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Earthworks

Part 8: Alternative materials in earthworks

National foreword

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A list of organizations represented on this committee can be obtained on request to its committee manager.

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les terrassements

Erdarbeiten - Teil 8: Alternative Materialien für
Erdarbeiten

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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European foreword

This document (CEN/TR 16907-8:2024) has been prepared by Technical Committee CEN/TC 396 “Earthworks”, the secretariat of which is held by AFNOR.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

This document complements the European Standards within the framework series of EN 16907 on Earthworks:

- EN 16907-1, *Earthworks — Part 1: Principles and general rules*;
- EN 16907-2, *Earthworks — Part 2: Classification of materials*;
- EN 16907-3, *Earthworks — Part 3: Construction procedures*;
- EN 16907-4, *Earthworks — Part 4: Soil treatment with lime and/or hydraulic binders*;
- EN 16907-5, *Earthworks — Part 5: Quality control*;
- EN 16907-6, *Earthworks — Part 6: Land reclamation earthworks using dredged hydraulic fill*;
- EN 16907-7, *Earthworks — Part 7: Hydraulic placement of waste*;
- CEN/TR 16907-8, *Earthworks — Part 8: Alternative materials in earthworks* (this document);
- CEN/TR 16907-9, *Earthworks — Part 9: Sustainable earthworks* (Under preparation).

These “Earthworks standards” do not apply to the environmental planning and geotechnical design that determines the required form and properties of the earth-structure that is to be constructed. They apply to the design of the earthwork's materials, execution, monitoring and checking of earthworks construction processes to ensure that the completed earth-structure satisfies the geotechnical design.

Any feedback and questions on this document should be directed to the users’ national standards body. A complete listing of these bodies can be found on the CEN website.

1 Scope

This document informs about the experience of European member state practices for successfully using alternative materials in earthworks. It covers all earthworks, whether for roads, railways, and other infrastructure, including fills, capping layers, transition zones, drainage ribs or others (for details, see EN 16907-1:2018, Clause 1 “Scope”).

Alternative materials have properties, on a geotechnical standpoint, which makes them different from the materials (soils and rocks) being normally used in earthworks. Therefore, the objective of this document is:

- to give an overview of the alternative materials that have been successfully used in earthworks in Europe;
- for the alternative materials, for which use in earthworks is adequately documented, to give general information regarding the points of attention that clients, designers and earthwork companies, keep in mind in any attempt to use them in earthworks.

This document does not deal with alternative materials used as aggregate.

This document does not deal with alternative materials used as binders (fly ash, granulated blast furnace slag or others) or binder components.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp/>

4 Abbreviations

ABS	air-cooled blast furnace slag
ASAM	<i>Asociace stavebních alternativních materiálů</i> (Association of construction alternative materials in Czechia)
BOS	basic oxygen furnace slag
CBR	California Bearing Ratio
CCP	coal combustion products
CO ₂	carbon dioxide
CSH	calcium silicate hydrates
ECOBA	European Coal Combustion Products Association
EAF S	electric arc furnace slag from stainless/high alloy steel production

EAFC	electric arc furnace slag from carbon steel production
EPB	earth pressure balance
FBC	fluidized bed combustion
FBCFA	fluidized bed combustion fly ash
FGD	flue gas desulphurisation
GBS	granulated blast furnace slag
LA	Los Angeles coefficient (see EN 1097-2)
LOI	loss on ignition
MDD	maximum dry density (see EN 13286-2)
MIBA	municipal incinerator bottom ash
MIFA	municipal incinerator fly ash
OMC	optimum moisture content (see EN 13286-2)
PAH	polyaromatic hydrocarbons
PFA	pulverized fuel ash
pH	decimal logarithm of the reciprocal of the hydrogen ion activity
SMS	secondary metallurgical slags
SNCR	selective non-catalytic reduction (method of denitrification)
TBM	tunnel boring machine
UIC	International Union of Railways (<i>Union internationale des chemins de fer</i> - French)
UKQAA	UK Quality Ash Association
UPS	<i>Polska Unia Ubocznych Produktów Spalania</i> (Polish Association of Coal Combustion Products)
WG7	working group 7 “Alternative materials in earthworks” of CEN/TC 396 “Earthworks”

5 Alternative materials definitions

Alternative materials are considered as anthropogenic materials according to EN 16907-2. In Table 1, groups of alternative materials are grouped according to the Table 5 of EN 16907-2:2018.

Table 1 — The groups of alternative materials by groups in EN 16907-2

Group	Source	EN 16907-2
A	Construction and demolition recycling industries	AR
B	Municipal solid waste incineration industry	AM
C	Coal Power generation industry	AM
D	Iron and steel Industry	AM
E	Non-ferrous industry	AM
F	Foundry industry	AM
G	Mining and quarry industry	AN (AM)
H	Excavated natural materials	AN
I	Other combustion residues	AM
J	Miscellaneous	AM (AR)
Key AN – natural materials processed mechanically; AM – manufactured materials (including secondary manufactured materials); AR – recycled materials.		

The definitions for the alternative materials described in document are listed in Table 2. They were inspired by the CEN/TS 17438, however for earthworks additional materials are defined (see Table 2).

Material sheets were prepared for majority of materials described in Table 2. In case of no or not enough practical applications in earthworks no material sheets have been prepared. A list of materials without material sheet is below:

- A1 Reclaimed asphalt
- B2 Municipal incinerator fly ash (MIFA)
- E2 Ferromolybdenum slag
- E3 Zinc slag
- E4 Phosphorous slag
- E5 Lead slag
- E6 Ferrochromium slag
- F2 Foundry cupola furnace slag
- I2 Sewage sludge incineration ash (municipal)
- I4 Oil shale ash
- J2 Cement and lime kiln dust
- J4 FGD artificial gypsum
- J5 Industrial artificial gypsum
- J6 Marginal materials

Dredged material – coarse (class H2b) for application as hydraulic fill is described in EN 16907-6.

Reclaimed natural soil (without processing) is assessed according to EN 16907-1 to EN 16907- 6.

NOTE Marginal materials represent local sources (e.g. China clay residues, peat ash, etc.). They are assessed individually.

Table 2 — Definitions of alternative materials

Group	Source	EN 16907-2 Group	Group	Subnumber (CEN/TS 17438)	Specific material	Definition
A	Construction and demolition recycling industries	AR	A1	A1	Reclaimed asphalt	Material resulting from processing bituminous layers.
			A2	A2	Reclaimed concrete	Material resulting from processing concrete.
			A3	A3	Reclaimed bricks, masonry	Material resulting from processing demolition brick work and masonry.
			A4	A4	Hydraulically bound and unbound materials	Material resulting from processing hydraulically bound and unbound materials.
			A5	A5	Mix of A1, A2, A3 and A4	Material resulting from processing a mix of bituminous layers and/or concrete and/or demolition brick work and masonry.
			A6	A6	Reclaimed railway ballast	Material resulting from recycling of railway ballast.
B	Municipal solid waste incineration industry	AM	B1	B1	Municipal incinerator bottom ash ^a (excluding fly ash) (MIBA)	Material resulting from processing 'bottom ash' ^b following the incineration of Municipal Solid Waste (domestic and commercial) by a 'moving grate' or 'fluidised bed' or gasification' process. Today also referred to as MIBA (Municipal Incinerator Bottom Ash).
			B2	B2	Municipal incinerator fly ash (MIFA)	Material resulting from flue gas following the incineration of municipal solid waste (municipal and commercial) by a 'moving grate' or 'fluidised bed' or gasification' process, captured by flue gas treatment (FGT) systems and in some cases electrostatic precipitators'. Today also referred to as MIFA (Municipal Incinerator Fly Ash).

Group	Source	EN 16907-2 Group	Group	Subnumber (CEN/TS 17438)	Specific material	Definition
C	Coal Power generation industry	AM	C1a	C1	Coal fly ash - siliceous	Material resulting from flue gas following the burning of pulverised hard (or bituminous) coal, with or without co-combustion materials, captured by electrostatic precipitators.
			C1b	C1	Coal fly ash - calcareous	Material resulting from flue gas following the burning of pulverized lignite with or without co-combustion materials, captured by electrostatic precipitators.
			C2	C2	Fluidized bed combustion fly ash (FBCFA)	Material resulting from flue gas following coal burning with or without co-combustion in fluidized bed combustion boilers at temperatures of 750 °C to 900 °C.
			C3	C3	Boiler slag	Material resulting from coal combustion in boilers at temperatures of 1 500 °C to 1 700 °C, followed by wet ash removal of wet bottom furnaces.
			C4a	C4	Coal bottom ash-siliceous	Material resulting from the bottom of dry boilers, derived from the combustion of (hard or bituminous coal) coal with or without co-combustion.
			C4b	C4	Coal bottom ash - calcareous	Material resulting from the bottom of dry boilers, derived from the combustion of lignite with or without co-combustion.
			C5		Fluidized bed combustion bottom ash (FBC bottom ash)	Material resulting from the bottom of fluidized bed combustion boilers at temperatures of 800 °C to 900 °C, derived from the burning of coal with or without co-combustion.

Group	Source	EN 16907-2 Group	Group	Subnumber (CEN/TS 17438)	Specific material	Definition
D	Iron and steel industry	AM	D1	D1	Granulated blast furnace slag (GBS) (vitrified)	Material resulting from the manufacture of iron by thermochemical reduction in a blast furnace and subsequently rapidly-cooled to form a glassy material. The rapid cooling (quenching) of the liquid slag generates the glassy granulated blast furnace slag.
			D2	D2	Air-cooled blast furnace slag (ABS) (crystallized)	Material resulting from the manufacture of iron by thermochemical reduction in a blast furnace and subsequently air-cooled to form a crystalline aggregate.
			D3	D3	Basic oxygen furnace slag (converter slag, BOS)	Material resulting from the conversion of liquid iron (hot metal) and steel scrap into steel during a batch process in a basic oxygen furnace.
			D4	D4	Electric arc furnace slag (from carbon steel production, EAF C)	Material resulting from melting steel scrap into steel during a batch process in an electric arc furnace.
			D5	D5	Electric arc furnace slag (from stainless/high alloy steel production, EAF S)	Material resulting from the manufacture of stainless or high alloy steel in different metallurgical vessels, e.g. electric arc furnace, converter and ladles.
			D6		Secondary metallurgical slags (SMS)	Material resulting from the manufacture of carbon steel in different metallurgical vessels, e.g. ladles.
E	Non-ferrous industry	AM	E1	E1	Copper slag	Material resulting from the manufacture of copper in a furnace process.
			E2	E2	Ferromolybdenum slag	Material resulting from a metallo-thermic reduction process to produce ferromolybdenum from roasted molybdenite concentrate and other raw materials.
			E3	E3	Zinc slag	Material resulting from the pyrometallurgical step when treating zinc-bearing materials.
			E4	E4	Phosphorous slag	Material resulting from the manufacture of phosphorus in an electric arc furnace process.
			E5	E5	Lead slag	Material resulting from the manufacture of lead.
			E6	E6	Ferrochromium slag	Material resulting from ferrochromium production. Slag product processing starts from melt phase.

Group	Source	EN 16907-2 Group	Group	Subnumber (CEN/TS 17438)	Specific material	Definition
F	Foundry industry	AM	F1	F1	Foundry sand	Material obtained in iron, steel and malleable iron foundries as well as in non-ferrous foundries during core making, preparation of moulding material and after casting and shake out of the moulds.
			F2	F2	Foundry cupola furnace slag	Material resulting from operation of a cupola furnace in iron foundries.
G	Mining and quarry industry	AN	G1	G1	Red coal shale Burnt colliery spoil after burning	Material resulting from uncontrolled burning of colliery spoil on tips of bituminous coal.
			G2	G2	Refuse from hard coal mining (black coal shale). Unburnt colliery spoil from hard coal mining.	Material from black coal shale (black minestone).
			G3	G3	Pre-selected all-in from quarry/mining	Material from the quarry or the mining industry which has processed mechanically. It includes quarry spoils.
			G4	G4	Spent oil shale	Material resulting from oil shale processing by heating under poorly oxidizing conditions to extract the oil.



Group	Source	EN 16907-2 Group	Group	Subnumber (CEN/TS 17438)	Specific material	Definition
H	Excavated natural materials	AN	H1a		Tunnel arisings from hard rocks traditional method	Coarse material excavated by blasting in hard rock by the traditional method (e.g. NATM – New Austrian tunnelling method).
			H1b		Tunnel arisings from hard rocks with TBM	Material excavated with a Tunnel Boring Machine in a hard rock.
			H1c		Tunnel arising from soft material Slurry shield	Material excavated with a slurry shield TBM.
			H1d		Tunnel arising from soft material Earth pressure	Material excavated with a TBM with earth pressure balance (EPB).
			H2a	H1	Dredge spoil - fine	Fine material excavated in lakes, dams, ports or rivers exhibiting a very moisture content and very low bearing capacity even after stockpiling.
			H2b	H1	Dredge spoil - coarse	Sandy or gravelly material excavated in lakes, dams, ports or rivers with permeability high enough to allow departure of free water after stockpiling.
			H3		Processed reclaimed natural soil	Material resulting from a screening or treatment process which leaves a residue of natural soils.
I	Other combustion residues	AM	I1	I1	Paper sludge ash	Material resulting from the incineration of paper sludge (from deinking process).
			I2	I2	Sewage sludge incineration ash (municipal)	Material resulting from the incineration of sewage sludge (mostly communal sludge) by a fluidised bed process.
			I3	I3	Biomass ash	Material resulting from the incineration of biomass.
			I4		Oil shale ash	Material resulting from incineration of oil shale.

Group	Source	EN 16907-2 Group	Group	Subnumber (CEN/TS 17438)	Specific material	Definition
J	Miscellaneous	AM	J1	I4	Crushed glass	Material resulting from the crushing of old glass products e.g., bottles.
			J2		Cement and lime kiln dust	Old tips of dust collected from the flue gas stream of cement or lime calcining operations
			J3a		Shredded tyres	Shreds resulting from mechanical process of tyres.
			J3b		Tyre bales	Processed tyres to get boxes.
			J4		FGD artificial gypsum	Material resulting from the desulphurisation process of coal-fired power plants.
			J5		Industrial artificial gypsum	Industrial gypsum is a by-product from industrial process. It contains mainly hydrated CaSO ₄ plus Fe and Ti oxides.
			J6		Marginal materials (local experience)	These alternative materials are meet very locally and are not part of this guide. They encompass e.g. China clay, peat ashes.
NOTE Shaded materials are without material sheet.						
^a Requirements on MIBA are based on experience with grated installations.						
^b Bottom ash can include as a small component 'boiler ash'.						

6 Incorporation of new source materials

A request for the incorporation of new source materials into this document will be considered when this request is made by at least one of the CEN members and the request is based on the actual routine application of material from this new source.

The request is formally taken into consideration by CEN/TC 396 after evaluation and recommendation of WG 7.

Basic information on the following items is provided as an input for the request (Table 3).

Table 3 — Information requested for new source materials

Subject	General information to be given by applicant
CEN Member	From one or more CEN Members
Definition	Clear description of the source material
Field of application(s)	Applicable CEN/TC 396 standard(s)
Technical information	Material characteristics and end use information
Experience/quantity/demonstration	Existing applications, not only laboratory experience
Criteria used to control the quality of material	Factory production control, national regulation(s) or private assessment
Additional requirements necessary to consider	

7 General technical perspective

Utilization of alternative materials ranks among the fundamental tasks of the developed world. The use of alternative materials in earthworks helps to protect the environment and reduces the need to use natural resources. Earthworks using alternative materials reduces the carbon footprint of construction and makes a significant contribution to the circular economy.

The use of alternative materials in earthworks is subject to the fulfilment of the same technical requirements as for natural materials, to achieve the design requirements of bearing capacity, serviceability, constructability and durability for earthworks. Geotechnical and technical requirements are defined in the earthwork project.

In earthworks, only such materials that have been suitability verified and fulfil the project requirements are used. In case of non-homogenous materials their usability according to the design are verified based on laboratory and full-scale trials or in situ testing.

Regarding the possible significant variability of properties and behaviour inside each class of alternative materials due to the non-homogeneous composition, the project design specifies the conditions under which their use is allowed. When using alternative materials in an earthwork project it defines the following items:

- description of the alternative material to be used;
- technology of their processing;
- mechanical/engineering properties (given by intrinsic and state properties);
- environmental properties;

- durability of mechanical properties (e.g. volume stability, etc.);
- quality control, including frequency of tests.

Achievement of designed parameters is supported by laboratory tests with respect to real conditions in earth construction and verified by relevant testing.

Most relevant physical, chemical and mechanical properties of alternative materials potentially utilized in earthworks are presented for each class material in material sheets (see Clause 11). More information concerning characteristics, testing and utilization of alternative materials in several countries (Czech Republic, France, Germany, United Kingdom) are presented in Annexes B to E. Apart from national specifications, the principal testing needs and evaluation schemes are provided in EN 16907-2.

8 General environmental perspective

8.1 Introduction

The use of alternative materials in earthworks is an important contribution to the European circular economy policy, aiming to increase resource efficiency in the field of building operations and contribute to the sustainability of construction. Following the principles of the circular flow economy, transport journeys can be minimized, CO₂ emissions reduced, and destructive land use downsized.

The use of materials in earthworks, either from natural or alternative origin, needs to take into account and manage potential impacts on environment and health, to ensure a safe use of the material. This part describes the main issues to consider in order to guarantee environmental performance consistent with the use of the material, in the same way as technical performances are required for building construction of earthworks.

NOTE This document does not deal with the Waste Framework Directive or the material's legal status in the different Member States.

8.2 General approach for environmental assessment

Management of the potential environmental impacts of materials – natural or alternative – for earthworks is based on a general risk assessment approach, to determine if the characteristics of the material are compatible with the conditions of use and with the sensitivity of the environment where the earthworks are to be constructed.

The potential environmental impacts which are considered for earthworks are either in the short-term, or in the long term:

- Short term environmental impacts in conjunction with the application of the materials:
 - The potential contamination during application (wind transport of fine particles or leaching during temporary storage before the final application);
 - The potential risks to working security, e.g. because of dust emissions;
- Long-term environmental impacts due to the use of the materials:
 - The potential contamination of ground (which is next to, under or over the application area) through short or long-term leaching or transfer of chemical substances with rainwater, flooding or wind transportation;
 - The potential contamination of water (ground water, surface water) either directly or after leaching and transfer of chemical substances with rainwater or through flooding.

Finally, when answering the question as to whether a material can be used for earthworks (or not), two main issues are taken into consideration:

- The evaluation of environmental properties of the material used (see subclause 8.3.1);
- The exposure scenario and conditions of use, considering environmental sensitivity of the area (protection areas, ground water vs. industrial areas) and the type of application.

8.3 Relevant aspects to be considered for environmental assessment

8.3.1 Environmental properties of the material used

Different approaches exist in national regulations to determine or estimate the environmental properties, or the material used:

- Determination of the total content of relevant chemical substances,
- Determination of the leachable amount of chemical substances by
 - simple and short batch compliance leaching tests (e.g. liquid/solid ratio 1:2 or 1:10), or
 - more complex and longer leaching tests (percolation test, pH-stat test),
- Evaluation in selected media: ecotoxicity-tests (daphnia, water plants, algae),
- Pilot scale/Full-scale experiments/trials.

For all these approaches, the sampling strategy used has very high importance, aiming at delivering representative samples for the (normally high amount of) material used. As a first approach, the sampling method can follow the procedure described in EN 932-1. Two main sampling strategies can be distinguished:

- Batch sampling: a specific amount of material is sampled and analysed, the quality for the specific mass of material can be determined;
- Continuous sampling: samples are taken at fixed intervals, either after a certain mass of material or after a certain time. The tested material is homogeneous during these intervals.

The main issues for some classes of alternative materials can be the homogeneity. Materials resulting from controlled industrial processes tend to have a good homogeneity, in this case continuous testing can be sufficient. Materials resulting from recycling process (especially construction and demolition waste, excavation material, tunnel arisings) can be very non-homogeneous, therefore batch sampling can be the most suitable method.

8.3.2 Site specific risk evaluation and conditions of use

The environmental sensitivity of the area, where earthworks are being undertaken, is one important factor which is taken into consideration when alternative materials are proposed. Different sensitive areas/targets can be identified and considered from the environmental perspective:

- water protection areas,
- groundwater,
- areas with contact to surface waters,
- areas subject to flooding,

- nature protection areas,
- areas with active agricultural production (plants, livestock farming).

Therefore, environmental properties of materials used in earthworks are considered and are evaluated to ensure compatibility in these (vertical and horizontal) sensitive areas.

Another key factor is the exposure to run-off rainwater, which can cause emissions of substances and transport these emissions to distant areas or water bodies (ground water, soil, surface water). The exposure can be different if the material is used under a non-permeable layer (for example, asphalt layers in road construction or under building constructions, etc.) or open to run-off rainwater (for example, dam construction, road shoulders, etc.).

NOTE The above-mentioned principles are finally set in national regulations.

9 Design testing and construction control

9.1 Testing philosophy

9.1.1 General

Like natural materials, alternative materials can be used in the construction of earth structures, provided they comply with the specification in place for the intended use. In all cases, they meet the following requirements:

- Provisions of the national legislation about the environment, health and safety, and storage, handling and transport of construction products;
- Physical and chemical properties of the materials for short and long-term stability and service conditions of the earth structure.

The selection of tests to be undertaken will be linked to the proposed use of the materials, their anticipated behaviour and the environmental regulations at the place of the use.

Testing of the materials will fall into two categories:

- geotechnical and
- chemical/environmental.

Parameters and intensity of testing vary in relation to the risks associated with the material used, the homogeneity of the material in relation to geotechnical and chemical properties and the site where the material will be placed. The proposed testing is in compliance with national regulations and practice.

9.1.2 Geotechnical testing in advance of construction

Geotechnical testing is carried out in order to determine the short-term and long-term characteristics of the materials.

The choice of geotechnical tests would be the same as for a natural soil and include for sufficient tests in order to accurately represent the behaviour of the material (some specific tests are in material sheets).

CEN Standards, where applicable, are used for the geotechnical testing of alternative materials.

9.1.3 Chemical testing in advance of construction

In addition to the geotechnical testing, chemical testing is undertaken to determine if there is a potential risk to the environment through the use of an alternative material.

The choice of chemical tests is made in relation to the potential risks associated with the alternative material and any identified risks associated with the intended location of use. Reference is made to Clause 7 for different approaches and methods to determine the risks to the environment.

The duration of the chemical testing is considered, particularly for leachate testing as the leachate levels will normally change over time.

CEN Standards, where applicable, are used for the chemical testing of alternative materials.

9.2 Control during construction

Geotechnical and chemical compliance testing, where applicable, is carried out during construction to ensure the material used is in accordance with the project specification. The choice and frequency of testing are specified in the project. Their specification could be based on the client requirements, on a risk assessment and considers the nature and intended use of the alternative materials.

Compliance testing, where applicable, allows for the potential variable nature of alternative materials. Compliance testing could also be used to assess the variance of the material from that tested in advance of construction.

All test locations are recorded in both horizontal and vertical position and each test give a unique reference.

European Standards, where applicable, are used.

10 Health and safety

10.1 General

There are both European and national legal frameworks relating to Health and Safety, and these are followed as applicable to the country of work. This section gives current best practice guidance to aid the management of risk to operatives and others.

The use of alternative materials in earthworks requires that operators working with them have adequate personal protection. The type of personal protection required will depend on the classification and risk assessment for the material being used. Typical personal protection equipment could include dust masks, overalls, gloves, goggles, etc.

10.2 Dust emissions

One of the biggest potential risks to Health and Safety is from airborne dust during earthworks operations.

Water bowsers or similar equipment are used to keep surfaces damp where vehicles will traffic the earthworks to reduce the risk of dust, particularly in environmentally sensitive and urban areas.

10.3 Runoff water and leachate

Runoff water and leachate can lead to potential health and safety issues both on the site and offsite. Precautions, if necessary, are taken to avoid any leachate or run off from of the site. This is normally in the form of cut off ditches and silt tanks/water treatment depending on the risk of the material being used.

11 Material sheets

11.1 General

Material sheets contain basic information on individual alternative materials that are used in earthworks, including:

- material definition;
- description of the material;
- typical applications in earthworks;
- specific technical properties – chemical, mineralogical, physico-mechanical;
- specific environmental properties;
- considerations during construction;
- long-term considerations;
- recommended specific tests;
- overview of countries that use the material;
- case studies.

Typical applications were adopted from other EN 16907 series standards:

- **capping layer**

Specific transition layer, part of the upper zone of the fill, placed below the superstructure. The capping layer is part of the earth structure (EN 16907-1:2018, 3.1.4).

- **fill**

Collective term used in EN 16907-1 to describe all earth-structures formed by the placement of fill material in a controlled manner for an engineering purpose (including embankment, infill, platform, etc.) (EN 16907-1:2018, 3.1.24). The fill can be divided into the following zones. The tables in this document for typical use only refer to fill rather than any sub division:

- **base**

Fill zone in direct contact with the existing ground. This zone can be divided into layers, e.g. for drainage, working platform, impervious protection layer. It includes replacement of existing foundation ground to some depth or improvement of existing ground by binders or installation of geosynthetics (EN 16907-1:2018, 6.2.2.2).

- **core**

Fill zone located between any base layers and the upper zone (where the embankment is of sufficient height). The core can be protected from water or isolated to limit pollution of the environment (EN 16907-1:2018, 6.2.2.2).

- **shoulders (side zones)**

Lateral zones of fills. These zones can have various functions, e.g. enable steeper slopes, protect the core, serve as filters, protect from erosion (EN 16907-1:2018, 6.2.2.2).

- **upper zone**

Zone located between the core and the superstructure (pavement, track). This zone can comprise different layers such as the "upper part of fill", the "capping layer", a "transition layer" to separate rock fill from the upper granular layers, an impermeable layer, or another layer with a particular function. It does not include the superstructure layers (EN 16907-1:2018, 6.2.2.2).

- **transition zones**

Embankments can comprise different types of transition zones: longitudinal transitions for half cut/half fill sections, transitions from embankments to cuts, transitions from embankment to structures, interactions with other earth-structures replacing usual lateral slopes, interactions with culverts or other structures crossing the embankment core (EN 16907-1:2018, 6.4.3).

- **hydraulic fill**

Material placed in a liquid form, as a mixture of soil particles and water, in a deliberate manner so that the soil particles accumulate as a deposit and densify as further fill is placed above to create a body of fill (EN 16907-1:2018, 3.1.29).

- **stabilized fill, stabilized capping layer**

Fill material or material in capping layer stabilized with binders (lime and/or hydraulic binders) according to EN 16907-4.

- **working platform**

Working platforms are temporary earth-structures made up of granular fill or stabilized material, typically between 300 mm to 800 mm thick, that provide a suitable foundation for heavy construction plant and machinery to carry out operations (e.g. piling).

- **drainage layer**

Drainage layer receives the excess water from the substrate and vegetation layer and transfers it to the installed drainage system to prevent waterlogging.

- **trench fill**

Material putting into a trench after excavation is complete.

It is stressed that for some groups of materials (CCP, slags, recycled materials) there are separate specifications in some countries, as these materials have long been used in earthworks. On the other hand, the requirements for specific tests vary from country to country. An overview of national regulations is given in Annexes B to E.

It is also noted that only representatives 9 CEN Member States sent questionnaire replies on the use of individual materials and therefore the information on practical experience is incomplete.

Case studies have been simplified to web links as possible.

Material sheets can be continuously updated based on documents supplied by representatives of individual CEN Members.

The material sheets are given in 11.2 to 11.11.

11.2 A group – recycled and demolition materials

Code: A2	Name: Crushed concrete							
Definition	Material resulting from processing concrete.							
Description	Concrete that has been reclaimed from either a site clearance or demolition scheme. The material has normally been crushed and possibly screened.							
Typical use in earthworks	fill, capping layer, working platforms, drainage layers, trench filling							
General properties								
Chemical: mainly composed of oxides predominating in rocks forming aggregate in concrete (usually SiO ₂ , Al ₂ O ₃), and cement (CSH gels).								
Mineralogical: minerals forming original rocks forming aggregate in concrete (quartz, feldspars, plagioclases, pyroxenes, amphiboles, carbonates, etc.) and minerals created during cement hardening.								
Environmental: Depending on the source of the reclaimed concrete there is the possibility of intrinsic content of contaminants (e.g. Cr, pH) and contamination from the materials it has been in contact with (e.g. asbestos).								
Physical: Processed by crushing, sieving, and proportioning.								
Parameter			Unit		Typical value			
particle density			kg.m ⁻³		2 200-2 600			
bulk density			kg.m ⁻³		1 900-2 200			
LA coefficient			%		20-45			
Earthwork specific properties								
Parameter			Unit		Typical value			
maximum dry density (MDD) (Standard Proctor), for 0/32 fraction			kg.m ⁻³		1 900-2 100			
optimum moisture (OMC) (Standard Proctor), for max. 0/32 fraction			%		4-10			
Considerations before and during construction								
No additional considerations compared to natural materials.								
Details regarding initial and control tests see in national specifications.								
Technical and environmental regulations in the place of use are considered.								
For use in environmental sensitive areas (e.g. drinking water area) technical measures can be considered. In other areas standard environmental tests are needed (see national specifications).								
Long term considerations								
There have not been observed any embankment damages caused by suitable processed crushed concrete as fill or capping layers so far. Depending on the strength of the original material the material can break down over time with trafficking (e.g. temporary platforms).								
Recommended specific tests								
Sulphate content – for material in contact with reinforced concrete.								
Experiences in European countries								
Austria	Czech Republic	Germany	Finland	France	Slovenia	Sweden	Spain	United-Kingdom
x	x	x	x	x	x	x	x	x
References (not fully completed)								
Crushed concrete is widely used in earthworks.								
French experience								
Guide d'utilisation en travaux publics Rhône Alpes – Graves de recyclage. Version 2 – 2005.								
Guide d'utilisation des matériaux lorrains en technique routière - Les matériaux de démolition. Février 2010. CFTR – CETE Est.								
Utilisation en technique routière des graves recyclés issues de la déconstruction. 2019. Novabuild.								
https://ofrir2.ifsttar.fr/fileadmin/contributeurs/OFRIR2/pdf/categories-materiaux/dechets-du-BTP/BETON_Vsite2014.pdf								

Code: A3	Name: Reclaimed bricks, masonry							
Definition	Material resulting from processing demolition brick work and masonry.							
Description	Bricks and masonry that have been reclaimed from either a site clearance or demolition scheme. The material has normally been crushed and possibly screened.							
Typical use in earthworks	fill, working platforms							
General properties								
Chemical: mainly composed of oxides predominating in original bricks and masonry (usually SiO ₂ , Al ₂ O ₃ , less Fe ₂ O ₃ and CaO)								
Mineralogical: minerals forming bricks and masonry (quartz, products of clay firing - mullite, cristobalite, metakaoline).								
Environmental: Depending on the source of the reclaimed concrete there is the possibility of intrinsic content of contaminants (e.g. V), and contamination from the materials it has been in contact with (e.g. plaster).								
Physical: Processed by crushing, sieving, and proportioning.								
Parameter			Unit		Value			
particle density			kg.m ⁻³		1 700-2 200			
bulk density			kg.m ⁻³		1 600-1 900			
LA coefficient			%		project related			
Earthwork specific properties								
Parameter			Unit		Value			
maximum dry density (MDD) (Standard Proctor), for 0/32 fraction			kg.m ⁻³		1 500-1 900			
optimum moisture (OMC) (Standard Proctor), for max. 0/32 fraction			%		4-10			
Considerations during construction								
No additional considerations compared to natural materials.								
Details regarding initial and control tests see in national specifications.								
Technical and environmental regulations in the place of use are considered.								
For use in environmental sensitive areas (e.g. drinking water area) technical measures can be considered. In other areas standard environmental tests are needed (see national specifications).								
Long term considerations								
There have not been observed any embankment damages caused by suitable processed bricks and masonry as fill so far. There can occur some problems with degradation of reclaimed bricks by water (e.g. temporary platforms).								
Recommended specific tests								
Sulphate content – for material in contact with reinforced concrete.								
Experiences in European countries								
Austria	Czech Republic	Germany	Finland	France	Slovenia	Sweden	Spain	United-Kingdom
x	x	x						X
References (not fully completed)								
Czech experience is summarized in [1], used mainly as temporary fill.								
British experience is summarized in [3], used mainly as temporary fill.								

Code: A4	Name: Hydraulically bound and unbound materials							
Definition	Recycled material resulting from processing hydraulically bound and unbound materials.							
Description	This material represents old construction layers both hydraulically bound and unbound that are processed mainly by crushing and sieving.							
Typical use in earthworks	fill, capping layer, drainage layers							
General properties								
Chemical: mainly composed of oxides predominating in original rocks forming unbound layers (usually SiO ₂ , Al ₂ O ₃), and binders (CaO) or soils treated by binders.								
Mineralogical: minerals forming original rocks forming unbound layers (quartz, feldspars, plagioclases, pyroxenes, amphiboles, carbonates, etc.) and minerals created during treatment by binders.								
Environmental: depending on composition of original rocks (unbound layers), secondary contamination during operation before old layers processing is possible.								
Physical: Processed by crushing, sieving, and proportioning.								
Parameter			Unit		Value			
particle density			kg.m ⁻³		1 800-2 200			
bulk density			kg.m ⁻³		1 500-2 000			
LA coefficient			%		project related			
Earthwork specific properties								
Parameter			Unit		Value			
maximum dry density (MDD) (Standard Proctor), for 0/32 fraction			kg.m ⁻³		1 700-1 900			
optimum moisture (OMC) (Standard Proctor), for max. 0/32 fraction			%		4-10			
Considerations during construction								
No additional considerations compared to natural materials.								
Details regarding initial and control tests see in national specifications.								
Technical and environmental regulations in the place of use are considered.								
For use in environmental sensitive areas (e.g. drinking water area) technical measures can be considered. In other areas standard environmental tests are needed (see national specifications).								
Long term considerations								
There have not been observed any embankment damages caused by suitable processed hydraulically bound and unbound materials as fill or capping layers so far.								
Recommended specific tests								
There are not any specific tests for using of hydraulically bound and unbound materials in earthworks.								
Experiences in European countries								
Austria	Czech Republic	Germany	Finland	France	Slovenia	Sweden	Spain	United-Kingdom
x	x	x		x				X
References (not fully completed)								
Hydraulically bound and unbound materials are widely re-used after their processing in earthworks during reconstructions of roads or motorways.								

Code: A5	Name: Mix of A1, A2, A3, A4							
Definition	Material resulting from processing a mix of bituminous layers and/or concrete and/or demolition brick work and masonry.							
Description	Material that has been reclaimed from either a site clearance or demolition scheme of buildings, civil structures, and/or bituminous layers.							
Typical use in earthworks	fill, capping layer, temporary platforms							
General properties Granular material can include concrete, bricks, natural aggregates, ceramic, and in minor content glass, metal, asphalt, and another type of material. Its properties can vary due to the inhomogeneity of the origin of materials and the process to obtain them. Can be susceptible to reduction in size and strength over time due to direct trafficking.								
Environmental Depending on the origin and demolition process, the material can contain a high amount of gypsum that could be resulted in high sulphate leaching. There is a possibility of migration of material with an elevated pH if the reclaimed material has a high fines content. Depending on the source of the reclaimed masonry there is the possibility of intrinsic contamination and contamination from the materials it has been in contact with. It is, therefore, necessary to test the material against recognized waste acceptance criteria to assess an environmental and personnel risk in using the materials. Physical: Processed by crushing, sieving, and proportioning.								
Parameter			Unit		Typical value			
particle density			kg.m ⁻³		*			
bulk density			kg.m ⁻³		*			
LA coefficient			%		*			
Earthwork specific properties								
Parameter			Unit		Typical value			
maximum dry density (MDD) (Standard Proctor), for 0/32 fraction			kg.m ⁻³		*			
optimum moisture (OMC) (Standard Proctor), for max. 0/32 fraction			%		*			
* Parameters are in a wide range and always they are project related.								
Considerations during construction The potential for dust from the material is considered. If the fines content or amount of ceramic and gypsum in the material is high, then the water content needs to be monitored (they increase the water absorption, a pre-soaking is recommended). Organic material is removed.								
Long term considerations Depending on the strength of the original material the material can break down over time. The amount of ceramic, gypsum and other materials ("X" in EN 933-11) can decrease the bearing capacity.								
Recommended specific tests The material geotechnical characterization is obtained by EN 13242. Components are classified and quantified by EN 933-11. Leaching test is performed to assure the not affection to the environment.								
Experiences in European countries								
Austria	Czech Republic	Germany	Finland	France	Slovenia	Sweden	Spain	United-Kingdom
x	x			x	x		x	X

References (not fully completed)

Spanish experience

[Obras de tierra y terraplenes | CEDEX \(cedexmateriales.es\)](https://www.euskadi.eus/contenidos/documentacion/aridos/es_doc/adjuntos/manual_aridos.pdf)

https://www.euskadi.eus/contenidos/documentacion/aridos/es_doc/adjuntos/manual_aridos.pdf

<https://federacionrcd.org/wp-content/uploads/Buenas-pr%C3%A1cticas-en-el-uso-de-materiales-reciclados-en-obra-civil-en-el-Pa%C3%ADs-Vasco-IHOBE-Febr.19.pdf>

<http://193.145.71.12/index.php/ingenieria-civil/article/view/2420/1979>

French experience

Guide d'utilisation en travaux publics Rhône Alpes – Graves de recyclage. Version 2 – 2005.

Guide d'utilisation des matériaux lorrains en technique routière - Les matériaux de démolition. Février 2010. 7CFTR – CETE Est.

Utilisation en technique routière des graves recycles issues de la déconstruction. 2019. Novabuild.

https://ofrir2.ifsttar.fr/fileadmin/contributeurs/OFRIR2/pdf/categories-materiaux/dechets-du-BTP/BETON_Vsite2014.pdf

www.afoco.org

Code: A6	Name: Reclaimed railway ballast							
Definition	Material resulting from recycling of railway ballast.							
Description	This material is composed of spoiled railway ballast (crushed rock), with grain size distribution of sand to gravels.							
Typical use in earthworks	fill, capping layers, drainage layers							
General properties								
Chemical: mainly composed of oxides predominating in original rocks (usually SiO ₂ , Al ₂ O ₃ , Fe ₂ O ₃ , CaO).								
Mineralogical: minerals forming original rocks (quartz, feldspars, plagioclases, micas, pyroxenes, amphiboles etc.).								
Environmental: depending on the source (place in railway track) of the reclaimed railway ballast there is the possibility of secondary content of contaminants (e.g. hydrocarbons).								
Physical: coarse particles (e.g. fraction 31,5/63 or 25/50) spoiled more or less by fines.								
Parameter			Unit		Typical value			
particle density			kg.m ⁻³		2 000-2 500			
bulk density			kg.m ⁻³		1 900-2 100			
LA coefficient (individual coarse particles)			%		20-45			
Earthwork specific properties								
Parameter			Unit		Typical value			
maximum dry density (MDD) (Standard Proctor), for 0/32 fraction			kg.m ⁻³		1 900-2 100			
optimum moisture (OMC) (Standard Proctor), for max. 0/32 fraction			%		4-10			
Considerations during construction								
Reclaimed railway ballast is suitable as fill.								
Using in capping layer depends on fine particles content and frost susceptibility of material (see national specifications).								
Details regarding initial and control tests see in national specifications.								
Technical and environmental regulations in the place of use are considered.								
For use in environmental sensitive areas (e.g. drinking water area) technical measures can be considered. In other areas standard environmental tests are needed (see national specifications).								
Leaching of heavy metals and other pollutants (hydrocarbons) contained in railway ballast before reclamation is mandatory.								
Long term considerations								
There have not been observed any embankment damages caused by suitable reclaimed railway ballast as fill so far.								
Recommended specific tests								
Leaching of heavy metals and other pollutants contained in railway ballast before reclamation – details in national specifications.								
Herbicides agents – see national specifications.								
Experiences in European countries								
Austria	Czech Republic	Germany	Finland	France	Slovenia	Sweden	Spain	United-Kingdom
x	x	x	x	x				x
References (not fully completed)								
French experience								
International project “Circular practices in the railway and ways forward – REUSE Project” from UIC Sustainability– June 2021 (www.uic.org)								
Czech experience is summarized in [1].								

11.3 B group - municipal solid waste incineration materials

Code: B1	Name: Municipal incinerator bottom ash
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Definition	Material resulting from processing bottom ash following the incineration of Municipal Solid Waste (domestic and commercial) by a moving grate or fluidised bed or gasification process. Today also referred to as MIBA (Municipal Incinerator Bottom Ash).	
Description	Granular material which can include glass, metal, ceramic and other not combustible and inert material. Its properties can vary due to the inhomogeneity of the origin of materials and process to obtain them.	
Typical use in earthworks	fill, stabilized fill or stabilized capping layer	
General properties		
Chemical: mainly composed of SiO ₂ , CaO ₂ , NaO ₂ and a small amount of Al ₂ O ₃ and Fe ₂ O ₃ . Also contains MgO, K ₂ O and P ₂ O ₅ (< 2% by weight). The material suffers chemical reactions of maturation during the first three months (hydration, salt formation, sulphate reactions, etc.); pH 7 – 11.		
Mineralogical: Their pozzolanic activity depends on the combustion process to obtain them.		
Environmental: The presence of a relatively high salt content and trace metal concentrations, including such elements as Pb, Cd, and Zn, in municipal waste (compared with conventional aggregate materials) has raised concerns in recent years regarding the environmental acceptability of using ash as an aggregate substitute material.		
Physical: It has a continuous grain distribution with low fine sizes. The fine size is enriched in metals. Particles are irregular and porous. The material is very water sensitive.		
Parameter	Unit	Value
Density (EN 1097-6)	kg/m ⁻³	2 400 – 2 680
Particle density		
Saturated Surface Dry (SSD)		
Oven dry (OD)		
Absorption	%	5,7 - 14
LOI	%	2-10
Earthwork specific properties		
Parameter	Unit	Value
Standard Proctor (MDD)	kg/m ⁻³	1 520 – 1 580
Modified Proctor (MDD)	kg/m ⁻³	1 580 – 1 760
CBR	%	21 - 103
DLA	%	40 – 42
Considerations during construction		
Details regarding initial and control tests see in national specifications.		
Technical and environmental regulations in the place of use are considered.		
For use in environmental sensitive areas (e.g. drinking water area) technical measures can be considered.		
Long term considerations		
Recommended specific tests		
Volumetric stability – swelling in CBR mould (see EN 13286-47), details in national specifications.		
Loss of ignition – see EN 196-1 (under 950 °C).		
Leaching test – see EN 12457-4.		

Experiences in European countries								
Austria	Czech Republic	Germany	Finland	France	Slovenia	Sweden	Spain	United-Kingdom
exp.	exp.	x		x		x	exp.	X
References (not fully completed)								
German experience https://www.emvau-schlacke.com/products/references/ https://www.remex.de/en/business-areas/secondary-aggregate-production/incinerator-bottom-ash-aggregates/ French experience Chambéry - Fin de l'aménagement du nœud autoroutier A43/A41 (savoie-news.fr) Guides techniques régionaux relatifs à la valorisation des déchets et co-produits industriels. 2011 – CETE Nord Pas de Calais et Mines de Douai. Matériaux alternatifs en infrastructures Grave de Mâchefer. Guide Normandie. 2019 – FRTP Normandie Finland: guide to use MIBA : https://www.uusiomaarakentaminen.fi/sites/default/files/K%C3%A4sitellyn%20yhdyskuntaj%C3%A4tteen%20pohjakuona%20k%C3%A4ytt%C3%B6%20infrarakentamisessa%2C%20ohjeistuksen%20k%C3%A4sikirjoitusluonnos%20koek%C3%A4ytt%C3%B6%2031.3.2022.pdf								