Information documents

NATURAL GEOLOGICAL MATERIALS EXCAVATED DURING UNDERGROUND WORKS

Specificities, management scenarios and the role of the actors

In collaboration with the Cerema

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Natural geological materials excavated during underground works

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FOREWORD

This information document is intended for project owners in order to help them implement an approach for the management of natural geological materials excavated during underground work (e.g. tunnel or utility shaft boring, the construction of a cut and cover tunnel, an underground station), from the initial design phases (definition[1]) up to the work phase. This document sets out the responsibilities of the project owner. The scenarios for management of the materials proposed in this document take account of the regulations in force, the content of various planning documents as well as voluntary commitments from professionals.

The goals are to preserve natural resources, mitigate the impact of transporting materials, through local utilisations and propose solutions for the reuse and recovery of excavated materials[2].

This document addresses the following points:

- the specificities of excavated materials according to the geological nature of the rocks and terrain encountered and the excavation method used;
- the scenarios for management of excavated materials, described and analysed in light of the responsibilities of each actor involved and related administrative procedures;
- the main uses and routes depending on the nature of the excavated materials;
- the role of the actors involved throughout the project (be they road or rail projects).

This document does not deal with the impact of excavated materials in terms of the potential risks to the safety, health and protection of workers. Similarly, soils identified as polluted are not concerned by the recommendations set out in this information document.

1. See Chapter 5.1.
2. For the sake of simplification, excavated materials will refer to the natural geological materials excavated during underground works.

1

INTRODUCTION

Future major transport infrastructure projects include long underground constructions and developments such as tunnels, cut-and-cover tunnels, underground railway stations, cavities and technical networks. Going underground overcomes topographical problems, preserves the lifestyle on the surface and the continuity of green and blue belts. In addition, when space is at a premium, especially in urban areas, an alternative is provided with the surface being returned for other uses.

These infrastructure and development projects are also of crucial importance in terms of the territory and mobility. As a result, they generate significant volumes of excavated materials. Estimated volumes on a few major projects currently under way are as follows:

- **the Grand Paris Express:** 205 km of subway line and 69 stations most of which are underground giving rise to 20 million m^3 of excavated materials;
- **the Lyon-Turin rail line:** 16 million m^3 generated by boring the base tunnel (57 km long) and 19 million m^3 for underground constructions for the French part between Lyon and Modane (86 km total length);
- **the new Provence Cote d'Azur line** including the planned underground train station in Marseille: some versions of this project indicate 60 km of tunnels for a total length of approximately 180 km, i.e. one third of the line will be underground generating some 15 million m^3;
- **the Lyon Part-Dieu underground train station:** 600,000 m^3 of muck excluding access tunnels.

These volumes of excavated materials are out of all proportion to those that were processed in the past and they no longer allow a balance to be struck between muck and backfill. In addition, the urban nature of some projects further restricts this opportunity.

The use of excavated materials during underground boring and construction work enables resources to be preserved, the impact of transportation to be mitigated through local utilisations and alternative solutions to be proposed.

This approach is in line with the Act No. 2015-992 of 17 August 2015 on the energy transition for green growth, which complements in particular article L. 110-1-1 of the Environmental Code as follows: "The transition to a circular economy aims to go beyond the linear economic model that consists of extracting, producing, consuming then discarding by calling for more sober and responsible consumption of natural resources and primary raw materials as well as, in order of priority, the prevention of waste production, in particular by re-using products, and, depending on the hierarchy of waste processing methods, re-utilising, recycling or, failing this, recovering waste."

It is the responsibility of underground project owners to manage excavated materials, in accordance with regulations, including the Environmental Code [1] and those parts of it relating to waste, ICPE[3] (classified facilities for protection of the environment) and IOTA[4] (classified facilities with respect to water legislation), as well as the City Planning Code [2]. For this reason, it is in the interest of, and incumbent on, project owners to establish a policy to handle excavated materials and to formally set down their requirements in terms of re-use and recovery of these materials.

In order to help them in this, an approach to managing excavated materials is proposed in this document, from the project definition and design phases right up to completion of the works. It incorporates a gradual increase in the level of knowledge about the nature of the materials as the work progresses [4] as well as the constraints related to construction site organisation. This approach also considers the data on the local economic fabric by identifying uses and defining the appropriate routes for excavated materials.

Project owners must also address management of excavated materials from the economic perspective, taking the local market price of aggregates into account. The local market price for aggregates along with transport and final storage costs are decisive elements in assessing the relevance of excavated material management scenarios.

3. Facilities classified for environmental protection.
4. Facilities, structures, works and activities.

2

SPECIFICITIES OF MATERIALS EXCAVATED DURING UNDERGROUND WORKS

The nature and characteristics of materials excavated during underground works obviously vary and depend on the geological context and the excavation method used. These elements have a direct impact on the possibilities of subsequently using the excavated materials.

In order to estimate the volumes of materials to be managed, to identify their nature and assess their initial characteristics when boring, a diagnosis must be performed by the project owner right from the project definition studies stage and then in greater detail in the design studies phase (see chapter 5).

2.1 THE INFLUENCE OF THE GEOLOGICAL CONTEXT

The nature, mechanical properties and physical and chemical characteristics of the geological terrains crossed are a fundamental parameter in defining management scenarios for excavated materials.

The diagnosis is established based on bibliographic data (for example: geological map, InfoTerre[5] database, previous investigations from works in the vicinity and geological, hydro-geological, and geotechnical investigations carried out in the framework of the project (geological land surveys, exploratory borings, etc.).

Certain types of materials may be difficult (or even impossible) to use on a public works site, particularly in the presence of asbestos, carboniferous shale, gypsum or anhydrite (not forgetting that gypsum and anhydrite are industrial minerals that can be used elsewhere).

Contamination (polluted soils) related to a human activity may also be encountered within the surface layers. Land identified as polluted a result of these investigations is not concerned by the recommendations in this information document.

In the case of a site likely to be polluted, a specific soil investigation will be carried out in accordance with the recommendations in the ministerial memorandum of 8 February 2007 and its appendices[6] [5] [6]. A historical study and diagnosis of the site will help identify and locate the pollution, determine the impact of pollutants on the environment and human health and implement a plan to manage contaminated materials (proposed preventive and/or soil management measures, drafting of a costs/benefit assessment and choice of handling measures).

2.2 THE INFLUENCE OF THE EXCAVATION METHOD

The excavation method used can also change the recovery potential of excavated materials. It may result in the use of these materials being subject to a treatment that could change the cost/benefit ratio from both an economic and environmental perspective.

Boring methods are usually divided into two categories:
- so-called «mechanised» tunnelling (hard rock TBM, Open face lining segment TBM, earth pressure balance TBM, slurry pressure balance TBM, etc.);
- the conventional method (drill and blast and/or using roadheader machines).

The choice of method depends on the geological nature of the terrain encountered. Table 1 shows the field of application of the different boring methods in schematic form.

This choice also depends on the length of the structure to be built. Indeed, a TBM will usually be economically viable on long structures (over 3,000 m) whereas the conventional method is usually more competitive for short works (less than 1,000 m), with both solutions being in competition within the 1,000 to 3,000 m range. For some projects, several excavation methods are implemented simultaneously over the length of the structure.

5. http://infoterre.brgm.fr/
6. Information is available on http://www.developpement-durable.gouv.fr

<table>
<tr><th></th><th colspan="4">Soft ground</th><th colspan="2">Rocky ground</th></tr>
<tr><th></th><th>Gravel</th><th>Sands</th><th>Silts</th><th>Clays</th><th>Soft</th><th>Hard</th></tr>
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<tr><td colspan="2">Slurry pressure balance TBM</td><td colspan="4"></td></tr>
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Table 1: Fields of application of the main excavation methods – Source: CETU

In the case of mechanised tunnelling, depending on the type of TBM used and its technical characteristics (design of the cutterhead and layout of disc cutters), the shape and size of aggregates obtained may vary, but they will be smaller and flatter than those obtained from conventional methods.

Gripper tunnel boring machines (or “hard rock” tunnel boring machines) are used in rock masses having good mechanical characteristics. The particle size obtained is generally less than 150 mm. No drilling additive is used. The shape of the aggregates is flatter than that obtained from blasting.

The materials excavated from earth pressure balance tunnelling are mainly clays, silts and sands, possibly with decimetre blocks. These materials are dry to saturated with water. They may contain foams and polymers injected into the excavation chamber during the work. The particle size obtained at output from the TBM is generally less than 40 mm.

With a slurry pressure balance TBM, excavated materials are mainly silts, sands and gravel. These materials may contain traces of bentonite (clay) injected at the excavation face, and recovered in the slurry treatment plant (see Figure 1).

The water content of the excavated materials varies. The presence of a crusher in the excavation chamber limits the particle size of excavated materials. It is generally less than 100 mm.

The muck from excavation by a roadheader varies considerably in nature (fine soils, grained soils and/or pluri-decimetre blocks). The size of the largest blocks will be conditioned by the excavation tool used. These materials can be dry to saturated with water. They do not contain additives.

In the case of blasting, the particle size obtained is in general less than 600 mm and depends on the spacing between blast holes in the blast pattern. Residues of unburned explosives and other chemical substances (in particular nitrates) may be present in the excavated materials [7]. The aggregates can also present significant microcracking.

The impact of any additives used on subsequent use of the excavated materials must be assessed depending on the excavation procedures and type of additives applied. It must be noted that treatments can facilitate this later use, such as separating bentonite slurry from aggregate material.

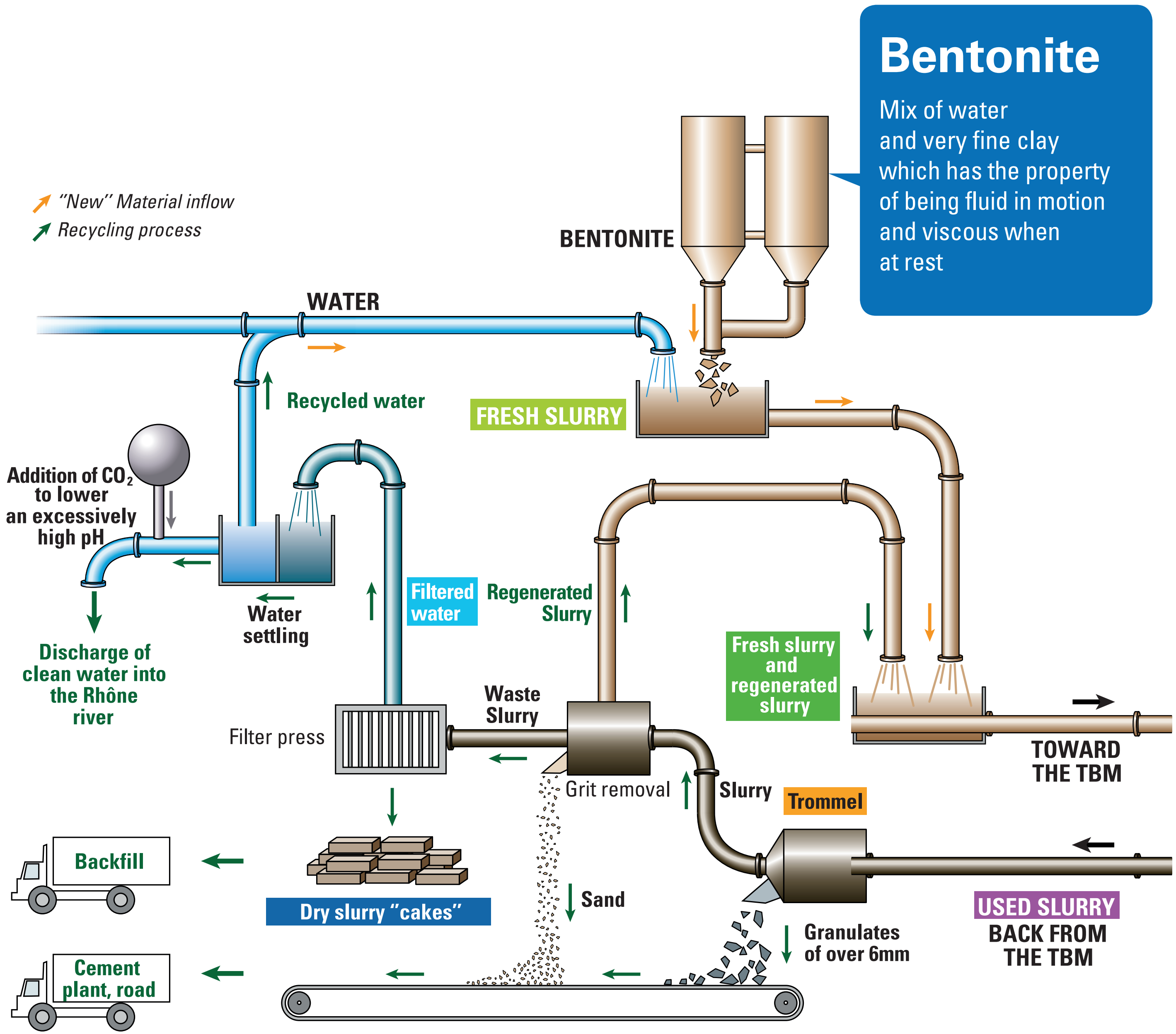


Figure 1: Used slurry treatment plant (slurry pressure balance TBM) – Source: Sytral – Egis

3

SCENARIOS FOR MANAGEMENT OF EXCAVATED MATERIALS

Following the diagnosis referred to in Chapter 2, three material management scenarios can be distinguished:

1. the site is short of material, the excavated materials are used on the extraction site if their characteristics so permit;
2. the excavated materials are used on another part of the same operation[7], with this operation under the control of the same project owner;
3. the project owner has no use for the excavated materials.

The project owner may resort to a combination of these scenarios depending on the material properties, needs and uses.

Treatments can be used to modify the characteristics of the materials to meet use requirements (for example, the bearing capacity may be improved by adding a hydraulic binder).

In the following paragraphs, each scenario is detailed, in particular in terms of:

- the responsibility of the project owner for managing the excavated materials;
- the administrative formalities concerning the methods used to treat the materials;
- the uses.

3.1 SCENARIO DEFINITIONS

3.1.1 Scenario 1: the project owner uses the excavated materials as part of the construction project

Figure 2 details movements of materials from their extraction to their use on the site.

To build the underground structure underground and its surrounding area, the project owner needs materials with specific characteristics for a predefined use. Some of the excavated materials can be used for this purpose.

In this case, the materials that are excavated from the underground works and used on the work site are not considered as waste[8]. In the event of a change of project owner during the operation, the new project owner takes on all the prerogatives and responsibilities of the previous project owner.

Any treatment of materials will be performed on the same site they are extracted from or on a dedicated site related or not to the extraction site. This treatment may be prior to or followed by temporary storage.

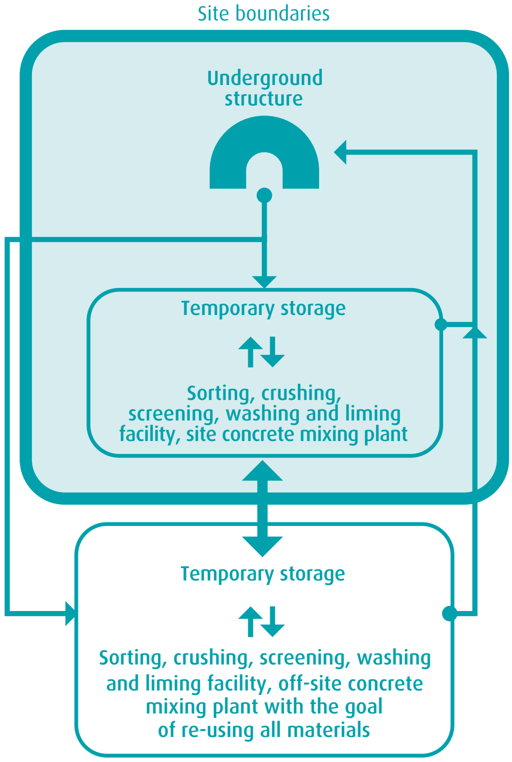


Figure 2: Movements of materials for use on the same site

7. By operation we mean all the work which is concerned by the declaration of public utility.
8. Article L.541-1-1 of the Environmental Code defines waste as "any substance or object, or more generally any movable goods, which the holder discards or which he/she intends or is obliged to discard".

Treatment on the construction site

In this case, the materials are treated and used on the site they are extracted from. The project owner may itself perform the treatment activities or the said activities may be entrusted to a third party.

Depending on the thresholds set in the ICPE or IOTA sections, the operator must file the administrative records concerning the activities with the Prefecture. The content of the files must be in conformity with regulations in force at the time of filing. After the submissions are processed, a declaration receipt or a prefectoral order setting out the conditions for admission of the materials will be issued by the prefect. Drawing up and submitting the filing for ICPE or IOTA purposes, must be anticipated taking account of the processing time required and depending on whether the filing comes under the authorisation, registration (in the case of ICPE only) or declaration regimes.

Times required to process administrative files (ICPE and IOTA):

- authorisation file for ICPE purposes: the entire file processing procedure takes on average 10 to 12 months between the date when a complete file that complies with regulations is deemed to have been submitted and the date the prefectoral order is signed (Articles R. 512-13 to R. 512-26 of the Environmental Code);
- registration file for ICPE purposes: at most 5 months from the date when a complete file that complies with regulations is received. The prefect may extend this time limit by 2 months, by a justified order (Article R. 512-46-18 of the Environmental Code);
- declaration file for ICPE purposes: 1 to 2 months (Articles R. 512-51 to R. 512-52 of the Environmental Code);
- authorisation file for IOTA purposes: 12 months (articles R. 214-9 to R. 214-9 of the Environmental Code) and up to 23 months;
- declaration file for IOTA purposes: 2 months at most if the file is complete and complies with regulations (articles R. 214-32 to R. 214-40 of the Environmental Code).

Note that the operation and transit sites must also be compatible with urban planning documents.

For transit facilities in which the materials are pending treatment, a prior declaration or a development permit will be filed with the local authorities depending on the surface area and deposit height set in Articles R. 421-18 to 421-23 of the City Planning Code [2].

The thresholds governing ground raising according to the City Planning Code:

- The thresholds to obtain a development permit for ground raising operations are:
  - a surface area ≥ 2 hectares and a height > 2 meters (article R. 421-19 k of the City Planning Code);
  - a surface area ≥ 100 m² and a height > 2 meters in the case of a facility established in a protected sector, a classified site (or in the process of being classified) or a nature reserve (article R. 421-20 paragraph 3 of the City Planning Code).
- The thresholds to make a prior declaration for ground raising operations are:
  - 100 m² ≤ surface area < 2 hectares and height > 2 meters (article R. 421-23 f of the City Planning Code).

In accordance with Article 2 of the order of December 12th 2014[9], temporary storage facilities are not final storage facilities if the storage duration is less than 3 years before the materials are recovered or 1 year prior to final disposal. The two types of storage (temporary and final) come under two separate ICPE sections.

If the operator of the transit facility is not the project owner of the site, a contractual document will be established with the owner of the site specifying in particular the maximum storage duration, the subsequent destination of the materials and the conditions for redevelopment of the site at the end of the project.

Treatment on a dedicated site

In this case, the excavated materials are treated on a dedicated site that may or may not be adjacent to the original project site. They are then brought back and used on the same site.

A third party (for example the operator of a nearby quarry) may perform the treatment operations (grinding, crushing, sorting, etc.) on behalf of the project owner. In this case, it may be considered that the project owner does not intend to discard the materials because the project owner will retrieve all materials back on the site they came from. A contractual document between the project owner and the third party will be established so the project owner can ensure that:

- inbound and outbound materials at the treatment plant comply with the conditions set down by the prefectoral orders;
- the materials returned after treatment will comply with the requirements for the uses identified;
- the materials from the underground works will not be mixed with other materials from the facilities.

9. Order of December 12th 2014 on general requirements applicable to facilities coming under the registration regime concerned by section No. 2760 of the nomenclature of classified facilities for the protection of the environment (ICPE).

The third party and the project owner will draw up procedures for the traceability of the materials with monitoring and controls. In this case, the excavated materials do not have the status of waste. However, any treatment residues or any material that does not return to the site takes on the status of waste (see Scenario 3).

The special case of asbestos-bearing soils:
If the works generate asbestos-bearing soils, management of these soils must be integrated right from the design phase. The INRS guide [8] recommends using the materials on site backfill, if the mechanical characteristics permit. The materials are covered with an earth material over a thickness of at least 50 cm in which vegetation will be planted. A warning grid may be placed between the material containing asbestos and the topsoil. The figure below shows an example of how the asbestos-bearing material may be backfilled.

If the materials do not meet the mechanical criteria requested, they may be directed to a facility for the storage of non-hazardous waste.

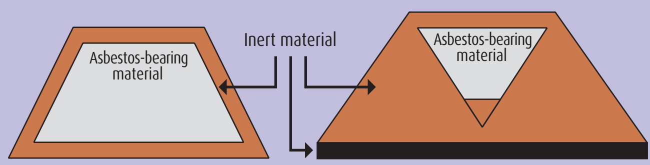


Figure 3: Example of the backfilling of asbestos-bearing material - source: INRS guide, 2013 [8]

3.1.2 Scenario 2: The project owner uses the excavated materials for a work site that is part of the same operation and for which it is project owner

In this case, the materials are used on another site of the same operation that is short of materials. The excavated materials are treated on a platform on site or off site before being used.

Figure 4 details movements of materials from their extraction to their use.

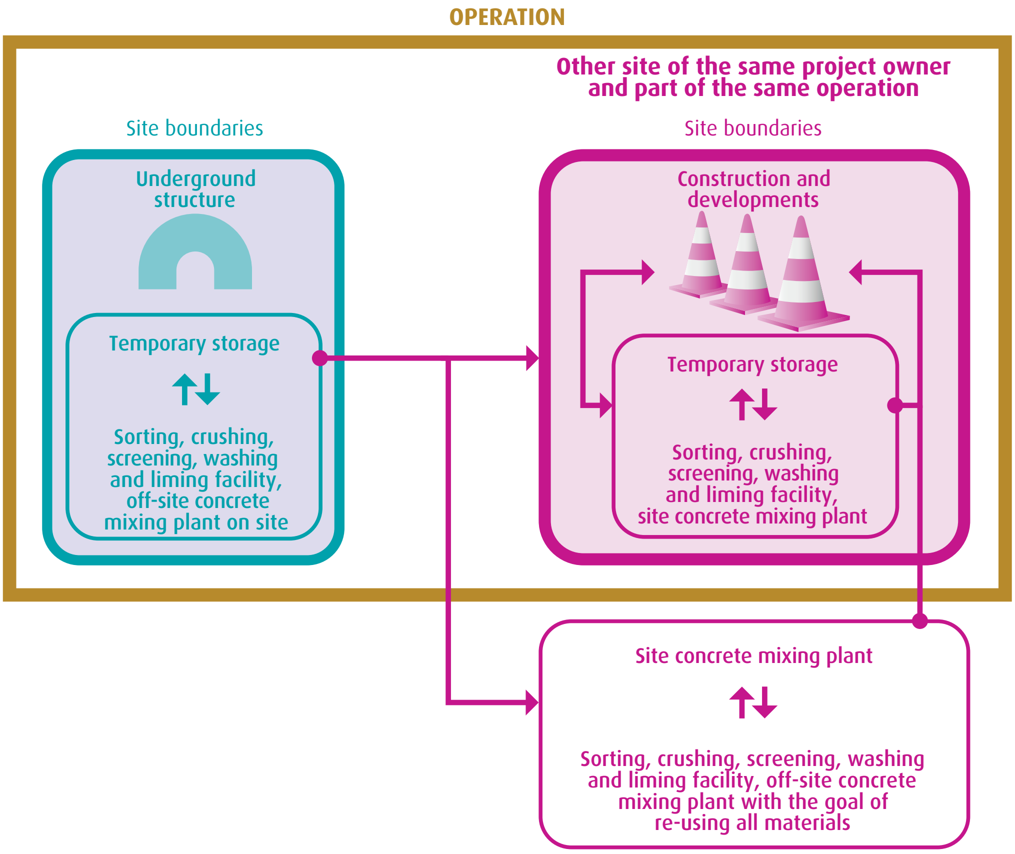


Figure 4: Movements of materials for use on a site belonging to the same project owner as the underground work and that is part of the same operation

In the case of treatment on a dedicated site, a contractual document will be drawn up between the project owner and the third party in charge of treating the materials, in order in particular to ensure traceability of the materials.

The project owner must apply the same requirements as for scenario 1.

It must ensure that:

- inbound and outbound materials at the treatment plant comply with the conditions set down by the prefectoral orders;
- the materials returned after treatment will comply with the requirements for the uses identified;
- the materials from the underground works will not be mixed with other materials from the facilities.

In this case, the excavated materials do not have the status of waste.

Notion of by-product

Article L. 541-4-2 of the Environmental Code defines the concept of a by-product: "A substance or object, resulting from a production process, the primary aim of which is not the production of this substance or object may only be considered to be a by-product and not waste, as defined under article L. 541-1-1 if all the following conditions are met:

- the subsequent use of the substance or object is certain;
- the substance or object can be used directly without additional treatment other than commonplace industrial practices;
- the substance or object is produced as an integral part of a production process;
- the substance or object meets all requirements relating to the products, the environment and the protection of health set down for products that will be subsequently used;
- the substance or object will not have any overall harmful impacts on the environment or human health.

Waste treatment operations do not constitute a production process as defined under this article."

The notion of by-product is specified in the communication from the European Commission No. 2007/59 of 21 February 2007 on the interpretative communication on waste and by-products [32].

3.1.3 Scenario 3: The project owner has no use for the excavated materials in the construction project

Figure 5 details movements of materials from their extraction to their recovery or disposal.

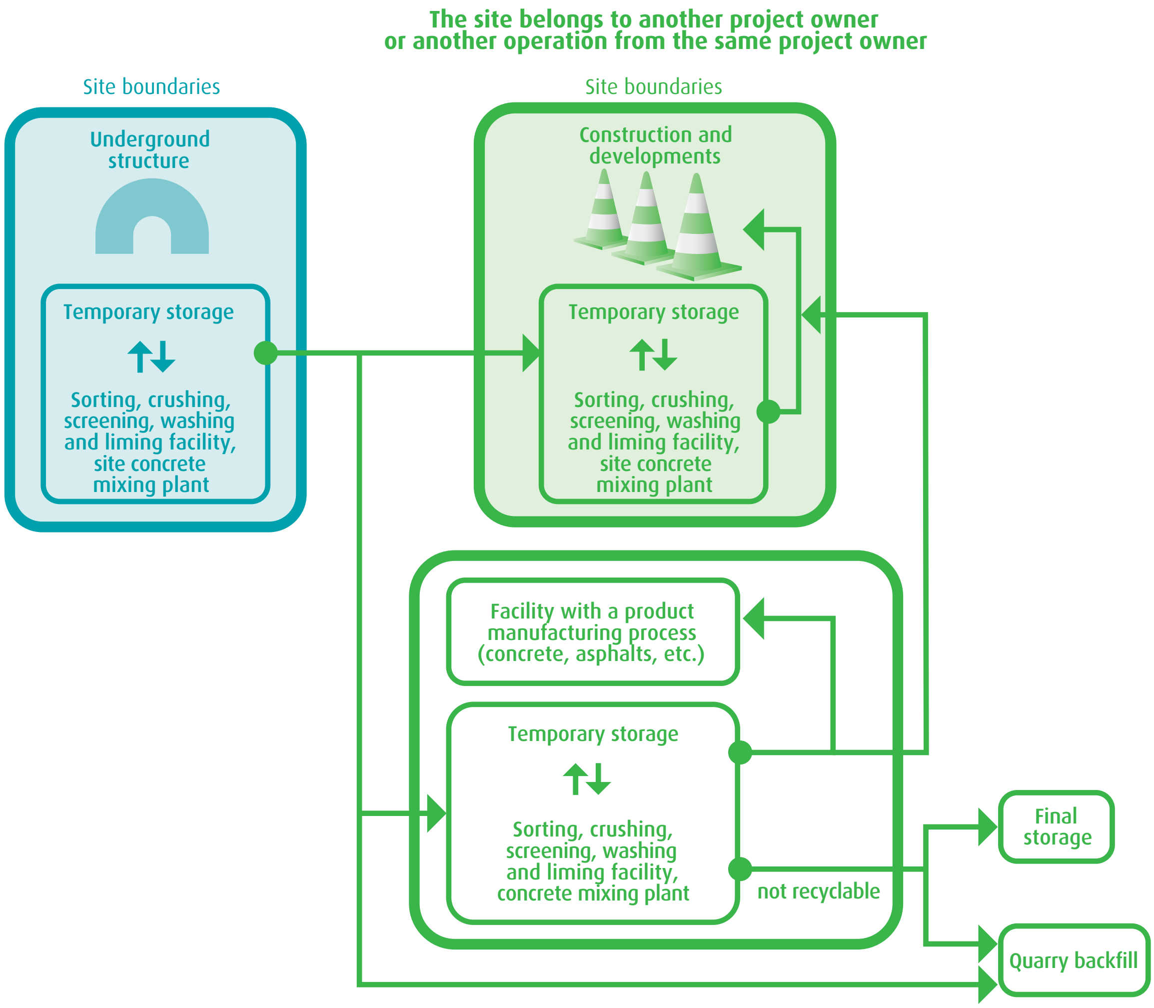


Figure 5: Movements of materials when the project owner wishes to discard the materials

The underground project owner wishes to discard the materials which then take on waste status. The project owner remains responsible (art. L.541-2 of the Environmental Code) for these materials until their disposal or final recovery unless the materials come out of an ICPE classified facility or an IOTA classified facility in the conditions laid down by the end of waste order (art. L.541-4.3 of the Environmental Code).

The project owner must ensure that the material complies with the conditions for admission to the transit facilities (temporary storage), for recovery and disposal, and that traceability is maintained. In particular the project owner must fill out and retrieve waste tracking documents.

3.2 CHOICE OF THE SCENARIO(S)

The choice of management scenario(s) will depend on the characteristics and treatment potential of excavated materials. It will also depend on the conditions for admission to the facilities and the planned uses. For ICPE and IOTA classified facilities, admission conditions are indicated in the corresponding regulations and prefectoral orders.

In line with treatment method priorities (article L. 541-1 of the Environmental Code), the project owner will focus on preventive measures in the area of waste production and the use of the excavated materials on its sites (scenarios 1 and 2), followed by the recovery of the waste for other uses, and as a last resort, if no recovery solution is possible, it will direct the materials towards disposal routes. It will also draw on the guidelines set out in planning documents (for example, the regional quarries plan and the regional waste prevention and management plan).

Still in accordance with article L. 541-1 of the Environmental Code, the project owner will organise the transport of waste by limiting it as much as possible in terms of distance and volume.

The choice of scenario(s) can also be influenced by a more detailed analysis, the main aspects of which are set out in the recommendations of AFTES working group No. 35 [4], as well as through a life cycle analysis (LCA) of the structure, some components of which will be described in the forthcoming recommendations from the AFTES working group No. 41 [10].

The different scenarios will be examined taking into account:

- treatment of the materials (for example, crushing, liming);
- complementary studies to be carried out (for example, physical and chemical analyses of the materials);
- transport between each transit facility and treatment;
- land acquisitions (for example for temporary storage of the materials);
- the savings of resources resulting from the re-use and recovery of excavated materials.

Figure 6 summarises the 3 scenarios for the management of materials excavated during underground works.

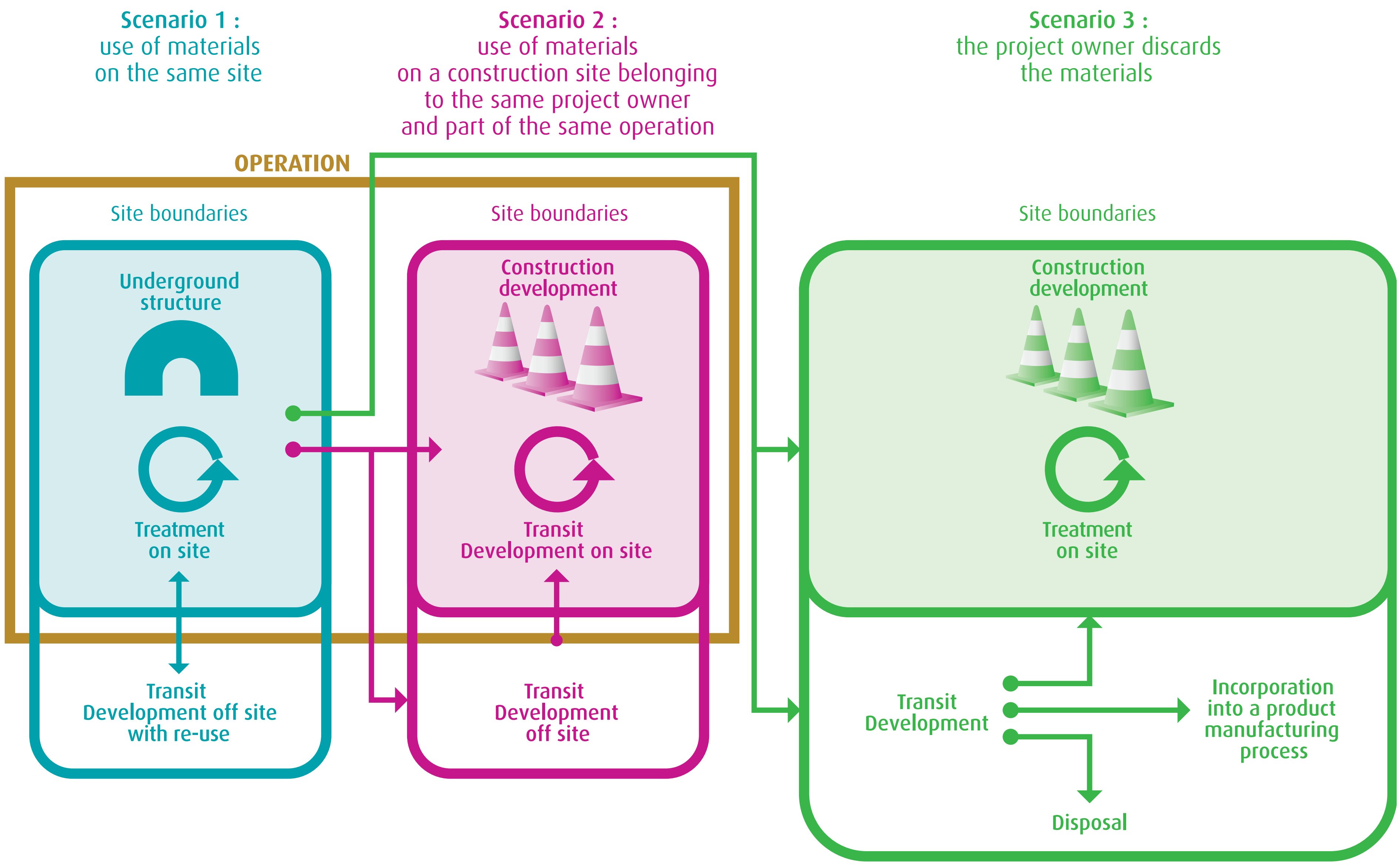


Figure 6 : Scenarios for management of materials excavated during underground works

4 MAIN USES AND ROUTES FOR EXCAVATED MATERIALS

As for any other natural mineral resource, there are numerous potential uses of excavated materials. However, certain uses will be chosen above others based on how the site is organised (temporary storage area, pace of extraction, etc.), transportation, existing treatment routes, regulatory and standards-based aspects as well as the costs incurred.

It must be noted that excavated materials containing materials that are hazardous to the environment or human health will be treated in accordance with regulations in force.

In practice, the project owner will analyse the different possible uses for the excavated materials, which may involve various routes, with these different routes involving various facilities (ICPE, IOTA, classified facilities etc.).

4.1 MAIN USES

The physical, mechanical and environmental characteristics depend on the geological nature of the terrain encountered and the excavation method used. These characteristics enable possible uses to be identified along with any treatments necessary. The following paragraphs summarise the main uses in the knowledge that several of them must be examined taking account of operational implementation feasibility and the significant volumes involved.

The main uses that stand out are those related to the development of linear infrastructures, the production of hydraulic concretes and mortars, landscaping (ground raising) and quarry backfill.

Factors linked to the development of linear infrastructures

Depending on their mechanical properties, the materials can be used in backfill, subgrade courses, pavement base courses, landscaping, or noise barriers. Depending on their use, the materials are classified in accordance with the reference standards. How they are applied is described in technical guides and information notes.

Standard and technical guides for uses related to linear infrastructure projects

Depending on their origin and how they are prepared for a given application, these materials must meet standards requirements and the way they are implemented is described in technical guides:

- Trench backfill
  - Standards NF P 98-331 [N1], XP P 98-333 [N2], NF P 11-300 [N3]
  - Setra/LCPC guides [15] [16] [17] [18], Setra [19], Information note No. 22 from Idrrim [20]
- Backfill and subgrade courses
  - Standard NF P 11-300 [N3], NF EN 14475 [N4]
  - Setra/LCPC Guides [11] [15] [16], Setra [21] [22] [23], Information note No. 22 from Idrrim [20]
- Pavement structure courses
  - Standards NF EN 13285 [N5], NF EN 13242+A1 [N6], NF EN 14227-1 [N7], NF EN 14227-5 [N8], NF P 18-545 [N9]
  - Setra Guide [23], LCPC/CERTU guide [24], information notes No.s 22 and 24 from Idrrim [20] [25], UNPG Aide-memoire [26]
- Surface courses (wearing and binder courses)
  - Standards NF P 18-545 [N9], NF EN 13043 [N10], NF EN 13108-1 [N11], 13108-8 [N12], 13108-20 [N13]
  - Setra Guide [23], information note No. 24 from Idrrim [25]
- Road concretes
  - NF P 18-545 [N9], NF EN 12620+A1 [N14], NF EN 206/CN [N15], NF EN 13877-1 [N16]
  - Information note No. 24 from Idrrim [25]
- Urban pavements
  - NF P 98-335 [N17]
- Bicycle lanes
  - Certu guide and recommendations for bicycle lane developments [27]

These documents describe in particular the tests to be performed to determine their intrinsic and manufacturing characteristics and their mechanical, physical and chemical behaviour, so as to define their geotechnical classification and areas of use. Specific treatments may be carried out to improve the performance of these materials, in particular by adding a certain percentage of lime and/or a hydraulic binder [11] [12] [13] [14] and/or of a hydrocarbon binder.

All these applications are therefore based on geotechnical data to be specified at the same time as the geological and geotechnical profile of the underground structure is specified.

Production of concretes and hydraulic mortars

The re-use and recovery of excavated materials in concretes and hydraulic mortars as aggregates is possible, subject to certain characterisation tests and treatments (crushing, screening, washing, etc.). They mainly concern rocky materials and can be facilitated by adapting the concrete specifications (a finer definition of exposure classes for example). In addition, the implementation of the Standard NF EN 206/CN [N15] and in particular of the performance-based approach should facilitate a wider use of the excavated materials as concrete aggregates.

One of the key steps lies in identifying the mineralogical nature of the excavated materials and in assessing their possible incompatibility with a use in cement matrix materials. The excavated materials must then be characterized from a physical and chemical perspective in accordance with the standards NF EN 12620+A1 [N14], NF EN 13139 [N18] and NF P 18-545 [N9], so they can be positioned in relation to conventional materials.

Characterization of extracted materials for use in hydraulic concretes

In accordance with standards NF EN 12620+A1 [N14], NF EN 13139 [N18] and NF P 18-545 [N9], the main characterisation tests to be carried out on extracted materials are the following:

- on the raw rock:
  - radioactive element content (for safety)
  - chlorine content (risk of reinforcement corrosion)
  - alkaline content (parameter involved in several pathologies)
  - sulphate content (risk of internal sulphate attack)
  - sulphur content (risk of internal sulphate attack)
  - reactivity as regards the alkali reaction (risk of alkali–aggregate reaction)
  - mass density (use to be examined if non-current value, see NF EN 13055 [N19])
  - petrographic analysis
- after preparation (crushing, screening, possible washing):
  - water absorption coefficient (impact on the formulation of the concrete)
  - Los Angeles test (aggregate resistance)
  - fines content (impact on the formulation of the concrete)
  - particle size analysis (impact on the formulation of the concrete)
  - cleanliness (impact on the formulation of the concrete)
  - liability to frost damage (if applicable)

In the specific context of underground constructions, special attention must be paid to the materials likely to contain sulphur (sulphate, anhydrite, sulphides, pyrite, etc.) and materials potentially reactive with respect to the alkali reaction. It is therefore essential to carry out in-depth geological investigations on the deposits and to ensure that the samples taken are representative of the quality of the excavated materials. Attention is drawn to the fact efficient quality monitoring, enabling stocks to be identified and characterised and the different operations to be traced, is of paramount importance for correct usage of the excavated materials.

In civil engineering in France, concrete production usually involves recommending concretes with properties specified properties in the standard NF EN 206/CN [N15]. In this case, the prescriber is responsible for defining the exposure classes to which the concrete will be submitted and the performances to be achieved, with the producer being responsible for the formulation and achieving these performances.

Conformity of the concretes with the standard NF EN 206/CN [N15] requires, among other things, conformity of ingredients with standards in force. When the excavated materials do not enable aggregates consistent with the regulatory and standards framework to be obtained, it is necessary to define the nature of the risk incurred with respect to the dispensatory parameter(s) identified. A specific study, including an assessment of this risk, must then be undertaken by the project owner at a sufficiently upstream stage in the project. It must integrate the variability of the dispensatory parameter(s) by setting limits and enable specific prescriptions to be complied with, where appropriate, through a performance-based approach. The project owner may then specify concretes based on a performance approach and/or propose a concrete composition in its contract in a way similar to a specified composition concrete. Everything should be done to maintain the regulatory and standards framework usually provided (NF EN-206/ CN [N15], Fascicle 65 of the general technical specifications for works [33]) for the other components, self-checks and delivery dockets in particular. An adapted control plan must be implemented for the dispensatory property(ies), in the knowledge that another solution must be considered and provided for in the contract if the properties of the materials are not within the limits examined and set beforehand.

Landscaping (ground raising)

Under certain conditions, the materials may be used for landscaping purposes (notably ground raising). For this, it will be necessary to establish the utility of the ground raising itself, as well as the usefulness of the materials employed.

Thus, article L. 541-32 of the Environmental Code specifies that "any person recovering waste for landscaping, rehabilitation or construction works must be in a position to justify to the appropriate authorities the nature of the waste used and the use of this waste for recovery purposes and not for disposal purposes. In the framework of these works, landfill and dumping of waste are prohibited on agricultural lands, with the exception of recovery of waste for the purposes of landscaping works or the recovery of waste authorised to be used as a fertiliser material or crop supports."

Quarry backfill

Quarry backfill is a waste recovery operation (article L. 541-1-1 of the Environmental Code).

Depending on the admission requirements indicated in the prefectoral orders for working quarries, excavated materials may be accepted partially or in full by these facilities.

4.2 MATERIAL MANAGEMENT ROUTES

The main routes accepting excavated materials in line with the uses identified in Chapter 4.1, are the following:

- the production of aggregate materials for use in civil engineering;
- the manufacture of building products;
- backfill for working quarries.

In addition to these routes, materials can be disposed of in waste storage facilities.

These routes may involve establishing facilities that may be submitted to ICPE, IOTA or City Planning Code regulations. These facilities require administrative formalities that must be anticipated and taken on by the project owner. These formalities can be outsourced to a third party under the responsibility of the project owner.

The operator of the facilities may be the project owner or a third party. If the project owner transfers the materials to a third party, the project owner must ensure that the materials meet the facility admission requirements.

The main facilities are grouped in tables 2 to 6, although this list is not exhaustive.

Preliminary note on temporary storage

Material management may result in the project owner placing the excavated materials in temporary storage. Administrative formalities under the Environmental Code are listed in Table 2. Temporary storage concerns most routes discussed below.

	Title	Regulatory references	Admission conditions
Temporary storage	Transit facility for mineral products or non-hazardous inert waste	Section 2517 of ICPE classified facilities	Natural geological materials that contain no hazardous substance (excluding topsoil, peat, soil and stones from contaminated sites, as well as materials with a dryness level of less than 30%) can enter the facility without any prior acceptance formalities and without chemical analyses[10]
	Transit facilities, grouping or sorting of non-inert non-hazardous waste	Section 2716 of ICPE classified facilities	A prefectoral order for the facilities sets down admission conditions

Table 2: Nature of facilities for the temporary storage of excavated materials and ICPE sections that may apply to them

10. Order of December 12th 2014 on conditions for the admission of inert waste into facilities coming under sections 2515, 2516, 2517 and into inert waste storage facilities coming under section 2760 of the nomenclature of classified facilities.

Production of aggregate materials for use in civil engineering

Table 3 lists the specific sections of regulations for classified facilities that may apply where aggregate materials are produced.

Route	Title	Regulatory references	Admission conditions
Production of aggregate materials	Facilities for grinding, crushing, screening, bagging, spraying, cleaning, sifting and mixing of rocks, stones, ore and other natural or artificial mineral products or non-hazardous inert waste	Section 2515 of ICPE classified facilities	Natural geological materials that contain no hazardous substance (excluding topsoil, peat, soil and stones from contaminated sites, as well as materials with a dryness level of less than 30%) can enter the facility without any prior acceptance formalities and without chemical analyses
	Permanent or temporary withdrawals from an aquifer system resulting from a borehole, shaft or underground structure, excluding water tables accompanying watercourses, by pumping, draining, by-passing or any other method	Section 1.1.2.0 of IOTA classified facilities	
	With the exception of withdrawals under an agreement with the entity in charge of the flow, as provided for in article L. 214-9, withdrawals and facilities and structures that enable withdrawals, including by-passing, from a watercourse, from its accompanying water table or from a body of water or a canal supplied by this watercourse or this water table	Section 1.2.1.0 of IOTA classified facilities	
	Discharge to shallow freshwater likely to change the status of the water	Section 2.2.1.0 of IOTA classified facilities	

Table 3: Nature of the excavated material treatment facilities for the production of aggregates and ICPE/IOTA sections that may apply to them

The manufacture of construction materials

Table 4 sets out the facilities that can manufacture construction products. In general, these facilities are operated by a third party.

Route	Title	Regulatory references	Admission conditions
Manufacture of construction products	Facility for the manufacture of concrete products using mechanical processes	Section 2522 of ICPE classified facilities	The materials must comply with the aggregates standards (NF P 18-545 [N9], NF EN 12-620+A1 [N14]), NF EN 13139 [N18]) The materials must comply with specifications and performance levels for use as concrete aggregates according to the standard NF EN 206/CN [N15]) or a specific formulation and tests will be carried out depending on the use
	Ready to use concrete production facilities, equipped with a mechanised hydraulic binder supply system, excluding the facilities covered by section 2522	Section 2518 of ICPE classified facilities	
	Manufacture of cements, lime, plasters	Section 2520 of ICPE classified facilities	
	Manufacture of refractory and ceramic products	Section 2523 of ICPE classified facilities	
	Asphalt concrete facility for road products	Section 2521 of ICPE classified facilities	

Table 4: Nature of the excavated material treatment facilities when the materials are to be used to manufacture construction products and sections of ICPE that may apply to them

Quarry backfill

Table 5 shows the facility that can be used for quarry backfill. In general, this type of installation is operated by an aggregates producer.

Route	Title	Regulatory references	Admission conditions
Materials recovery	Quarry backfill	Prefectoral order for the facility	Ask for the facility's prefectoral order to check admission conditions

Table 5: Nature of the facility accepting excavated materials from underground structures

Disposal in a waste storage facility

Table 6 sets out waste storage facilities. Natural geological materials, encoded in waste section No. 17 05 04 (soil and stones that contain no hazardous substance) can enter inert waste storage facilities without chemical analyses (see order of December 12th 2014[11]).

Route	Title	Regulatory references	Admission conditions
Disposal	Inert waste storage facilities	Section 2760 -3 of ICPE classified facilities	Natural geological materials containing no dangerous substance (and the dryness level of which is greater than 30%) may enter the facility without any prior acceptance procedure and without chemical analyses
	Facilities for the storage of non-hazardous waste	Section 2760 -2 of ICPE classified facilities	Ask for the facility's prefectoral order to check admission conditions

Table 6: Nature of excavated material storage facilities when the materials are to be disposed of and sections of ICPE regulations that may apply to them

11. Order of 12 December 2014 on conditions for the admission of inert waste into facilities coming under sections 2515, 2516, 2517 and into inert waste storage facilities coming under section 2760 of the nomenclature of classified facilities

5 ROLE OF THE ACTORS

At each stage in the project, management of excavated materials will be taken into account. The policy by which these materials are managed must be implemented by the project owner. For this purpose, the project owner may be assisted by a project owner assistant during definition studies and hire a project supervisor for design studies and the works themselves. Figure 7 shows the classic steps in an underground works project.

5.1 DEFINITION STUDIES

Definition studies are carried out before the public inquiry and include opportunity studies or prior functional studies and studies prior to the public inquiry.

Based on geological investigations and existing documents on the project terrain (for example, by consulting databases, planning documents on waste prevention and management or the regional quarries plan), the project owner will establish, either itself or with the help of an assistant, a compilation of the knowledge on the excavated materials and possible uses.

The aim is to notably assess the nature, quality and quantity of the materials, in light of:

- initial geological and geotechnical cross-sections describing the intrinsic properties of the materials;
- the interaction between the proposed excavation method and its impact on the quality of the excavated materials (shape of the materials, particle size, physical and chemical characteristics and mechanical characteristics, as well as their water content);
- to identify possible uses, a report will be drawn up of uses made of materials of the same type in the project region.

AFTES working group No. 35 [4] specifies in detail the technical approach to be implemented to obtain the characterisation and the tests to be performed on the materials.

The project owner will also identify the quantities and qualities of materials generated during site preparation work (for example, excavation of access roads and the construction platform).

The project owner will locate the soils likely to be polluted and which must undergo a characterisation process in line with the national policy for managing polluted soils (see chapter 2.1).

The project owner will also determine needs for materials from the site depending on the uses.

A (quantitative and qualitative) critical analysis of the reliability of the data will be made in order to come to a summary and interpretation of this data with margins of uncertainty clearly explained. The summary will take account of the project phasing timetable. Planning documents, including regional quarries plans and regional waste prevention and management plans, will have to take the data from this analysis into account.

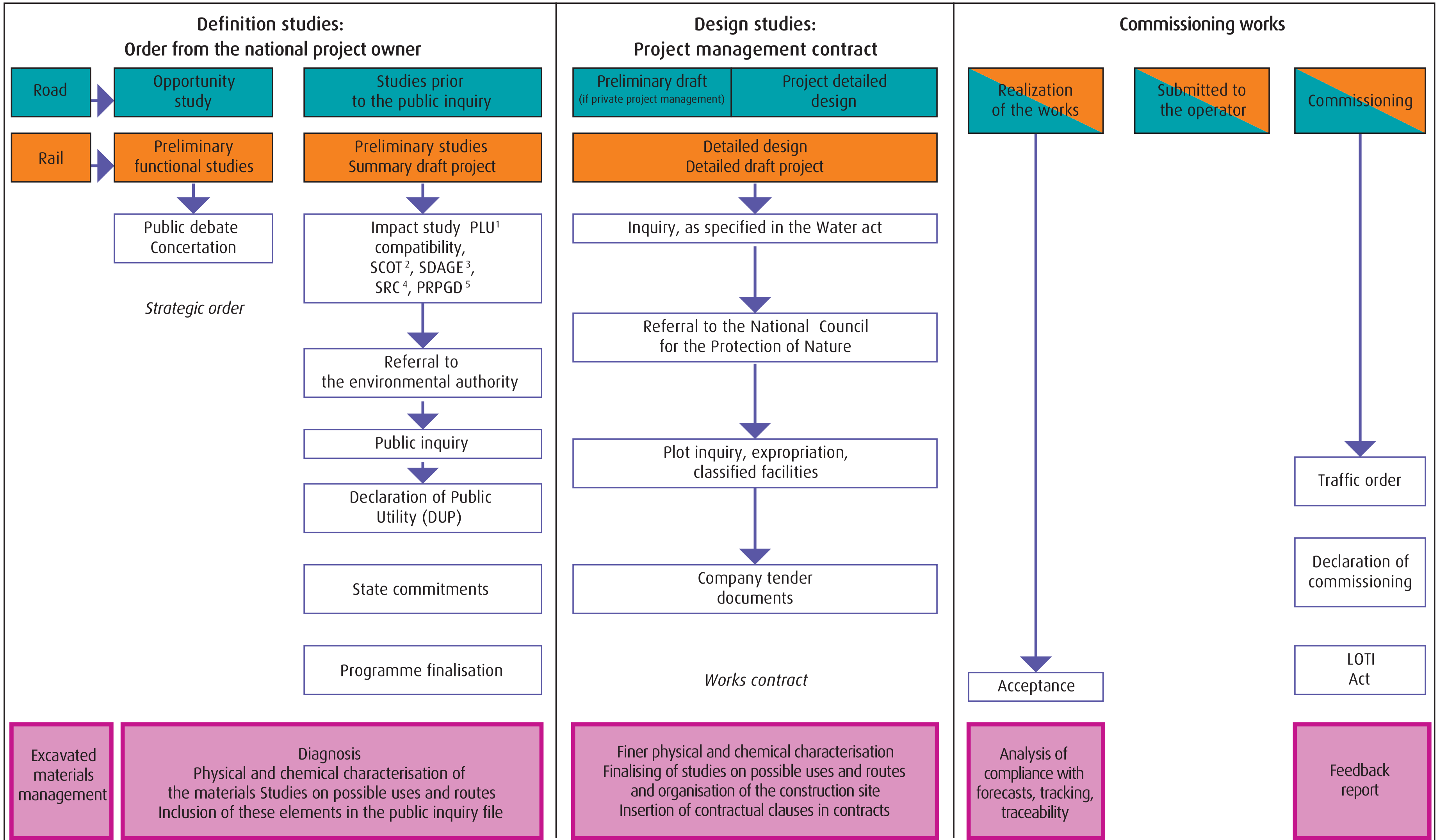
In addition to the quantities and qualities of excavated materials, the following information will be necessary, in order to study management scenarios:

- the planned uses based on the intrinsic characteristics of the materials;
- treatments likely to improve the characteristics of the geological excavated materials, including sorting, washing, crushing, lime treatment and / or hydraulic binders;
- the projected extraction pace;
- material transportation modes;
- existing routes on the project territory. For this, the project owner will contact industry bodies and federations such as UNICEM[12], UNPG[13], AIMCC[14], construction or public works federations;
- the orientations of planning documents (regional waste prevention and management plan, regional quarries plan).

Reflections on managing, supplying and removing the materials must be undertaken from the definition studies phase to facilitate re-use and recovery of excavated materials.
The diagnosis will be updated as the project advances and new data are acquired.

This approach, described in the recommendation from AFTES working group No. 35 [4] is part of an iterative process of risk management, similar to that described in the recommendation from AFTES working group No. 32 on the Characterisation of geological, hydrogeological and geotechnical uncertainties and risks [30], which will enable uncertainties to be reduced as the studies progress.

12. UNICEM: Union nationale des Industries de Carrières et Matériaux de Construction (French quarry and construction materials industry body) — 13. UNPG: Union Nationale des Producteurs de Granulats (French aggregates industry body) — 14. AIMCC: Association des industries de produits de construction (French construction products industry body).



1. Local city planning plan – 2. Territorial Coherence scheme – 3. Master plan for water development and management – 4. Regional quarries plan – 5. Regional waste prevention and management plan

Figure 7: Administrative stages in an underground works project according to the Government's instruction of 29 April 2014 [28] and circular No. 2000-98 [29]

The following elements must be produced for the public inquiry:
- the policy carried out by the project owner with respect to management of excavated materials, including the project owner's requirements in terms of re-use and recovery, with the setting of targets for use of the geological materials extracted from the tunnel depending on the excavation option chosen, and the integration of these goals into the project and into operations already scheduled;
- a comparative analysis of the excavation methodology in light of the uses to be made of the materials and highligh-ting the advantages and disadvantages and taking account of costs and environmental issues;
- a first indication of the locations of treatment zones (e.g., crushing and washing) and transit zones for excavated materials;
- the justification of the scenarios adopted.

Table 7 summarises the actions to be taken by the project owner or project owner's assistant during definition studies.

What	Who?	And how?
Knowledge of the excavated materials (nature, characteristics, volume, classification)	Project owner	Documentary study (infoterre), geotechnical investigations, longitudinal profiles and cross-sections, geotechnical model, characterisation tests
Presence of polluted soils?	Project owner	Historical study of site (existence of human activities, soil diagnosis)
Possibility of re-use or on site use of the materials	Project owner	Definition of possible uses depending on the mechanical characteristics of the materials encountered Estimate the treatments to be applied to obtain the required performance depending on the uses (possibly study on how appropriate it could be to mix different types of materials found or use a part of the particle size classes) Prior tests Identification of necessary on-site facilities (ICPE, IOTA) Study of how adequate the facilities are in light of city planning regulation documents
Knowledge of local waste management routes	Project owner	Take account of voluntary commitments from industry actors, planning schemes and documents (regional waste management plan, regional quarries plan, SDAGE, SCOT, PLU) Knowledge of local routes

Table 7: Role of actors at the definition study stage

5.2 DESIGN STUDIES

Design studies are carried out by the project supervisor hired by the project owner. At this stage, additional geological investigation campaigns should be conducted to clarify the qualitative and quantitative data related to the materials and thus clarify management scenarios. Where appropriate, chemical analyses will also be conducted to confirm or deny the presence of substances that may influence management methods.

The organisation of the site that enables the management scenarios selected to be implemented will be developed, with:
- account being taken of material extraction paces as these affect both the material storage capacities and the quantities that can be treated on site depending on needs. The phasing of the works will ensure the production of materials from excavation works matches uses on the site;
- the strategy for the storage and movement of these materials; the site organisation must minimise impacts on the environment.

In an iterative manner, all the elements established during definition studies are updated as studies advance.

The project owner may proceed with the regulatory formalities prior to the works such as the plot inquiry and expropriation procedures and apply for authorisations related to ICPE and IOTA classified facilities. The project owner must ensure that facilities required to manage excavated materials are authorised to operate.

At the end of this stage, the works contract will be drafted and will include in particular information on:
- the policy conducted by the project owner in terms of excavated material management;
- the summary of studies carried out (diagnoses of the quality and quantity of excavated materials, location of the transit and treatment facilities to be developed or already existing in the territory);
- the scenario(s) adopted;
- the documents taken into account when drawing up management scenarios (in particular the regional quarries plans and regional plan(s) to prevent and manage the waste generated by construction and public works sites);
- the schedule of unit prices specifying prices for each excavated material management scenario.

The works contract will integrate specific requests with regards to the management of excavated materials, in particular in terms of:

- the organisation and monitoring of the management of excavated materials, from the time of extraction up to re-use, recovery or disposal;
- the assessment of the operation (quantity and quality of the excavated materials, uses, costs, any malfunctions and solutions implemented to overcome these malfunctions).

In its response, the company must in particular detail how the site is organised along with control resources and the means put in place to trace the materials.

Table 8 summarises the actions to be taken by the project owner or project supervisor in the design studies.

What	Who?	And how?
More detailed knowledge of the nature and volume of materials excavated from the site	Project supervisor	Additional investigations, geotechnical and/or environmental tests, refined geotechnical model
Study of parameters influencing the quality of the materials	Project supervisor	Studies on excavation resources and on-site treatment to be implemented to improve quality
Possible uses	Project supervisor	Suitability and formulation testing, tests to validate the mechanical characteristics Chemical salting-out analysis to validate environmental aspects
Choice of the treatment organisation to be put in place (on-site, off-site, operator)	Project owner or supervisor	Identification of the on site surface areas required for treatment based on the pace at which materials are extracted and the treatment facility put in place Definition of the analyses to be run and their frequency to ensure quality for use according to the “product” standards in force (NF EN 13139 [N18] for mortars and NF EN 12620+A1 [N14] for concrete) Check that off-site operators are authorised to carry out their activities
Anticipation of the processing of administrative files	Project owner	Establishment of a specific contract for ICPE / IOTA files
Integrate excavated material management into contract documents	Project owner	Indication of the waste management policy adopted by the project owner with the re-use and recovery goals to be achieved – make the studies performed available (diagnoses, tests to define the uses of the excavated materials)

Table 8: Role of actors at the design study stage

5.3 WORKS

During the works, on-going quality controls must be carried out on excavated materials to ensure conformity of the materials for a given use.

Contractors on site must ensure that the materials coming out of the site meet the facilities admission requirements or have the characteristics required for the use chosen. Contractors will establish, with the project supervisor, documents to trace the materials indicating the quantities and qualities of the various types of materials as well as their management routes. Contractors will keep the project supervisor informed at all times during site work of the tracking performed on the materials excavated.

An asbestos waste document (BSDA) is issued in the presence of asbestos-bearing soil excavated on the construction site. This document enables the waste to be tracked, from the time of production up to the final disposal. This document is available on the site of the French administration[15].

In case there is a discrepancy in relation to forecasts, the project supervisor must inform the project owner and offer the management solutions that will have been anticipated in the risk analysis.

At the end of the works, a general assessment on the use of the excavated materials must be drawn up and compared to the draft scenario. Drawing up this assessment enables the project owner, in charge of the excavated materials, to ensure they are properly managed. In addition, it provides feedback which will enable a better technical and economic understanding of future sites. This assessment sets out the qualities and quantities of excavated materials and the different uses. It compares what had been envisaged with what is actually done in terms of material management. It shows up the problems related to material management and corrective actions implemented.

Transit facilities for recovery or disposal and related costs must be included in this assessment.

15. http://vosdroits.service-public.fr/professionnels-entreprises/R14335.xhtml

Table 9 summarises the actions to be taken by the project owner, the project supervisor and contractors during the works phase.

When?	What?	Who?	And how?
Preparation period	Change in the holder of administrative files	Contractors	Submission of administrative files by the contractor
Works and commissioning	Organisation of the work site phase	Project supervisor	Check on how appropriate the useful floor space is for temporary storage of the materials (depending on the pace of extraction, the materials encountered and planned uses)
	Implementation of traceability tools	Project supervisor / contractors	Establish: • tracking of the quality and quantity of materials on site and off site • procedures to validate material treatment for the chosen use • discrepancy management procedures
	Assessment of the operation	Project supervisor / contractors	Retrieval of all information on the quality and quantity of excavated materials, practices, discrepancies and contingencies relating to the materials or organisation put in place and the related costs

Table 9: Role of actors during the works

6 SUMMARY

The management and use of excavated materials is becoming increasingly important for major underground works projects. This is firstly due to the large volumes generated and secondly to the increasingly demanding expectations from society at large in terms of respect for the environment.

The project owner must tackle this issue right from the project definition phase in order to manage it at an early stage in the most efficient way possible.

The regulatory environment as well as technical innovations mean that project participants must acquire specific skills. Synergies must be developed with the local economic fabric, in order to identify routes for the re-use and/or recovery of the excavated materials, thus optimising their transport and minimising volumes going into final storage.

The natural geological materials excavated are a resource that can deliver substantial savings by having recourse to fewer natural resources.

DEFINITIONS

Collection: any operation involving the collection of waste for transport to a waste treatment facility (article L. 541-1-1 of the Environmental Code).

Waste: any substance or object, or more generally any movable goods, which the holder discards or which he/she intends or is obliged to discard (article L. 541-1-1 of the Environmental Code).

Waste holder: producer of the waste or any other person in possession of the waste (article L. 541-1-1 of the Environmental Code).

Disposal: any operation that is not recovery even when the said operation has as a side effect the retrieval of substances, materials, products or energy (article L. 541-1-1 of the Environmental Code).

Route: set of activities and players ranging from the mobilisation of the waste deposits[16] to the use of recycling or energy raw materials. The concept of route refers to the idea that a product, good, or service, is placed at the disposal of the end user through a succession of operations carried out by units performing a range of different activities. Each route comprises a chain of activities that complement each other and that are linked up by buying and selling transactions.

Waste management: the collection, transport, recovery and disposal of waste and, more broadly, all activities involved in organising waste management from production to final treatment, including trading or brokerage activities and the supervision of all these operations (article L. 541-1-1 of the Environmental Code).

Preparation for reutilisation: any operation to check, clean or repair with a view to carrying out recovery operations by which substances, materials or products that have become waste are prepared so they can be re-used without any other processing operation (article L541.1.1 of the Environmental Code).

Prevention (article L541-1-1 of the Environmental Code): any measures taken before a substance, material or product becomes waste, when these measures help reduce at least one of the following items:

- the quantity of waste generated, including through the re-use of products or an extension to the useful life of substances, materials or products;
- the adverse impacts of the generated waste on the environment and human health;
- the content levels of substances harmful for the environment and human health in the substances, materials or products.

Waste producer: any person whose activity produces waste (original waste producer) or any person who carries out waste treatment operations leading to a change in the nature or composition of such waste (subsequent waste producer) (article L. 541-1-1 of the Environmental Code).

Recycling: any recovery operation by which waste materials, including organic waste materials, are reprocessed into substances, materials or products for the initial purpose or for other purposes. Operations in which energy is recovered from waste, those relating to the conversion of waste into fuel and backfilling operations, cannot be qualified as recycling operations (article L. 541-1-1 of the Environmental Code).

Re-use: any operation by which substances, materials or products that are not waste, are used again for a usage that is identical to that for which they had been designed (article L541.1.1 of the Environmental Code) For example: when on the same site (construction site), muck is used for backfilling operations, this is a re-use operation [31].

Backfilling: a recovery operation where suitable waste is used for reclamation purposes in excavated areas or for engineering purposes in landscaping and where the waste is a substitute for non-waste materials (decision of the Commission on November 18, 2011).

Reutilisation: Any operation by which substances, materials or products that have become waste, are used again (article L541.1.1 of the Environmental Code).

Treatment: any recovery or disposal operation, including the preparation which precedes the recovery or disposal (article L. 541-1-1 of the Environmental Code).

Recovery: any operation whose main result is that waste is used for useful purposes in replacement of other substances, materials or products that would have been used for a particular purpose, or that waste is prepared to be used for that purpose, including by the waste producer (article L. 541-1-1 of the Environmental Code).

16. The term “route”, defined above is based on the definition provided by ADEME ("Collection, sorting, recycling and recovery of waste – strategic roadmap", May 2011), and is used in this document to mean re-use, insofar as the same activities and facilities may be concerned without, however, the materials taking on the status of waste.

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[N17] NF P 98-335 – Urban Pavements – assembly of concrete paving blocks and flagstones, of terracotta paving blocks and of natural stone paving blocks, AFNOR.

[N18] NF EN 13139 – Aggregates for mortar, AFNOR.

[N19] NF EN 13055 – Lightweight aggregates for concrete, mortar, bituminous mixtures and surface treatments and for unbound and bound applications, AFNOR.

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