Disclaimer

This sheet is intended for designers, specifiers and other members of construction project teams wishing to reuse this building material or product. It is part of a collection of sheets aimed at bringing together the available information to date that is likely to facilitate the reuse of building materials and products.

This sheet has been produced by Bellastock within the framework of the Interreg FCRBE project - Facilitating the Circulation of Reclaimed Building Elements, supported by the entire project partnership. Sources of information include the experience of reclamation dealers and involved project partners, lessons learned from exemplary projects, available technical documentation, etc.

The sheets have been produced between 2019 and 2021. As the reclamation sector is evolving, some information, notably regarding pricing and availability, may change over the time. When the text refers to European standards, it is up to the project team to refer, if necessary, to their national implementations and local specificities.

It is important to note that the information presented here is not exhaustive or intended to replace the expertise of professionals. Specific questions are always project related and should be treated as such.

The complete collection of sheets (including the introductory sheet) is freely available from different reference websites (a.o. opalis.eu, nweurope.eu/fcrbe, futureuse.co.uk).

Non-exhaustive directories of dealers in reclaimed building materials are available on www.opalis.eu and www.salvoweb.com.

Interreg FCRBE partnership: Bellastock (FR), the Belgian Building Research Institute / BBRI (BE) , Brussels Environment (BE), the Scientific and Technical Center of Building / CSTB (FR), Confederation of Construction (BE), Rotor (BE), Salvo (UK) and University of Brighton (UK).

The information contained in this document does not necessarily reflect the position of all the FCRBE project partners nor that of the funding authorities.

Iconography

Figure 1 and Figure 2: BENOIT J, SAUREL G, BILLET M, BOUGRAIN F, LAURENCEAU S, ADEME, BELLASTOCK, CSTB, *REPAR#2 Le réemploi passerelle entre architecture et industrie,* mars 2018, p108.

Material description

The concrete pavers and slabs referred to in this sheet concern modular elements obtained by cutting, cleavage or fragmentation with a mechanical shovel of concrete elements having two flat and parallel faces (slabs, panels, trusses) and used as a paving product. The original elements undergo a transformation and a change of use. They are therefore different from pavers and concrete slabs which were initially produced for this purpose, and whose reuse is also possible (but not discussed here).

Pavers and slabs obtained by transforming concrete construction elements (hereinafter referred to as pavers and slabs) may be suitable for various outdoor applications: landscaping, building surroundings, roads and public spaces.

These are the dimensional aspects that distinguish slabs from pavers:

- any element whose overall length divided by its thickness is greater than 4 and whose length does not exceed one metre is considered to be a "slab".
- any element whose overall length divided by its thickness is less than or equal to 4 and at a distance of 50 mm from any edge is considered to be a “paver". No cross-section has a horizontal dimension less than 50 mm.

In practice, slabs and pavers cut from concrete elements may have irregular contours. They generally have sizes between 20 cm and 40 cm in order to facilitate handling.

Comparison of an irregularly shaped concrete slab resulting from a demolition operation and a new regular slab

At present, pavers and slabs resulting from the transformation of concrete construction elements are not marketed. This is an initiative led by sponsors and designers, most often taking advantage of opportunities present on or near the site.

Different types of concrete construction elements can be salvaged to produce slabs and pavers, in particular:

→ *Interior crosswalls cast in place.* These are structural walls positioned inside the building, perpendicular to the façade plane. These walls are generally 15 to 20 cm thick. Their height most often corresponds to that of a storey, i.e. around 250 cm in a residential building (*for more details, see sheet “2.91_Concrete shear wall”*).

→ *Prefabricated panels*. There is a wide variety of types of prefabricated panels. While some have significant thicknesses (> 15 cm) and contain a lot of reinforcement, others are thinner (~ 10 cm) and contain less (or no) reinforcement. This is particularly the case with panels used to make interior partitions. The latter are suitable for cutting into slabs and pavers (*for more details, see sheet “2.91_ Concrete shear wall”*).

→ *Compression slabs on a shuttering slab floor system*. This is a floor system made up of a shuttering slab of variable thickness (minimum 5 cm in the case of prestressed materials) on which a compression slab is then cast (approximately 10 cm thick). The dimensions of the shuttering slabs depend on the floor span. On average, they have a width of 2.50 m and a maximum range of 5 m. This system can often be recognized by the smooth underside of the floor and the presence of a joint running perpendicular to the direction of the beams. However, a site visit may not be sufficient to identify this system with certainty. The study of the original documents (in particular the documents of works carried out) can then provide additional information.

Several aspects must be taken into account in order to identify the most suitable source elements, in particular:

→ *Thickness*. This must be sufficient to meet the constraints of installation and use of slabs and paving stones (*see § “Applications and installation”*).

→ *Reinforcement*. The presence of reinforcement in the original elements tends to complicate the process of removing, transforming and reinstalling slabs and pavers. Therefore, it is more interesting to focus on elements with little or no reinforcement (generally the interior walls).

→ *Surface condition*. If necessary, surface treatments may be considered to adapt the properties of the surfaces.

→ *Logistical considerations*, particularly in terms of accessibility, handling and site planning.

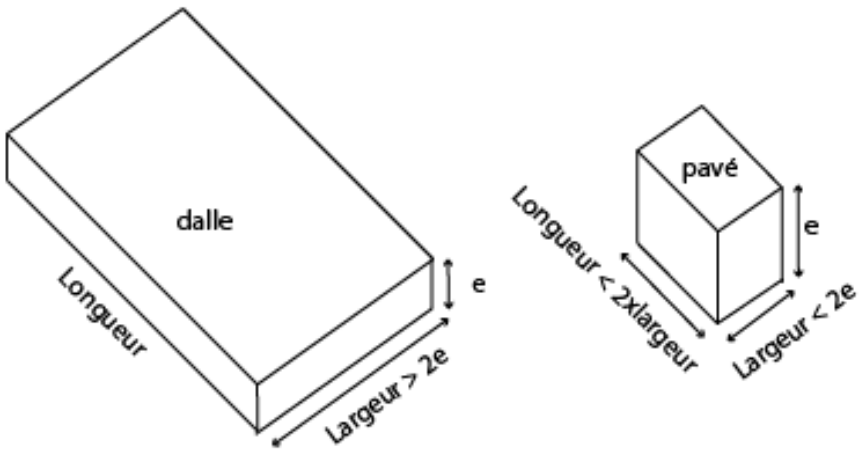


Figure 1: Geometric characteristics of a slab and a paver

Material reclamation

Before being reinstalled, slabs and pavers made from concrete construction elements go through several stages:

1. Preliminary studies.
2. Removal of original elements.
3. Transformation of the original elements into slabs or paving stones.
4. Complementary treatments.
5. Storage and transport.

Some of these steps, in particular removal and conversion, involve relatively heavy mechanical means. They require good preparation and excellent coordination with demolition works. The targeted elements must in fact be carefully extracted from the building and then transformed on land. This involves cutting operations on site (in particular for exposing keying steel binding prefabricated elements) and the use of lifting devices (with, if necessary, the installation of anchor points to allow fixing the slings).

In all cases, it is a question of putting in place all the necessary precautions in conjunction with the site safety coordinator.

→ *Preliminary studies*. These make it possible to ensure the feasibility and profitability of removing the targeted elements with a view to transforming them into pavers or slabs. Given the experimental nature of the approach, it makes sense to rely on the advice of experts in the field, demolition and/or concrete cutting companies, as well as on feedback from similar constructive typologies.

→ *Removal*. Removal must above all aim not to damage the elements taken and to avoid any mixing. The degree of care and precision required must be proportional to the requirements relating to the use of the slabs and pavers. While some applications are relatively undemanding and accommodate speedy demolition techniques, others require significant care and specific removal.

Two main methods can be considered:

A. *Advance removal by clipping*. Clipping refers to the demolishing of a building from top to bottom. Each floor is demolished by small machines steered from the cabin or controlled remotely. The materials are generally discharged as they go through the elevator hoppers or through a chute system. A lifting system is brought to the right of the building in order to transport operators and machines. In this approach, the elements to be recovered are made accessible as the demolition progresses. The operations required for cutting the walls and/or slinging the prefabricated panels must be taken into account in the site planning. Depending on the possibilities, the elements may be pre-cut directly to the required dimensions during their removal, this makes it possible to limit the volumes of materials to be shifted during removal.

B. *Collection upon demolition through picking with a mechanical shovel*. In this approach, the building is demolished more quickly and the elements to be recovered are taken from the rubble. This method has the advantage of not slowing down the demolition but turns out to be much more uncertain as to its results. In all cases, a mechanical sorting strategy for the demolition of the building must be established in consultation with the demolition company in order to guarantee a minimum of results, limit mixing and avoid rendering certain elements unusable.

→ *Transformations*. The production of pavers and slabs from more or less complete concrete elements (walls and whole slabs or fragments thereof) requires at least a treatment of the edges and a calibration to obtain a product in the desired shape and easy to install.

Fragments with very irregular shapes can be placed using an opus incertum apparatus. This makes it possible to limit the transformation operations to the treatment of the edges, which can be carried out in progress when laying the floor covering. When laying, however, the builders will have to make small adjustments between the different pieces. Therefore, this installation requires specific know-how. Compared to other stone-settings, it is relatively time consuming.

Orthogonal pavers and slabs can be obtained by cutting the original elements to the desired dimensions. Cutting can be done using a rail saw or a bridge saw with a rotating table. This last device allows movements on three axes and a greater flow. The implementation of such a device must be studied in detail.

Note: The use of a hydraulic cleaver as used for the production of natural stone pavers has not yet been tested for concrete. For large volumes, this solution may be of interest in terms of profitability. The way in which concrete behaves during such an operation remains however an unknown.

→ *Additional treatments*. Depending on the requirements relating to the intended use, pavers and slabs may be subject to additional treatments, in particular:

- *Surface treatment*. There are a multitude of surface treatments for concrete: bush hammering, polishing, shot blasting, etc. In the case of floor coverings, these treatments generally aim to reduce slipping. They can also be motivated by aesthetic reasons (highlighting the grains of concrete, for example) or to improve its durability (resistance to wear and fouling, for example).
- *Treatment of porosity*. To reduce the risk of concrete deterioration (especially caused by freeze/thaw cycles), the application of a pore filler or mineraliser can help make the concrete surface water repellent.

In all cases, the choice of these surface treatments must take into account any original coatings that may still be present on the paving stones and slabs.

→ *Storage*. The slabs and pavers can be packaged on a pallet. Pay attention to the large mass of these elements. On a pallet, the elements must be held in place by means of a banding device and/or a heat-shrinkable or stretchable film (beware of packaging waste overproduction). The arrangement of the elements on the pallet must comply with the elementary rules of stability and regularity, in particular by not overloading.

The large sized elements can be superimposed on each other by inserting wooden wedges between each element.

Although they are inert by nature, for long periods of storage, it is recommended to protect the slabs and paving stones from bad weather (for example by tarpaulin or covered storage) .

→ *Transport and delivery*. All necessary precautions must be taken during transport and delivery to limit falls and shocks (strapped pallets, etc.). Unless specific equipment is used, transport must be carried out flat. However, racks can be used, as wall formwork manufacturers do for on-site transport. The lifting means must be consistent with the dimensions and weight of the parts to be handled. It is advisable to involve specialised professionals to ensure the smooth running of these operations.

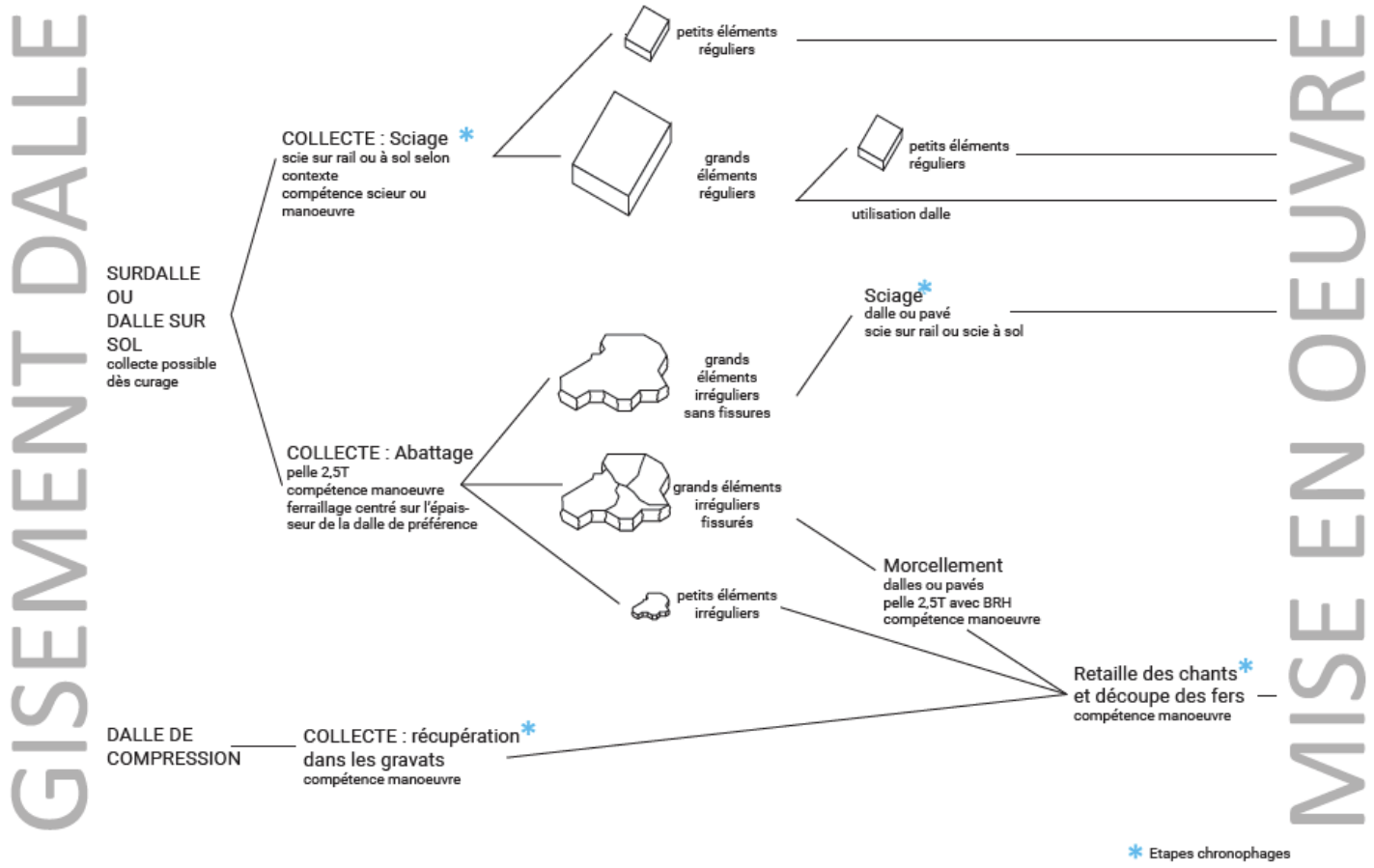


Figure 2. The steps from the concrete elements to the product, recovery of a compression slab. Control of the technical performance of concrete is carried out prior to the recovering operations. The control of the state of the materials is done at each stage of the process.

Concrete pavers and slabs
(resulting from the transformation of concrete construction elements) *Applications and installation*

Applications and installation

Pavers or slabs resulting from the cutting of concrete construction elements are mainly used as exterior flooring.

Their installation must respect the same points of attention and the same regulations as their new equivalents, in particular - and non-exhaustively - with regard to slippage, durability, choice of installation methods, preparation of laying sub-structures, slope management, joint thickness, etc. Regulatory aspects are included in the following standards in particular: pavers for roads and public spaces: EN 1338 - Concrete slabs for roads and public spaces: standards of use, including EN 12371 - Natural stone test methods - Determination of frost resistance, EN 14231 - Natural stone test methods - Determination of the slip resistance, EN 1936 - Natural stone test methods - Determination of real density and apparent density, and of total and open porosity, and EN 13242 - Aggregates for unbound and hydraulically bound materials for use in civil engineering work and road construction.

To facilitate laying, the specifier will take care to use batches with a certain degree of uniformity in terms of the following characteristics:

→ *Batch composition*. The origin of the materials must guarantee the uniformity of their characteristics.

→ *Dimensions.* Opt for elements that are easy to handle. As an indication, a 20 to 40 cm diameter size, with two flat parallel faces, for a total mass of less than 25 kg is a good candidate. The use of large size slabs is not impossible but involves specific machinery and installation. Execution studies and dialogue with specialised companies should then be provided for.

Design tip!

When the constraints of use allow it, a dry installation is to be preferred to a sealed installation. This indeed offers several advantages: facilitate maintenance, preserve soil permeability and allow possible future reuse of the elements!

The thickness of the elements varies according to the operating loads and the mechanical characteristics of the concrete (which here depend on the materials collected).

Dimensional tolerance: the variation in thickness between the pavers must be < 3 mm.

The joint dimensions between pavers must be between 2 and 4 mm. A specific study should be planned if the thickness of the joints is greater than 4 mm. In general, the dimensions of the elements must be relatively uniform to ensure an acceptable joint width during installation.

→ *Colour*. The colour largely depends on the original concrete (generally in grey tones) and varies according to its quality, date and place of manufacture. Variations may also be due to the stresses during use, to the previously applied treatments, etc. Unless the project expressly requires the use of particular colours (for example, in the context of a heritage renovation), it is recommended to remain relatively open on this characteristic.

→ *Condition.* The reclaimed concrete pavers or slabs may have minor deterioration such as traces of superficial wear, stains, traces of mould, efflorescence, etc. In principle, these do not affect the suitability for use. On the other hand, the elements must not have any defect indicating a diversity in the structure, neither cracking, nor chipping, nor visible deformation or tearing, under penalty of disqualification.

→ *Quantity.* The loss of materials during the slab and paver extraction and production process should be studied in advance, in order to assess the end quantity of materials ready for installation.

The "Opus uncertum" of Clos Saint Lazare in Stains (FR), 2017. The concrete resulting from the demolition of a residential building built in 1959 was reused on site to cover the ground of the outdoor spaces.

Characteristics and fitness for use

The requirements relating to the physical and mechanical characteristics are directly linked to the mechanical resistance over time of the paving stones and slabs, which largely depend on the qualities of the original concrete from which they are produced. Regarding the mechanical properties of modular concrete elements, the normative requirements (EN 1338 et EN 1339) relate to the following characteristics:

	Use type 1 *Concrete pavers for garden*	**Use type 2** *Concrete pavers for roads and public spaces*	**Use type 3** *Concrete slabs for roads and public spaces*
Breaking load per unit length (splitting failure test)	X	X	X
Flexural splitting strength		X	
Flexural strength			X

Characteristics	Comments
Dimensions (length, width), regularity of shape	These characteristics are dependent on the cut. The irregularity of the pavers/slabs will influence the thickness of the joints during laying.
Thickness	• Paver: minimum thickness of 60 mm for vehicular traffic; • Slab: for light traffic loads no minimum thickness is defined, but the requirements for flexural strength must be met; • The difference between 2 thickness measurements of the same slab < 3mm; • The elements have straight edges, with a tolerance of +/- 1cm.
Surface quality	Pavers with defects characteristic of non-uniformity of the structure, or with visible cracks, chipping, deformation or tearing must be rejected. Visual examination during demolition and/or checking with a Ferroscan.
Impermeability/Water absorption	Porosity according to EN 1936. Determining resistance to water absorption is not required for the first marking designation defined by standards EN 1338 and EN 1339.
Flexural splitting strength	The thickness of the concrete pavers must be estimated according to the compressive strength of the initial product. It should be noted that the concretes used in the building mainly belong to resistance class C25/30, which gives a resistance to the breaking load through splitting and through sufficient unit length so long as the thickness of the product is greater than 60mm.
Freeze/thaw resistance	• No recommendation for use type 1 pavers. • No recommendation for pavers and slabs for use types 2 and 3 unless there are specific conditions such as frequent contact with de-icing salts (according to EN 1338 and EN 1339 standards).
Abrasion resistance (wear)	The determination of abrasion resistance is not required for the first marking designation defined by EN 1338 and EN 1339.
Slipperiness	Slip resistance should be assessed, particularly if the surface of the pavers has been polished or ground. If not, surface treatments can improve this characteristic.
Steel	Corrosion of any reinforcements in the paving stones resulting from the reclamation of concrete is not desirable. The following precautions should be taken: • Remove as many irons as possible when making modular elements; • Make the pavers in such a way that the residual reinforcement is placed horizontally in relation to the laying surface; • Ensure, by visual observation and via a phenolphthalein test that the reinforcement covering is sufficient; • When installing modular elements containing residual reinforcement, a dry installation allowing the development of possible corrosion is preferred, limiting the pressure on the joint and on the concrete.

In the event of specific and demanding applications (i.e. high exposure to de-icing salts, high traffic class, etc.), characteristics such as mechanical resistance, frost resistance or impermeability can be measured using tests carried out by accredited laboratories.

Concrete pavers and slabs
(resulting from the transformation of concrete construction elements)

Availability

The pavers and slabs resulting from the cutting of concrete construction elements are not marketed products. To date, this is a strategy applicable to the scale of a project, by identifying a source site.

Indicative prices (Excl. tax)

The absence of an established commercial channel does not allow us to indicate the selling price of slabs and pavers. The cost of operations must be studied for each project, taking into account factors such as the quantity of materials involved, the complexity of the dismantling, the transformation operations required, the installation constraints, etc.

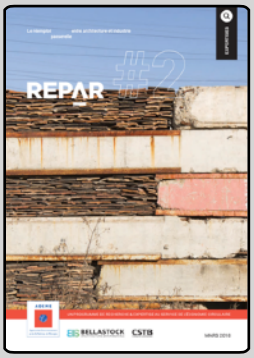
Hazardous substances and precautions

During documentary investigation, certain usage restrictions may be issued, in particular in the following cases:

→ Presence of asbestos in coatings applied to concrete or in concrete. The study of the asbestos diagnosis upstream allows to control the presence of asbestos, in case of suspicion it is preferable to establish samples and a complementary asbestos diagnosis. As a general rule, during demolition, asbestos-contaminated surfaces are removed before demolition of the concrete.

→ Concrete that has been subjected to chemical attack by soils and natural groundwater (corresponding to the three exposure classes XA1, XA2 and XA3 of standard EN 206).

→ Possible presence of plaster residues in the concrete, a priori incompatible with reuse as a floor covering. In fact, the presence of water when using the pavers risks causing the formation of swelling mineral species such as ettringite, which may eventually cause deterioration of the paver or the slab.



More info!

As an indication, the REPAR #2 study carried out in France in 2017 on a tangible case of on-site reclamation of concrete elements as exterior floor coverings (60 m²) demonstrated that this approach could lead to savings in the order of 10 €/m² excluding VAT. These results must however be interpreted in the light of the specific nature of the case study and of the assumptions taken into account to carry out the calculations .

Link (in French) : https://www.bellastock.com/projets/repar-2/

Embodied carbon (Cradle to gate - production A1-A3)	kg CO_2 eq./m²	kg CO_2 eq./kg
INIES databank (FR) - Individual declaration - PREFABRICATS LLEILDA SL - Exterior covering: paving stone (v.1.2) *	21.6	0.08
INIES databank (FR) - Collective declaration - SNBPE - Paving on a 0.15 m thick concrete platform, C25/30 XC1 CEM II/A**	49.8	0.14

** 8 x 10 x 20 cm pavers. Transport distance: 400km*

** * Transport distance: 18.5km, for a concrete paving 15cm thick. 30 kg of steel/m³. NB: the steel production steps (A1-A3) have been added, when these were not taken into account in the sheet*

Depending on the sources, reusing 100 m² of concrete elements to create reclaimed concrete pavers and slabs prevents the equivalent production of ~ 2160 to ~ 4980 kg of CO_2 equivalent related to the manufacture of new elements (production phase only). According to sources, this corresponds to the emissions of a trip of ~ 12,950 to ~ 29,900 km in a small diesel car.