction).

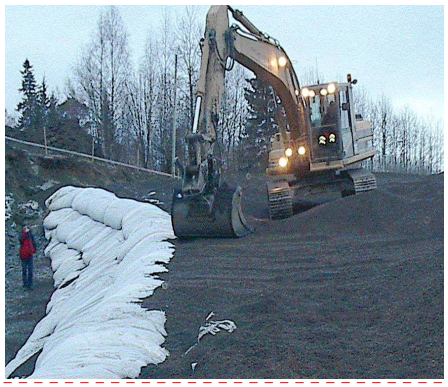

Figure 9 Installation by tipping from truck Spreading by a back excavator

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Installation by blowing directly into the place (Figure 10) can be useful at construction sites with difficult access conditions. Blowing enables unloading of expanded clay LWA directly on site of installation in places which are difficult to reach by conventional methods. It is possible to blow expanded clay LWA up to 100m horizontally or 20m vertically and in some circumstances even further. Installation by blowing will in most cases result in an initial compaction of the material thus reducing the need for additional mechanical compaction after the installation.

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Figure 10 Installation by blowing

Expanded clay LWA can also be installed from big bags. The big bags commonly contain about 1 m^3 material.

Construction traffic directly on the expanded clay LWA should be avoided with construction equipment having a belt or tire pressure higher than 50 kN/m^2. Trafficability for the construction equipment on the expanded clay LWA fill can be achieved by the construction of an access road on top of the expanded clay LWA, as seen in figure 11. A separating geotextile should be used between the expanded clay LWA fill and the access road base layer. Provided the use of conventional trucks (axle load less than 150 kN) the access roads can be designed according to conventional recommendations. As a general recommendation a total road base thickness for the access road of 300 mm unbound material above the expanded clay LWA is sufficient to provide required bearing capacity and avoid crushing of the expanded clay LWA. By the use of bound material it is possible to reduce the required thickness of the access road. The base layer material for the access road should be of sufficient quality (gravel, crushed rock according to national requirements for road base materials).

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Figure 11 Access road on top of expanded clay LWA-fill

4.4.3 Compaction

Generally embankments with expanded clay LWA are used in areas with soft and compressible subsoil. It may be difficult to obtain an optimal compaction of fill materials on this type of subsoil due to lack of response from the subsoil. Accordingly the compaction of expanded clay LWA fill in the embankment and the road base should be considered carefully to obtain a good result.

For the most commonly used rounded material the contractor should be aiming at a compaction of about 10% in relation to the loose fill state. When installing the material by blowing an initial compaction of maximum 5% is possible, depending on blowing pressure and installation procedure, and hence the need for additional mechanical compaction is reduced. The rate of compaction can be controlled by measurement of volume reduction during compaction or by measuring dry density on samples taken from the site after compaction.

Note: For some specific crushed materials (with or without fines) the amount of compaction can be significantly higher (up to 25%).

Compaction of expanded clay LWA requires less energy than conventional material, accordingly requirements for compaction equipment and recommendations for layer thickness to achieve a good compaction is not similar to conventional materials. The equipment and procedure for compaction should be related to the type of structure, compaction of small areas and close to structures will require smaller and lighter equipment than the compaction of large areas e.g for a road or railway embankment.

Dependent on local conditions and requirements two different procedures are given:

-compaction of conventional structures with compaction directly on the expanded clay expanded clay LWA layer

-compaction with vibrating roller in layers after the installation of a sand layer on top of the expanded clay LWA.

Note: Over-compaction (compaction leading to extensive crushing of the material) of the material should be avoided, especially if the material is used as frost insulation since this will increase the required volume and reduce the frost insulation properties. Also over-compaction will reduce the volume of the material and increase the need for material on site compared to the theoretical volume.

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4.4.3.1 Compaction directly on the expanded clay LWA-fill

As the required energy is less than conventional materials it is not recommended to use heavy equipment or equipment with high ground pressure. Conventional compaction equipment (vibrating roller o.s) should not be used to compact directly on the expanded clay LWA-fill as this cause the machinery to sink into the fill.

Some recommendations on equipment characteristics and procedures for the compaction directly on the expanded clay LWA-fill are given in Table 1.

Table 1 Recommendations on equipment and procedures for compaction directly on expanded clay LWA fill

Equipment	Recommendations
Dozer	To be used directly on the expanded clay LWA Only dozer with belts is recommended, Belt pressure<50kN/m^{2,}
Vibrating plate	To be used directly on the expanded clay LWA. Especially convenient close to other structures such as bridge abutments and for compaction of limited areas. Use of extended plate is recommended to avoid that the plate buries itself. Typical Weight 50-140 kg, width 50-80 cm, ground pressure <5kN/m^2, frequency 75-100 Hz

Examples of compaction by the use of a dozer and vibrating plate are presented in Figure 12.

Figure 12 Compaction by dozer Compaction with vibrating plate

Recommendations to achieve proper compaction directly on expanded CLAY LWA-layer are given in Figure 13. Often the specified compaction is reached during installation and no further compaction needs to be carried out. The optimum compaction varies with type of material and data for optimum compaction should be provided by the manufacturer.

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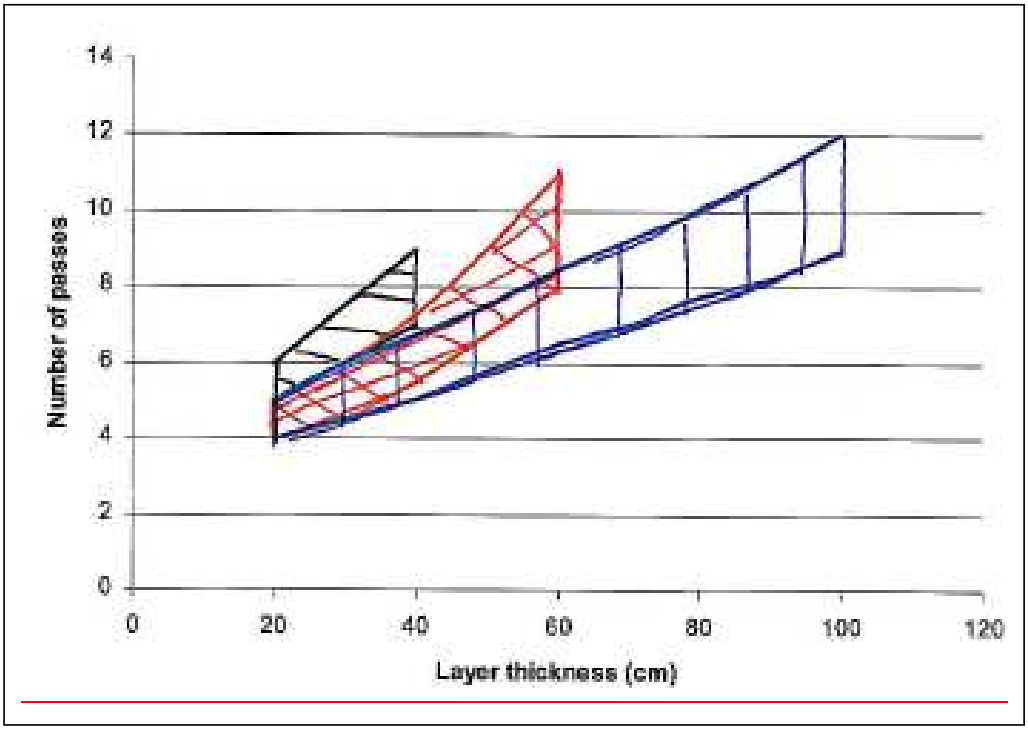

Figure 13 Recommendation on required compaction effort for expanded clay LWA-fill (vibrating plate 80kg, vibrating plate 140 kg, dozer)

4.4.3.2 Compaction in layers with intermediate layers of geotextile and sand

For severe conditions (e.g in areas with seismic actions) compaction of the expanded clay LWA-fill should be done after the installation of a separting geotextile and a sand-layer on top og the *expanded clay* LWA. Maximum thickness of the total layer (including geotextile and sand layer) is 1 m (0,8 m expanded clay LWA + 0,2m sand layer). The principle of the structural layout for this procedure is presented in Figure ??. Compaction is performed……..

Figure 14 Compaction roller, impact 26/37 kN

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////to be completed by input from Italy/////

4.4.3.3 Compaction of base layer on top of expanded clay LWA

It is very important for the total quality of the whole structure to obtain a proper compaction of the base layer on top of the expanded clay LWA. With maximum total layer thickness (expanded clay LWA and base layer on top) of 1m compaction of the total layer should be performed on top of the base layer using conventional equipment and procedures.

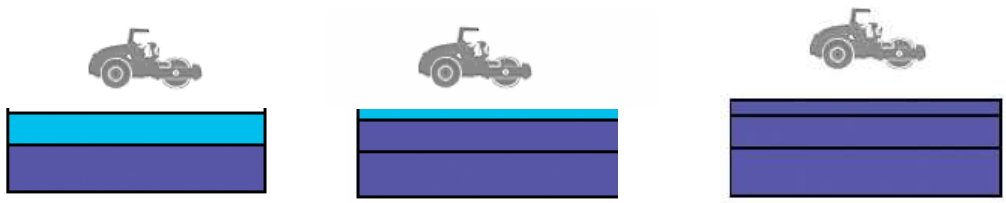
The compaction of unbound layers on top of expanded clay LWA should preferably be carried out with a vibrating oscillating roller with the possibility to adjust amplitude and/or frequency. The roller weight and compaction energy should be carefully considered based on the type of material and thickness of the base layer. Compaction energy should be limited to avoid risk of crushing of the expanded clay LWA-material underneath, and to obtain an optimum compaction effect of the base layer.

Some recommendations on equipment characteristics and procedures for the compaction directly on the expanded clay LWA-fill are given in Table 2.

Table 2 Recommendations on equipment and procedures for compaction of base layer on top of expanded clay LWA fill

Equipment	Recommendations
Vibrating roller	Typical weight 15-50 kN
Vibrating oscillating roller	Typical weight 15-50kN

To obtain maximum effect of the compaction of the base layer on top of the expanded clay LWA it is recommended to use vibrating equipment with the possibility to modify amplitude and the frequency and to perform the compaction in 3 steps as illustrated in figure 14.



1 Compaction of base layer with high amplitude and high frequency

2 Compaction of bearing layer with low amplitude and high frequency

3 Compaction with low amplitude and low frequency followed by a levelling compaction

Figure 15 Stepwise compaction of cover layer above expanded clay LWA fill

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4.5 Structural Quality control

The structural quality control is intended to control that the material has been installed in a proper way and is fulfilling the intended function in the structure.

4.5.1 Visual inspection

The surface of the expanded clay LWA should be inspected visually to check for uneven surface or crushing of the material due to overcompaction. If there are clear indication of overcompaction samples should be taken from the field according to annex A to control the material in the laboratory.

4.5.2 Installed thickness

The installed thickness and variations should be according to the project specifications and national requirements. Installed thickness is controlled by surface levelling.

4.5.3 Degree of compaction

The degree of compaction can be controlled by levelling, by relative volume control or by installed density.

Levelling should be performed on top of the expanded clay LWA layer and the degree of compaction should be estimated as the average deformation from at least 5 measuring points for each 1000 m^2 surface. It should be noted that possible changes in the fill profile should be evaluated as this will influence the measurements of compaction based on levelling only.

The relative compaction and the installed density can be controlled on samples taken in the field. The samples should be minimum 5 dm^3 and can be taken by the use of a sampling tube that is driven into the fill mechanically. Sampling of expanded clay LWA material can preferably be done by the use of a sampling tube combined with a vacuum cleaner device as seen in Figure 12.

The relative compaction can be controlled directly in the field by comparing the volume of loose material from the sampling with the volume of the volume of the material in the tube in situ.

The method is described in report from Swedish testing Institute /1/ /2/.

Figure 16 Sampling by vacuum cleaner device

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4.5.4 Bearing capacity/stiffness measured on top of the base layer

It is recommended that the measurements of the bearing capacity/stiffness is performed after the installation of a cover layer of minimum 300 mm on top of the expanded clay LWA-fill. For stabilized materials less cover layer thickness may be used.

4.5.4.1 Static plate bearing test

The bearing capacity/stiffness may be measured by a plate load tests on the covering layer on top of the expanded clay LWA fill The plate load test can be performed according to DIN 18 134 :2001-09 /3/. The results should be based on the average result from minimum 2 tests per 1000 m^2 surface.

It should be noted that the result in this case will reflect the stiffness and bearing capacity of the entire structure, not the expanded clay LWA layer alone.

4.5.4.2 Dynamic Plate bearing test

The method is basicly using the same equipment as for static plate load tests but with the application of a cyclic load. The method is not commonly used for verification of bearing capacity but is used for development and research projects.

It should be noted that the result in this case will reflect the stiffness and bearing capacity of the entire structure, not the expanded clay LWA layer alone.

4.5.4.3 Falling weight deflectometer

The falling weight deflectometer should be performed according to COST 336. Falling weight deflectometer will provide information on the elastic stiffness of the structure.

It should be noted that the result in this case will reflect the stiffness and bearing capacity of the entire structure, not the expanded clay LWA layer alone.

4.5.5 Measurements on top of installed expanded clay LWA Layer

If static or dynamic plate load tests are performed directly on the expanded clay LWA layer it is necessary to use a modified load plate with increased diameter (minimum 600mm) and testing procedures and evaluation of the results should be based on national experience with correlation with the bearing capacity of expanded clay LWA from field experience with similar structures.

4.5.6 Other methods not adapted

CBR (California Bearing ratio) is generally used for evaluation of bearing capacity of granular materials in a number of countries. The method has proven not to be suitable for the use of controlling the bearing capacity of expanded clay LWA-material.

Some other methods which may prove to be useful but where relevant experience is still limited are:

-compaction response on compaction equipment

-light weight falling weight equipment

-CPT

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Loadman

These methods need to be evaluated more before they can be taken into use for general quality control of expanded clay LWA-materials.

5 References

/1/ SP Method 3751 LEHA method: Determining the compaction and bulk density of expanded clay lightweight aggregate embankments – simplified method.

/2/ SP Method 3751 LEHA method: Determining the compaction and bulk density of expanded clay lightweight aggregate embankments.

/3/ DIN 18134 Determining the deformation and strength characteristics of soil by the plate loading test.

/4/ COST 336 Falling Weight Deflectometer

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Annex A

Installers declaration

The installer should as part of his general work reports declare that the work has been carried out in accordance with the requirements of this technical report using an expanded clay LWA product that complies with prEN 0008165-1.

The installer should also give at least the following information:

- Trade name and designation code of the installed expanded clay LWA product
- Date of installation
- Installed thickness
- Total quantity of the material used
- Equipment and procedure for installation and compaction

The installer should be trained in accordance with the guidelines given by the manufacturer or the system supplier.

During the installation the installer should verify that the expanded clayLWA is installed in layer of the prescribed thickness.

After the installation the expanded clay LWA should be fixed or stabilized if prescribed by the designer and according to the procedure prescribed by the designer.

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Annex B

Marking and labelling

Products conforming with the standard prEN 000189 shall be clearly marked on the label on the packaging or on an accompanying document, with the following information:

- product name or other identifying characteristic
- *name or identifying mark and address of the manufacturer or his authorised representative (always stated on the regular documents)*
- *date of delivery, manufacturing plant and/or traceability code (always stated on the regular documents)*
- reaction to fire class
- designation code as given in clause 6
- *quantity of material, in m^3 (always stated on the regular documents)*

It is recommended to make available the complete (AOC-level 3: 2 documents, AOC-level 1: 3 documents) CE declaration and declaration of conformity on the companies' internet pages:

- EC Declaration of conformity
- CE Technical Data sheet

and if AOC-level 1:

- Certificate of Factory Production Control (FPC) with surveillance (EC certification from Notified body)

CE **07**	**Product name: <e.g.: EXCA 10/20 >** **Article number: <e.g.: 150600>** • Reaction to fire: Euroclass A1 • Designation code: Exp. clay LWA prEN 00088199 - LD250 - PS(8-20)
	A complete CE declaration and declaration of conformity to be found on www.excacompany.net or will be forwarded on request

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Annex C

Delivery control

C.1Sampling

The normal delivery control includes a checking of the CE-marking of the product and that the deliverance is confirmed with the requirements. If additional delivery control is required, sampling of the material shall be performed according EN 932-1. See Table 1.

The number of tests shall be agreed upon before deliverance and installation. It shall also be agreed upon where the test samples shall be taken. Note that there might be considerable variations in the loose bulk density depending on where the material is taken due to separation during transport and tipping of the material. A recommended method for sampling with expanded clay LWA producer and external laboratory or third party to compare results is proposed in clause 4.

The test sample is taken	Sampling according to
on the truck load	EN 932-1, clause 8.9
after unloading	EN 932-1, Annex C

Table 1 Sampling procedure

The required number of test samples for delivery control on site should depend on the total volume of material delivered and should be defined in the procurement documents. Some general recommendations for delivery control are given in Table 2.

The test result is the mean value of 3 test specimens.

Volume delivered (m^3)	Loose bulk density	Particle size distribution	Water content
< 1000	1	1	1
1000-5000	3	2	2
>5000	1 per 2000 m^3	1 per 4000 m^3	1 per 2000 m^3

Table 2 Required number of tests for delivery control

C.2Loose bulk density

When required the loose bulk density can be determined in accordance with EN 1097-3.

Note : When required, the water content shall be measured in accordance with EN1097-5.

As the water content is a automatically result of the loose bulk density test it is not relevant to test water content if the loose bulk density is not tested.

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C.3Particle size distribution

When required, the particle size distribution shall be measured in accordance with EN 933-1.

Due the fact that this standard is a generel standard for aggregates, the weights of samples used for the test are not suitable for expanded clay LWA - because much more porous and lighter.

The required and adapted volume of expanded clay LWA for particle size distribution is proposed in the table 3.

Aggregate size D (mm)	Minimum volume of expanded clay LWA (litres)
63	(*)
32	2.1
16	1.7
8	0.8
4	0.3

(*) the typical max D for expanded clay LWA is 25.

The volumes for other aggregate sizes are calculated by interpolation.

Table 3 Required volume of expanded clay LWA for particle size distribution

C.4Method of sampling with expanded clay LWA producer and third party

Method of sampling : see clause 1. The samples are taken together from minimum 10 different places on the truck load or in the stock pile after unloading according EN 932-1 (by 1000 m³).

The volume of these expanded clay LWA tests specimens could represent 20 to 30 litres, then the reducing of sample is applied according EN 932-2 to have 2 parts of expanded clay LWA : one for expanded clay LWA producer and one for third party. From these samples the loose bulk density (and water content when required) and particle size distribution shall be performed according clause 2 and 3.

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