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 Rotor vzw/asbl 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.

Material description

Used and reused throughout the ages, natural stones setts have long been the solution of choice for planning roads and public spaces. They were, however, ousted throughout the 20th century by road surfaces such as concrete and by-products from the petroleum industry. In recent decades, stone setts have received renewed interest from some planners, particularly in contexts involving a heritage approach.

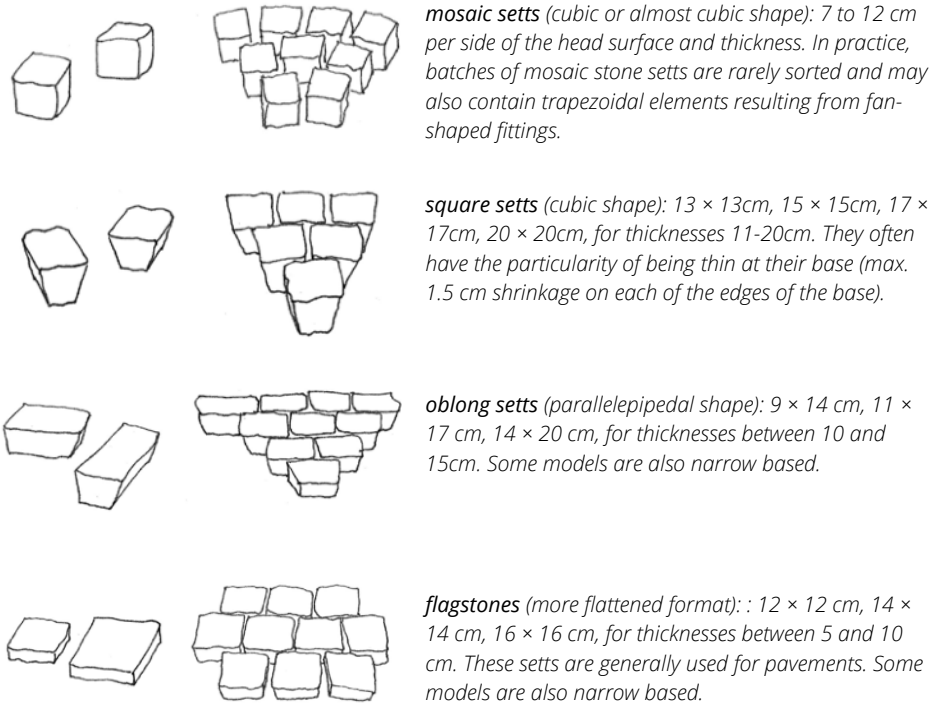
Emblematic of a form of circular economy before its time (the reclamation of paving stones is widely documented in history), stone setts are today caught up in a somewhat paradoxical situation. Europe imports large quantities of new stone setts (mainly from Asia) while it exports a significant amount of its stock worldwide.

Despite these underlying trends, the reclamation of setts remains a relatively well established practice in public works and the construction industry. There are many well established companies specialising in their recovery and resale. In addition to sorting, cleaning and packaging old setts, some companies are also exploring new ways to meet the requirements now expected by developers, in particular by developing techniques for cutting stone setts or by imagining new applications.

This sheet mainly focuses on the use of natural stone setts for exterior (surrounding area) and interior flooring, in contexts other than public roads (the latter being the subject of specific specifications).

It should also be noted that the term “stone setts" actually covers a huge variety of parts that are ultimately very different. While setts can be defined in a very general way as hard, parallelepipedal elements used through juxtaposition to compose a floor covering, it is necessary to take into account the possibility of almost infinite variations.

→ *Formats*. There is a wide variety of setts sizes, depending on the era, region and use, some of which are more common (*Figure 1)*. Beyond these large groups of formats, there are a multitude of specific names, often closely linked to a region, a format, a type of rock or a particular treatment. To name but a few: “pavés du Roy “(French sandstone setts measuring 23 × 23 × 23 cm), “pavés Napoleon” (French sandstone setts measuring 20 × 20 × 20 cm), “Boerenkasseien” in Belgium and the Netherlands, Yorkstone setts in UK, Sampietrini in Italy, etc.



mosaic setts *(cubic or almost cubic shape): 7 to 12 cm per side of the head surface and thickness. In practice, batches of mosaic stone setts are rarely sorted and may also contain trapezoidal elements resulting from fan-shaped fittings.*

square setts *(cubic shape): 13 × 13cm, 15 × 15cm, 17 × 17cm, 20 × 20cm, for thicknesses 11-20cm. They often have the particularity of being thin at their base (max. 1.5 cm shrinkage on each of the edges of the base).*

oblong setts *(parallelepipedal shape): 9 × 14 cm, 11 × 17 cm, 14 × 20 cm, for thicknesses between 10 and 15cm. Some models are also narrow based.*

flagstones *(more flattened format): : 12 × 12 cm, 14 × 14 cm, 16 × 16 cm, for thicknesses between 5 and 10 cm. These setts are generally used for pavements. Some models are also narrow based.*

Figure 1. Main families of natural stone setts of common sizes and proportions

→ *Geological nature*. Many types of stones have been used for cutting producing setts. Beyond the large petrographic families, the origin of the stones also have great diversity (*see on the right*).

→ *Colours.* The diversity of the rocks means that there is a wide range of colours. The same rock can also vary greatly in colour. A specific vocabulary makes it possible to designate the encrustations of the stone (veins, grains, strata, holes, etc.).

→ *Texture and finish.* The more or less pronounced texture of the setts depends on the stone used and the production techniques (cleavage, dressing, sawing). The visible face may have a domed, flat or irregular shape if it does not undergo any treatment and is smooth and flat when the block is sawn. The performance associated with the paving stone's finish, such as slip resistance and wear resistance, determine its use (pavement, suitable for disabled people, etc.). The stresses to which setts are subjected during use can also result in a gradual softening and polishing of the visible face.

Magmatic (or igneous) rocks

Granite
Basalt
Porphyry

Metamorphic rocks

Gneiss
Marbles
Quartzite

Sedimentary rocks

Sandstone
Limestones
Sandstone limestones

Material reclamation

Natural stone setts are mainly found in exterior applications such as roads, squares, terraces, walkways, or even retaining walls and low walls. As long as they are not sealed with cement mortars, their recovery is easy. For reclamation on the same site, it is possible to carry out on-site sorting, cleaning and possibly sawing operations, as far as conditions allow. Most of the time, the dismantled setts are sent to a specialised company which can also take care of delivering batches of stone setts ready for installation. These professionals are able to ensure the smooth running of the following operations:

→ *Dismantling tests.* Dismantling tests make it possible to verify the feasibility and profitability of the removal. The type of bedding, the characteristics of the joints and the nature of the stone setts are the main factors which affect the ease of dismantling.

→ *Removal.* During disassembly, the main point of attention is to make sure to maintain a certain uniformity of the batches. There is little risk of material deterioration. Disassembly is carried out manually for lines of specific formats (start of line, backstop, etc.) and mechanically for uniform surfaces. The use of a hydraulic shovel equipped with a lattice tray (or screen) can remove the worst residues of sand, earth, moss and gravel.

→ *Cleaning and sorting.* Batches of dismantled setts are generally handled on conveyor belts on which they undergo operations such as:

- water cleaning;
- manual sorting and cleaning to remove mortar and/or asphalt remains;
- specific sorting (sifting machine plus semi-automated or manual sorting) in order to separate the setts according to the type of stone, the format and the colour.

During this process, setts that are split or have visible damage are rejected. The rate of loss strongly depends on the type of rock and the original use conditions. It can go up to 20% for sandstone flagstones (generally, sedimentary rocks, which have a natural cleavage plane, are more sensitive to cracks and breaks).

Sandstone setts and traditional laying on a sand bed: recovery is generally easy

Setts with cement joints: recovery promises to be difficult

Use of a riddle bucket

Example of a poorly laid sandstone sett. The cleavage plane must be parallel to the direction of laying. In this case, the sett probably underwent stresses which caused its cleavage. This sett will be discarded during sorting related to reclamation.

Did you know?

Some towns have their own stock of road materials. In Paris, for example, it is mandatory to reuse suitable stone setts on site or to divert them to a centralized stock, which contractors must also use for new developments. This platform, set up more than 20 years ago, ensures, among other things, the collection, sorting, cleaning and storage operations of Parisian stone setts. In addition to minimizing the costs associated with the purchase of new materials, it would prevent the dumping of 7,000 to 8,000 tonnes of granite per year (setts + kerbs), corresponding to 600 tonnes of not emitted CO_2. (Source : Paris City Hall Maintenance and Supply Centre (CMA, ADEME).

Specific sorting station

→ *Treatments.* While some stone setts can be reused as they are after a rough cleaning, others go through additional operations that affect their characteristics:

- *Sawing in 2 equal parts (Figure 2).* Provides two setts of equal thickness with a new smooth head surface. These elements no longer meet the same level of performance as the original element. In the case of narrow stone setts (that is to say, the base of which is narrower than the visible face), cutting gives rise to elements of different dimensions. In addition, the upper part of the sett is placed in a direction that no longer respects the narrowness. Some operators do not sort between the two items. This can have an impact on some types of installation so it should be taken into account.

- *Sawing of the upper part of the sett* (*Figure 3*). Results in a thick sett whose new visible face is very smooth and with similar mechanical performance to that of the original product (also called rectified sett). It also results in a thinner by-product (1 to 4 cm) called a "cap", "crown" or "head-shaped stone". The latter is not always valued locally, but large quantities are nevertheless exported abroad. This operation is also used to get rid of asphalt remains that are difficult to remove by cleaning.

- *Cleavage*. Splitting a sett into two equal parts. Using a splitter can produce a more irregular head surface than by sawing. Be careful in case of narrower base.

Sawing of hard stones (such as granites and porphyries) is rarer. For sedimentary rocks, the sawn face must necessarily be parallel to the stratification plane.

→ *Storage and packaging*: unsorted stone setts are generally stored in bulk in outdoor silos. Sorted and cleaned setts are stored in the same way. They can also be packaged on pallets, in wooden crates or big bags to avoid mixing. Mosaic setts are usually delivered in bulk.

Ready-to-install soon setts are clearly identified and labelled in uniform batches. They are sold by the m² or by the ton. Most suppliers are able to provide a technical sheet showing the characteristics of the stone setts (type of rock, nominal dimensions and tolerances, finish, intended applications) as well as their origin. More exceptionally, some suppliers can more precisely characterise the performance of a batch of stone setts depending on a test report carried out on a reference sample (petrographic, chemical, physical and mechanical characteristics).

It is advisable to involve specialised professionals to ensure the smooth running of these operations.

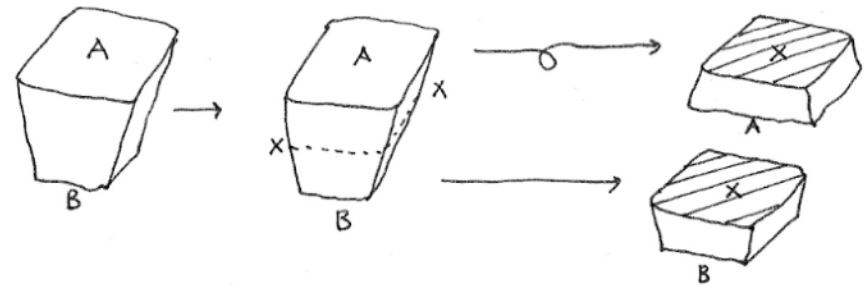


Figure 2. Sawing in 2 equal parts

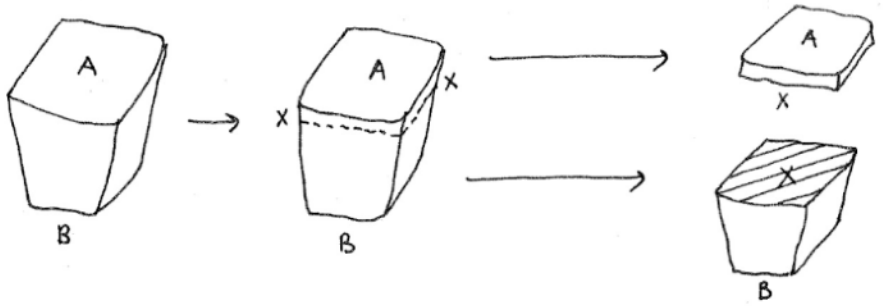


Figure 3. Sawing of the upper part of the stone sett

Sawing of the upper part of the stone sett

Storage of stone setts

Storage of stone setts

Storage on "palette-box"

Storage of paving stones in big bags

Applications and laying

For three decades, the evolution of the urban environment and the awareness of the aesthetic and heritage interest of stone setts have enhanced their use and that of natural stones in general. The recent design of works in reclaimed natural stone setts generally incorporates a multidimensional approach: historical, architectural, functional, sociological and environmental.

Reclaimed setts are mainly used as modular elements for covering exterior or interior floors, for applications subject to moderate stress (pedestrians, squares, alleys, etc.) or more intense (roads suitable for motor vehicles). They are also suitable for masonry constructions in low walls and retaining walls. The by-products resulting from sawing ("caps" 1 to 2 cm thick) can be used as a floor covering for uses subject to low stresses, as wall and façade cladding or as exterior floor covering element.

The choice of a type of sett depends on the stresses specific to the intended use: expected traffic, climatic conditions, noise level, permeability of the pavement, town planning rules, etc. The pavement as such is not everything. The installation technique envisaged also contributes greatly to meeting the expected requirements - in particular, and not exclusively, according to the type of foundation and the laying layer, the type of jointing, the type of equipment, the nature of the blocking elements, etc. Likewise, the quality of the installation can make all the difference between a floor covering that meets expectations and a covering that does not (for example, in terms of flatness). Finally, the design of paving stone structures requires taking into account the planned maintenance. For example, it is preferable not to use gravel joints in a market place where a brush/sweeper passes regularly.

In this regard, the points of attention related to the installation of reclaimed stone setts do not differ from those related to new ones. It is up to the designers/specifiers to rely on the regulations, the rules of practice and the technical standards in force in this field (in particular the European standard for exterior paving EN 1342). It should be noted that some local reference guides on the installation of stone setts already include the case of reclaimed setts (for example: the Qualiroute standard developed in the Walloon Region, Belgium).

The table below (*table 1*) shows the main requirements applicable to the installation of road stone setts for information purposes.

Think reversible!

Certain laying methods complicate or even prevent the recovery of stone setts. This is particularly the case with rigid laying, involving mortars and hydraulic binders. In this sense, as soon as possible and with comparable performance, it is preferable to favour a flexible installation (flexible base, sand bed and sand joints, stabilised sand or from a bituminous emulsion). Carried out according to the rules of practice, this installation method is very resistant to stress, is easily repaired and does not cause damage such as lifting or cracking.

Table 1 : Main requirements for the installation of stone setts

Recommended use	Compressive strength (MPa)	Minimum thickness (cm)	Stone setting	Installation type
decoration	no requirement	no requirement	All	Flexible or rigid
pedestrian use only	> 50	6	All	Flexible or rigid
pedestrian and cycling areas	> 85	8	All	Flexible or rigid
occasional access for light vehicles, garage entrances	> 100	8	All	Flexible or rigid
pedestrian traffic area, market places, occasional circulation of delivery/rescue vehicles	> 100	10	Not in panel	Rigid
pedestrian traffic area frequently used by heavy trucks	> 100	10	Not in panel	Flexible or rigid
roads and streets	> 100	12	Not in panel	Rigid

Sawing in 2 equal parts

Installation of sawn setts

Installation of sawn / rough pavers

The following characteristics can be described and specified when drafting the technical requirements related to the delivery of a batch of reclaimed stone setts:

→ *Batch composition.* The batch consists of reclaimed stone setts of the same type, same geological nature or even from the same original use. It is advisable to define one batch as a surface to be paved, with the same application and a maximum of 500 m². However, mixed stone setts batches may be suitable for less demanding applications.

→ *Format.* Depending on the installation, the stone setts must have a greater or lesser dimensional stability (same dimensions and same narrowness). Note: "mosaic" type installations accommodate greater variability in this regard.

→ *Colour.* By nature, variability in colour and appearance is specific to natural stones.

→ *Condition.* The batch must not contain items with cracks or major damage. Depending on the requirements, specify that the setts must be free of mortar and asphalt remains.

→ *Shape and finish.* According to the required needs, specify the appearance of the visible face (sawn, cleaved, convex, irregular, flat, etc.) and ask that it be identical for the entire batch.

→ *Quantity.* Some suppliers may include surplus when the product is delivered if they are not able to guarantee the absolute uniformity of the characteristics mentioned above. This surplus can also be applied in the case of an on-site salvage scenario. It is generally advisable to provide a reserve stock of stone setts in order to carry out subsequent repairs.

Most professional suppliers are able to ensure that delivered batches meet these requirements. A control test procedure based on a contractual sample and sampling upon receipt can be set up.

Most of the reclaimed building materials are sold as is. The conditions of sale may however contain special guarantees specific to the material. Some suppliers are able to indicate the origin of the material and/or provide documentation on the product purchased (for more information, see the introductory sheet).

Design tip!

To increase the chances of meeting the offer available on the reclamation market, the designer/specifier can choose to split large surfaces into smaller quantity batches (for example, by providing different assemblies and patterns on the surface to be paved).

Raeren town square (BE) © Carrière de la Hazotte

Project "Charles Malis", Molenbeek (BE) (Archi : Mamout + Willocx + LD2) © Studio Fiftyfifty

Characteristics and fitness for use

The harmonised European standard EN 1342 establishes the relevant characteristics (depending on the context) in order to determine the fitness for use of natural stone setts intended for exterior paving. Although detailed for new materials from the extraction and processing of natural stones, these characteristics may prove useful in considering the specific case of reclaimed setts (*table 2*).

Table 2: Characteristics relevant for determining the fitness for use of natural stone setts for external paving

Characteristics	Comments
Geological origin and petrographic description	The reclaimed stone setts come from works that may have been made from batches of multiple origins. If it is possible to visually characterize the type of rock present, it is however very rare that we can say with certainty that their geological origin is identical, unless there are records that allow it to be attested (for example: a certificate of origin for recent items or archival documents for older items). This is all the more true for the batches made up of stone setts of various origins.
Geographical origin	As with the geological provenance, information on the original geographic provenance of a batch of reclaimed stone setts is difficult to certify with any certainty. On the other hand, we can deduce certain characteristics if we know where the setts were removed. Thus, stone setts in good condition that have been dismantled in an area subject to strong freeze/thaw cycles are likely to show good frost resistance. Another example: stone setts in good condition coming from a street subjected to intensive traffic by heavy vehicles testify in some way to their good compressive strength. Thus, in the absence of information on the original quarry, it may be useful to have information on the roadway where the setts come from.
Bulk density and porosity	These characteristics are specific to each stone and can easily be found in the technical documentation. If necessary, they can be measured by an identity test as defined by a test standard (EN 1936). The porosity of a stone (or water absorption) does not directly affect its frost resistance. On the other hand, it influences its degree of resistance to soiling.
Flat dimensions (length, width)	This characteristic can be found out by taking simple measurements. It is closely related to the degree of sorting and cleaning of reclaimed stone setts. It is advisable to define with the supplier the applicable dimensional tolerance, depending on the equipment required and the functionality of the work. For example: flagstones in a straight fit require high dimensional stability (tolerance ± 10 mm).
Thickness	Use and type of stress generally define the minimum thickness required. The thickness tolerance is mainly dependant on the laying method and the thickness of the laying bed. For example, in flexible laying on a sand bed, a tolerance of more than 15 mm thickness is possible if the sand layer is 7 cm thick (± 1.5 cm). In rigid or semi-rigid installation, a lower tolerance applies. It is therefore advisable to define this tolerance with the supplier.
Narrowness, flatness and irregularity of the cleaved faces	These characteristics are closely related to the degree of sorting and cleaning of reclaimed setts. A visual or detailed examination of the batch is often sufficient to estimate them.
Compressive strength	This factor mainly determines the capacity of the work to withstand loads (vehicles, heavy goods vehicles). It is recommended to use paving stones with a strength greater than 60 MPa for structures subject to the passage of light vehicles (up to 25 heavy vehicles/day) and >120 MPa if the number of heavy goods vehicles exceeds 150/day. A standard test makes it possible to measure this parameter (EN 1926).
Slip and skid resistance	This feature influences the comfort and safety of users. It mainly depends on the roughness and texture of the surface. This characteristic changes over time under the influence of the surface wear, the presence of dirt, the maintenance conditions, the slope, the density of the joints and the climatic context (rainfall). In general, stone setts with a coarse texture (sandstone) and an irregular finish (not sawn) have sufficient slip resistance. A test standard makes it possible to measure this parameter for stone setts which have been sawn or have irregularities of less than 1 mm (EN 14231). The in-depth assessment of slip resistance is relevant when the work is intended for pedestrians and the skid resistance when the structure is intended for vehicular traffic. Specific finishing treatments (flame treatment, for example) may be applied during use in order to meet the requirements in force.

Characteristics	Comments
Resistance to freezing/thawing (and de-icing salts)	The source and condition of a batch of stone ettss can provide a useful guide to determining their resistance to freezing/thawing. Many old paving stones are in fact likely to have withstood, during their first use, more freezing/thawing cycles than what is recommended by the test standard which allows this performance to be evaluated on batches of new stone setts. (standard EN 12371 is indeed based on a test device which amounts to a laboratory simulation of cycles of successive exposure to climatic conditions varying in temperature and humidity). Less resistant setts that have suffered frost damage will probably have been discarded during the sorting steps.
Abrasion and scratch resistance (wear)	This durability characteristic depends on the intensity and type of traffic, the presence of abrasive particles and the maintenance conditions. If there is a test standard which allows this characteristic to be evaluated with precision (EN 14157 - Capon test), it can also be used for reclaimed stone setts, by relying on the way in which they have withstood the demands of their first use. In general, granites, porphyries and basalts are suitable for intense stress and are more resistant to wear than sandstones and limestones.
Dirt resistance	A porosity of less than 4% is generally satisfactory in order to limit the risks of soiling. It is also possible to visually identify the degree of soiling of the reclaimed stone setts by observing the visible face of the unprocessed (sawn) elements. Specific surface treatments can also be recommended to improve this performance.

As an indication, the following table (*table 3*) shows some of the known performances of some types of rock constituting stone setts which are frequently reclaimed. Once again, it is important to point out that each stone has its own characteristics and that two batches of stone setts of the same rock can however have quite different performances.

Table 3: Characteristics of the most common types of rock constituting stone setts which are frequently reclaimed

	Bulk density (kg/m³)	Compressive strength (MPa)	Porosity	Wear resistance
Sandstone	2000 - 2700	200 - 260	little porous	++
Bluestone (and limestone)	1500 - 2800	60 - 200	little porous	++
Porphyry	2000 - 2800	280	very little porous	+++
Granite	2500 - 3000	100 - 210	very little porous	+++
Basalt	2800 - 3000	320	very little porous	+++

Molenbeek town square (BE)
© a practice, Atelier Ruimtelijk advies et Marie-Françoise Plissart

Community center Werf 44, Schilde (BE)
© Conix RDBM Architects

Natural stone setts

Availability

The professional market for reclaimed natural stone setts is quite substantial. Suppliers are able to easily supply large quantities (>1000 m²).

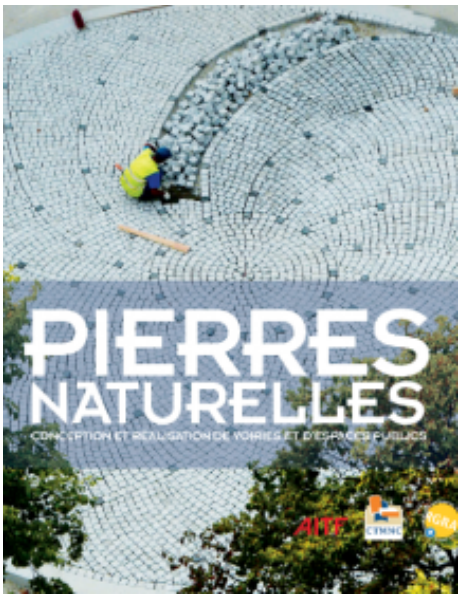
Indicative prices (excl. tax)

Random sampling of the reclamation market in Western Europe (Belgium, France, Great Britain and the Netherlands) made it possible to extract some indicative prices. These vary depending on the availability of the size and type of stone, as well as the degree of sorting and cleaning requested. A sorted stone sett is often more expensive than an unsorted one, but is easier to place.

- Cost of removal: 10 - 15 €/m². If the quantity is sufficient, disassembly can be taken care of by the operator.
- Supply: depending on size, type of stone, general condition of the batch, etc.
- The sawing operation generally costs between 30 and 60 €/m².

Did you know?

In his memoirs, Baron Haussmann recounts that he tried to convince Napoleon III to choose porphyry setts for the roads of the new Paris. Haussmann is full of praise for them: cleanliness, strength, durability, etc. But Napoleon III is a horseman! And hooves don't like cobblestones, they slip! He wants dolomite everywhere - and so much for the footmen who will have to deal with the mud on rainy days. Haussmann does not drop the subject. He urges his technical teams to think about a rubber horseshoe system, which would be better suited to cobblestones. He'd rather change the hooves of all the horses in Paris than see that damn dolomite. Ultimately, it is all the same for the emperor who will succeed and Paris will not have porphyry! (Memoirs of Baron Haussmann, 1890, Victor-Havard, Paris).



Pierres naturelles - Conception et réalisation de voiries et d'espaces (2019) (In French), RGRA, 440 p., ISBN : 978-2-913414-52-5

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Pavés de Bruxelles (2015) (in French), AAM Editions, 521 p., ISBN : 978-2-87143-308-8

Sorted and cleaned reclaimed stone setts	New stone setts
Sandstone 40 - 50 €/m²	Belgian sandstone : ~ 90 €/m²
Granite : 30 - 40 €/m²	Indian sandstone : ~ 30 €/m²
Basalt : 30 - 50 €/m²	Portuguese granite : ~ 30 €/m²
Porphyry : 20 - 30 €/m²	Vietnamese basalt : ~ 35 €/m²
Porphyry (mix of formats) : 15 - 20 €/m²	
Mosaic paving stone : 30 - 40 €/m²	

Embodied carbon (Cradle to gate - production A1-A3)	kg CO_2 eq./m²	kg CO_2 eq./kg
INIES database (FR)- Generic data *	45.0	-
ICE database (UK)– Granite **	175.0	0.7
ICE database (UK)– Sandstone ***	12.0	0.06

** Indicative value for a 1 m² and 15 cm thick natural stone covering of roads or public spaces for a reference lifespan of 150 years.*

*** Indicative value for a 1 m² covering in granite (thickness = 10 cm, density = 2500 kg/m³)*

**** Indicative value for a 1 m² covering in Sandstone (thickness = 10 cm, density = 2500 kg/m³)*

According to the sources, reusing 100 m² of reclaimed natural stone setts prevents the production of ~ 1,200 to ~ 17,500 kg of CO_2 equivalent related to the manufacture of new stone setts (production phase only). According to sources, this corresponds to the emissions of a trip of ~ 7,200 to ~ 105,000 km in a small diesel car.