GUIDE FOR THE DESIGN, CONSTRUCTION AND MAINTENANCE OF NATURAL STONE FOR EXTERNAL PAVING

CTG
Fundación Centro Tecnolóxico do Granito de Galicia
cluster del granito

Guide for the design, construction and maintenance of natural stone for external paving

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PRESENTATION

This technical guide to pavements introduces the reader to the world of natural stone, explaining the wide range of advantages offered by this material in terms of design and construction as well as the requirements that must be met to optimize its use.

The guide describes in detail and simply, the methodology to be used for the proper development of a natural stone paving, not only from the point of view but also from project implementation work, including controls reception of both materials and finished work units.

Also, it provides the reader a classification of the most common damage caused to stone pavements and the adequate procedure to repair them. This prior analysis prevents damage on stone pavements.

In addition, it provides a compendium of recommendations regarding pavement conservation and maintenance and an analysis of cleaning techniques. This section underpins the importance of proper maintenance and cleaning throughout the pavement lifespan in order to get the most from the qualities offered by this material.

The last chapter shows the base price of granite. This is an application that allows FIEBDC format a full description and the approximate price of each item of work that incorporates granite.

José Ángel Lorenzo Ramírez
Coordinator FCTGG

INTRODUCTION

The use of stone for pavement construction has been practiced by man throughout time with satisfactory results.

Today, the wide range of materials offered by the sector go beyond the natural stone products typical of the region opening the market to new varieties from anywhere in the world, wherever they may come from, as long as they can offer new features to the ones we already known.

With regard to granite, the entire value chain is concentrated in Galicia. Therefore this is a strategic sector for a region with an important concentration of natural resources, a significant extractive and productive industry and the necessary technology and know-how to provide a quality product to the end customer.

Galicia is the undeniable leader in raw granite production in Spain. Each year, around 800 000 granite blocks are extracted from Galician quarries, equivalent to 92% of the national total. In addition, the region is leader in granite transformation in Spain. The twelve million square meters of products manufactured in Galicia annually accounts for 78% of the total production in Spain.

The outstanding quality of its raw material and a state-of-the-art transformation industry stands the region at the second most important in Europe and the fourth in the world. This has led to international recognition resulting in important financial, social and technological changes for Spanish producers.

One of the most significant factors on the industries development is associated to architectural design as it prompted the emergence of different varieties of granite, enabling prescribers to find solutions to any architectural idea they may need to develop.

Therefore, granite varieties used for construction continue to grow with new surface finishes, greater formats and advanced quality controls at production process.

1.

STONE FOR PAVEMENT CONSTRUCTION

Stone is one of nature's most beautiful materials. Each piece stands out for its unique value and good performance over time, leading us back to our ancestor's footprints.

Today, this natural product offers endless design possibilities thanks to new surface finishes, cutting technologies and the broad range of varieties on the market.

Compared to other pavement materials, stone stands out for its high level of resistance and excellent durability.

1.1. Brief historic overview

Roman roads prove how suitable granite is as pavement material, about which there is much evidence in Spanish geography. Historically, this material was used by man to transform transportable routes into passable roads.

The stone's excellent durability represents an unquestionable fact as evidenced by the many roads constructed from this material where the wearing course stone, apart from being in a good state of conservation, has contributed to the conservation of the remaining system.

Despite the stone's excellence, these roads are also an example of high aesthetic value and construction techniques that, to some degree or another, could be valid today.

There were two different types of **Roman roads** sections: those with a wearing course layer made of natural stone flagstones and those with a wearing course layer made of granular soil with stone coating in order to lessen its erosion.

The first road type was typical of the streets of Roman cities and nearby vicinities. The presence of flagstones in these roads aimed to prevent strong dust emission of the carriage wheels when passing over them.

Roman road

The latter type was constructed for longer journeys between cities where dust emission was not a serious pollution problem although the purpose of this design was mainly economical.

Roman roads were made of four **layers** from the natural subgrade: *pavimentum, nucleus, rudus* and *statumen.* This constructive system's typology ended up being surprisingly similar to today's roads as in both cases they have a four layer configuration. The *pavimentum*, as the wearing course layer made of flagstones or cobblestones, the *nucleus* as the sitting bed, the *rudus* as the structural base and finally the *statumen*, as the subbase, whose addition to the system today depends on the load bearing of the subgrade.

Section ofroa

From a modern-day perspective, weariness caused by traffic is what makes analysis of any roadways more complicated. Nowadays, the concept of equivalent axial load is considered more as a design criterion.

Aside from being a technological example of good construction, Roman roads are also a historical sample of the importance of natural stone as a suitable material for pavement construction.

1.2. Natural stone designation

According to European regulations, in any pavement project, stone should be classified right from the outset from two points of view: a scientific or petrographic classification and a commercial designation or classification.

Scientific or petrographic identification establishes classification groups with common characteristics, both physical and chemical, in order to provide a basis, not only for commercial designation, but also for the establishment of prior evaluation criteria on rock behaviour in different applications.

On the other hand, **commercial designation** is established by the manufacturer according to the **marketing** strategy considered more suitable for each product. In short, the **rocks most used in construction** are:

- **Granite:** Crystalline rock with magmatic origins with a good level of resistance against compression and erosion caused by abrasion as well as an excellent environmental performance.

- **Marble:** Carbonated rock with metamorphic qualities made of calcite or dolomite crystals with a compact and crystalline texture, subject to good polishing. It has a good level of flexural and compression resistance and to a lesser degree, to erosion caused by abrasion.

- **Limestone:** A sedimentary rock made of calcite carbonate crystals but less crystalline than marble. There are frequent bioclastic varieties with many fossilized shell remains.

- **Sandstone:** A sedimentary rock made of quartz sand, feldspar, etc. bound together by variable composition cement.

- **Quartzite:** A metamorphic rock made of quartz crystals. It is very resistant to erosion caused by abrasion.

1.3. Varietie(4 04(fn)43(a)1 t)1uraa

Pavements constructed with different stone varieties

- **Slate/phyllite:** A metamorphic rock made of clay sediment. It has a very high level of flexural resistance, although some varieties are at risk of shearing.

On the Web www.clustergranito.com includes a list of companies in the cluster of granite, as a reference tool for prescribers. You will find all necessary information for each company and can get data from commercialized varieties.

1.4. Surface finishes

The surface finish of the stone constitutes its paving coat and represents its hallmark, along with size and petrographic varieties.

Surface finishes are always undergoing new developments but these are the most important ones:

- Polish: A finish whose final appearance is achieved through solutions, waxes, etc, and offers a mirror-like shine appearance. This type of finish cannot be used on outdoor pavements for safety reasons due to risk of slippage.

- Honed: Finish achieved with a variable granulometric grinding wheel which gives a smooth surface with a somewhat matt appearance. It is necessary to carry out a study to evaluate the risk of slippage in each case.

Main surface finishes

Polished (unsuitable for outdoors)

Honed

Bushhammered

Flamed

Slotted

Sheared

Brushed

Sandblasted

Sawn

- Bush hammered: A finish achieved with variable geometry bush hammers or spiked wheels that bang the stone surface, giving it a rough surface. Bush hammered surfaces do not present danger from slippage.

- Flamed: Achieved by thermal lance which gives a rough finish and does not present danger from slippage.

- Sheared: A natural stone shearing given by sedimentation or schistosity planes.

- Sand blasting: Achieved by the firing of a blast of sand giving a rough but smooth appearance to the surface due to the aggregate abrasion which can thus involve a certain slippage risk.

- Brushed: A finish similar to sand blasting but, in this case, metallic fiber brushes are used for the final finish.

- Sawn: Achieved with a diamond wire saw or gang saw.

- Slotted: Achieved by making slot drawings on the visible surface. Frequently used for pedestrian access signage.

1.5. Advantages of stone for pavement construction

Pavements constructed with natural stone for outdoor use have many advantages compared to other competitive products. Three features make the use of this material inviting: beauty, durability and design possibilities.

These three features are due to its properties, leading to a number of **advantages,** some of which are cited below:

- **Excellent physical properties:** The high level of resistance to stone compression, in particular granite, makes it an extremely strong and consistent construction material. The same can be said about its flexural resistance and especially to abrasion which is a priority in terms of durability for a pavement destined for vehicle or pedestrian traffic.

- **Non-flammable:** Natural stone has an A1 Class rating for its fire performance, classifying the material as «non-combustible, with no reaction even at the highest degree of fire». In the event of a fire, natural stone does not release substances that are harmful to health.

- **Excellent intrinsic features:** Stone is the only construction material that remains exactly as it was when it was first extracted from nature, without any chemical changes made to its structure or composition.

- **Different types of roughness and texture:** Achieved though several surface finishes that not only affect the aesthetic end result of the pavement but also improve certain technological features such as slippiness.

- **Different types of weaves and chromatisms:** Achieved thanks to a wide range of sizes, shapes and surface treatments due to the technological development of an industry that never fails to surprise prescribers, presenting them with an unlimited range of products that can be adapted to any environment.

- **Possibility of large formats:** Among all the materials used for paving, stone is the one that can offer the greatest formats.

- **Low maintenance costs:** Natural stone is not more expensive than other materials if we consider the total costs of construction material over a thirty year or more lifespan. Investment costs are offset by a low maintenance cost and a long service life.

- **Contemporaneity:** Stone is becoming a material widely used in contemporary construction today. Thanks to modern industrial techniques, it opens up a great number of possibilities for architectural design.

- **Sustainability:** The manufacture of stone clearly requires less energy consumption than many other materials such as ceramic

KEY IDEAS

- There is no question of stone's durability in pavements as demonstrated by the numerous architectural remains that were constructed from this material.
- Variations in colour, texture and finishes make each piece unique. Today, there is an infinite range of stones for pavement project development.
- Stone's good mechanical performance along with its excellent resistance to abrasion makes it a perfect material for outdoor pavement construction.
- Stone manufacturing requires much less energy consumption than many other materials.
- The possibilities of stone reuse in pavements makes it a sustainable material.

2.

PAVEMENT UNITS

*Generally, there are two natural stone **pavement types: slabs and setts.***

Both types of pavements involve keeping certain size requirements. Slabs for vehicular traffic involve intensity limitations on traffic during its service life.

*Apart from flagstones and cobblestones, there are other complementary natural stone units such as **curbs** and **footing trenches,** which also form part of the pavement.*

2.1. Slabs

Can be used to pave pedestrian transit spaces (footpaths) or vehicle traffic spaces (roads).

In pedestrian transit spaces, its use is limited to people or light vehicle transport (manually or engine operated with an unlade weight of no more than 200 daN, such as forklifts, bicycles, shopping trolleys, etc). Heavier vehicles can operate on this type of pavement on sporadic basis.

It must be noted that there is no such thing as exclusively pedestrian traffic. It is important to consider occasional parking or uncontrolled vehicles operation on city sidewalks when considering these types of pavements.

Natural stone slabs are paving units obtained by cut or shear with a nominal thickness greater than 12 mm and a width two times its thickness. They are supported on a mortar, adhesive or granular structure.

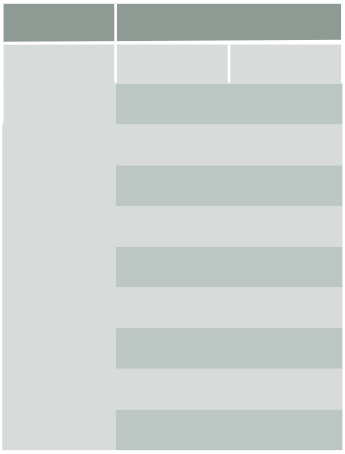
When using slabs on roads, it is recommended not to measure more than 500mm on surface and at the same time, not to exceed the 15,000 units of axis equivalent to 13 t over the pavement's service life[1].

1 See chapter 5: Calculation of paving system.

Slabs are also characterized by the type of stone selected, their measurements, thickness, shape and surface finish.

In terms of measurements, commercial catalogues of this product offer the market a wide range of formats. The formats currently demanded are increasingly greater in size although the most common ones are detailed below:

Most common slabs measurements



2.2. Setts

There are no limits for the use of this type of pavement. It can be used for any intensity of traffic, whether pedestrian or vehicular, and for any commercial tonnage, since it adapts to its intended use thanks to its resistant characteristics associated with the dimensional conditions.

It is often used to pave city streets, loading and service stations, parking areas, squares and even pedestrian footpaths.

Setts, just like slabs of natural stone, generally have a simple prism, rectangular or square shape. Mosaic and paved variety also exist. The former consists of small pieces of 4 to 5cm thick, creating a pavement for both pedestrian and vehicular traffic (very restricted in this case). A pavement of this type is found in the famous Portuguese streets.

Cobblestones also constitute smaller sized units with round pebbles and acicular tendency.

The many **advantages** of its use are: speed in its laying down, option of partial execution of special features (canalization through paving, unique meeting points, areas with interspersed vegetation, etc.), speed in operation (given that it can be opened to traffic flow as soon as completed since it is supported on a sand bed as well as bound with the same material), flexibility (due to its reduced size and its discontinuous nature), resistance and reuse.

2.3. Kerbs

These prism pieces have a square and rectangular section with a flat face. Its directive can be straight or curved as prescribed.

Kerbs are units for paving that are greater than 300 mm long and that, unless otherwise stated, are supplied in free length form.

They are stone elements in the shape of a belt or tape that finish off the edge of a sidewalk, footpath, etc.

Depending on its **geometric features,** there can be different **types** of kerbs:

- **Straight kerbs:** characterised by a completely rectangular section, where all corners are straight.
- **Bevelled edge kerbs:** can be identified by an almost rectangular section with bevelled edges.

Kerb sections

Granite is the most used **base material** for the construction of kerbs since it performs better in aggressive conditions due to its high mechanical and environmental resistance. The most used **surface finishes** are sawn kerbs, kerbs with visible faces flamed, rustic kerbs with all faces sawn and bush hammered kerbs.

Furthermore, there are other natural stone complementary units that should be taken into account, such as: **footing trenches** and **chamfered edges**.

Footing trenches are designed elements normally attached to the curbs embedded in the road. They are typically used for road traffic with the purpose of collecting and conducting run-off water. Therefore, it is quite common on roads and sidewalks, car parks, housing developments, industrial parks, etc.

Footing trench section

On the other hand, **chamfered edges** are used to separate panels of different appearance or function placed at the same pavement levels. Its thickness and width must be greater than 80mm with no length limitations.

Chamfered edges section

KEY IDEAS

- In practice, there is no such thing as exclusively pedestrian traffic. Occasionally, uncontrolled vehicles, motorcycles, cleaning trucks, etc. could park or drive in pedestrian areas in cities, a fact that needs to be considered when planning pavements.

- Setts can be laid down on pavements for intense traffic since they can fully adapt to any need thanks to their resistant features associated to size conditions.

3.

GUÍA PARA EL DISEÑO, CONSTRUCCIÓN Y MANTENIMIENTO DE PAVIMENTOS EXTERIORES DE PIEDRA NATURAL

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