IMPROVE TECHNIFICATION AND LCA QUALIFICATION OF WORKERS IN CERAMIC SECTOR WITH THE SUPPORT OF BIM APPLICATIONS

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REPORT 1.2.12

REPORT ON BEST PRACTICES ON METHODS, SKILLS AND COMPETENCES IN RELATION TO CLAY PRODUCTS

LAYING PROCESS OF CERAMIC PAVERS ON SAND BED

Consortium members: Associação Portuguesa da Indústria de Cerâmica (APICER), Centro Tecnologico da Cerâmica e do Vidro (CTCV), Asociación Empresarial de Investigación Centro Tecnológico del Mármol, Piedra y Materiales (CTM), Asociación Española de Fabricantes (Hispalyt), Institute of Entrepreneurship Development (iED).

Content

1. INTRODUCTION 3
Background 3
2. ENVIRONMENTAL CONSIDERATIONS 4
3. CONSTRUCTIVE CONSIDERATIONS 6
4. CONSTRUCTION PROCESS 10
CONSTRUCTION OF FLEXIBLE PAVEMENTS 10
1. Preparation of the surface. 10
2. Gravel sub-base layer dosing and roller compaction. 10
3. Base layer dosing and roller compaction. 14
4. Placing of the confinement edges. 15
5. Laying the ceramic pavers on the sand bed. 21
6. Grouting joints the sand and compacting. 26
CONSTRUCTION OF RIGID PAVEMENTS 30
1. Preparation of the surface. 30
2. Gravel sub-base layer dosing and roller compaction. 30
3. Laying of the base. 30
4. Spreading of mortar layer. 32
5. Laying the ceramic pavers. 32
6. Grouting the joints and cleaning. 33
5. SUMMARY OF STEPS TO BE FOLLOWED IN THE CONSTRUCTION PROCESS 35
6. REFERENCES 36

1. INTRODUCTION

Background

The BIMclay project was born with the purpose of producing and developing didactic materials based on the BIM methodology, which address the challenges related to Life Cycle Analysis (LCA) of clay products, to serve as a training base for professionals in the ceramic sector. To this end, it is necessary to define and compile the most suitable execution systems and tile installation methods for clay and ceramic products.

The first task of the BIMclay project "O1. Establishment of common learning results on clay placement methods, Life Cycle Analysis (LCA) and regulations" encompasses a series of specific tasks among which we find the elaboration of this report "Laying process of ceramic pavers on sand bed".

This best practice report addresses the establishment of skills and competences, as well as the definition of the most sustainable and environmentally friendly construction processes.

This report “Laying process of ceramic pavers on sand bed” deals with the execution of the construction process of an exterior pavement on sand bed.

2. ENVIRONMENTAL CONSIDERATIONS

The Environmental Product Declarations (EPDs) are the clearest, most rigorous and internationally accepted way to provide the environmental profile of a product throughout its life cycle.

The EPD "***Adoquines cerámicos según la Norma UNE-EN 1344 (Ceramic pavers according to UNE-EN 1344)***" has been verified and published in AENOR's GlobalEPD programme.

The EPD of ceramic pavers has been carried out according to the LCA (Life Cycle Assessment) methodology with quantified environmental information of its entire life cycle. In other words, the EPD of ceramic pavers is of the "cradle to grave" type, as can be seen in the following table, which includes the life cycle stages considered.

Etapa de producto	A1	Suministro de materias primas	X
	A2	Transporte a fábrica	X
	A3	Fabricación	X
Construcción	A4	Transporte a obra	X
	A5	Instalación / construcción	X
Etapa de uso	B1	Uso	X
	B2	Mantenimiento	X
	B3	Reparación	X
	B4	Sustitución	X
	B5	Rehabilitación	NR
	B6	Uso de energía en servicio	X
	B7	Uso de agua en servicio	X
Fin de vida	C1	Deconstrucción / demolición	NR
	C2	Transporte	X
	C3	Tratamiento de los residuos	X
	C4	Eliminación	X
	D	Potencial de reutilización, recuperación y/o reciclaje	MNE

X = Módulo incluido en el ACV; NR = Módulo no relevante; MNE = Módulo no evaluado

Source: Manual para el Uso del Adoquín Cerámico

This EPD has been developed and verified according to the UNE-EN 15804 and UNE-EN ISO 14025 standards and the Product Category Rules (PCR) for fired clay products used in the construction of AENOR's GlobalEPD programme.

The Hispalyt EPD functional unit is defined as 1 tonne of ceramic pavers with an average reference service life of 150 years.

The EPD details the formulation to be used (conversion factor) to transform the functional unit of one tonne of ceramic pavers to one square meter of pavement.

3. CONSTRUCTIVE CONSIDERATIONS

There are two different types of ceramic pavers:
- Flexible pavement.
- Rigid pavement.

USE AND SELECTION OF THE TYPE OF PAVING:

Ceramic pavers laying as rigid pavement are recommended in the following cases:
- Floors with a slope of more than 9%.
- Areas where continuous projections of water are foreseen, such as car washes, edges of swimming pools and shower areas, industries where frequent pressure washing of the pavement is required, etc.
- When the designer or prescriber looks for the effect of a wide sore, or when other conditions of the project require it.

Apart from the cases previously mentioned as advisable for rigid pavement, the solution of flexible pavement with ceramic pavers is recommended for the following reasons:
- The use of sand means a reduction in costs, both in materials by avoiding the use of mortars, and in labour, as the yields of this increase considerably.
- It is not necessary to make expansion joints in this type of paving, which gives continuity to the pavement that improves the aesthetic aspect and allows the designer greater freedom in the design of the space.
- With a well-calculated base and choosing the appropriate paving stone model, it allows, with total guarantee, the paving of roads that support heavy vehicle traffic.
- It facilitates any type of reform that wants to be done to the pavement later. This is especially useful when repairs are needed to service networks buried under the pavement, as it allows the reuse of parts that have to be lifted in the same position. This is not only an economic saving, but also avoids the usual "patches" that are produced in other pavements.
- The commissioning of these pavements is immediate, without having to wait for the binders to acquire the necessary strength.

COMPONENT ELEMENTS OF EACH TYPE OF PAVING:

Flexible pavement.

The constructive system for the execution of flexible pavements with ceramic pavers consists of the placement of the pieces on a bed of coarse sand, pre-compacted without agglomerates and the subsequent filling of the joints with sand of smaller diameter and compaction of the set.

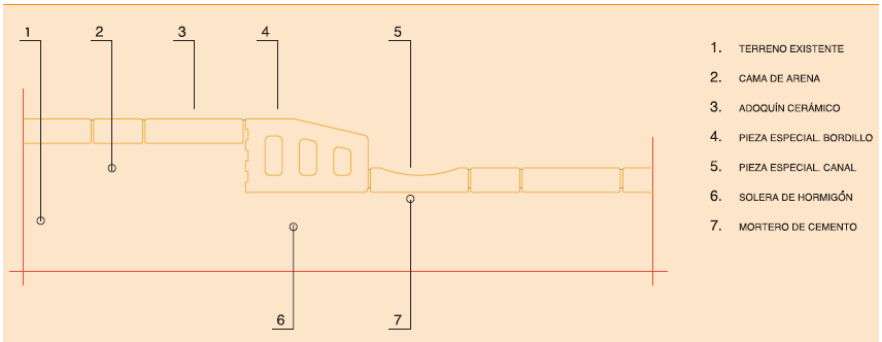
The elements that compose this pavement are:

- Confinement edges.

These edges are the elements of containment of the pavement that precede the placement of the sand layer.

Their main functions are: to avoid the displacement of the pieces, the opening of the joints and the loss of interlocking between the pavers of fired clay.

In order to guarantee these functions correctly, a minimum fixing is necessary, supporting the confinement edges at least 15 cm below the lower level of the pavers.



Source: Manual para el Uso del Adoquín Cerámico

- Cover or sand bed.

This element is placed on the already executed base of the surface, being advisable the execution of this layer of levelling or sand bed with natural sand well washed. The particle size should be between 5 and 0.4 mm, and no more than 10% of the material should exceed or be below these margins. In general, coarse natural sands give good results. The material shall not contain more than 3% clay and silt and shall be free from foreign matter and harmful salts.

Once the ceramic pavers have been laid and the pavement has been vibrated, the thickness of this layer will be between 3 and 5 cm, and the entire layer of sand must be of uniform thickness.

If the thickness of the paving sand layer is reduced (< 5 cm), it has been shown that the deformations due to vehicle tracks also decrease.

One of the most common causes of failure in paved floors is the execution of a layer of sand with too much thickness to correct an incorrect levelling of the base. This thick layer is compressed and consolidated with the passage of the vehicles, causing irregularities in the paved surface, therefore, it is recommended the execution of the sand layer with the thicknesses mentioned above.

- Ceramic pavers.

They are the resistant and, at the same time, decorative pieces placed on the sand bed previously executed. It should be remembered that, for ceramic pavers on flexible pavements, the nominal thickness of the pieces must not be less than 40 mm and the nominal dimensions must be such that the ratio between total length and width does not exceed 6.

The ideal joint between ceramic pavers should be between 3 and 5 mm and in no case should butt pieces be placed, thus discouraging the use of automated tools that place the pieces in this way.

- Sealing sand.

Grouting the joints between ceramic pavers, using natural, fine, dry sand with a grain size of between 0 and 2 mm, free of harmful soluble salts.

The use of limestone crushing sands is discouraged, as they often have a high dust content that would tarnish the surface of the pavement. Very clean sands facilitate the filling of these joints, but they may have the defect of being loose in a first stage, clumping little by little with the passage of time. Sand with a moderate silt content improves this initial sealing of the paving.

Rigid pavement.

The constructive system for the execution of rigid pavements with ceramic pavers consists of the placement of the pieces with mortar joints on a similar mortar bed, the latter in turn placed on a rigid base.

The elements that compose this pavement are:

- Mortar layer.

This element will be placed on the concrete floor of the base of the pavement.

For this layer, we recommend the use of an M-15 mortar (with dosages of 1:3, or 1:1/4:3 if you want to add lime), with a hard consistency and layer thicknesses of about 3 cm.

- Expansion joint.

The expansion joint of the ceramic paved shall coincide with the joints already made in the base layer, having a depth equivalent to the entire thickness of the ceramic pavement. Its mission is to accommodate movements that may occur as a consequence of thermal expansion, expansion due to humidity, etc.

The dimensions of this element will be about 20 mm, being necessary to place expansion joints every 5 x 5 m.

These joints must be filled and sealed with a sufficiently elastic material.

- Ceramic pavers.

They are the resistant and, at the same time, decorative pieces placed on the previously executed mortar layer. It should be remembered that, in rigid pavements, the ceramic pavers should not have spacing peaks and it is recommended that they be separated by a mortar joint of between 6 and 10 mm.

The thickness of the ceramic pavers, in rigid paving, shall not be less than 30 mm.

- Grout filling mortar.

Once the ceramic pavers have been laid correctly aligned and levelled, the joints are filled with a mortar of the same dosage as that used for laying the ceramic pavers, but with a soft or fluid consistency. In the latter case, containers can be used with jar-type mouths, which will allow for less dirtying of the pavers.

4. CONSTRUCTION PROCESS

CONSTRUCTION OF FLEXIBLE PAVEMENTS

1. Preparation of the surface.

The area to be paved must be cleaned, cleared and excavated or filled to the appropriate level necessary to achieve the thicknesses, slopes and levels required by the project, ensuring that deviations are minimal.

The resistance of the ground, the phreatic level and the levelling of the prepared surface must be known for a good realisation of the pavement.

In the case of soils classified as unsuitable for use as a levelling base, in accordance with the Pliego de Prescripciones Técnicas Generales para Obras de Carreteras y Puentes (General Technical Specifications for Road Works and Bridges) PG-3, they shall be replaced or consolidated.

Care shall be taken to eliminate softened areas and to prevent water accumulation during the work.

Source: BIMclay project website.

2. Gravel sub-base layer dosing and roller compaction.

It is advisable to add this layer, provided that the paving will withstand heavy traffic. In the case of pedestrian areas, depending on the nature of the base of the levelling and the type of base to be projected, it may also be necessary to include a sub-base.

The material to be used will be composed of natural aggregates or from the crushing of quarry stone or natural gravel, slag, selected soil or local materials free of clays, loams or foreign matter.

Its maximum size shall not exceed 1/2 of the thickness of each layer. The granulometric curve will be adapted to the spindles defined by the PG-3, in the case of natural gravel it will be adapted to one of the following ones:

Cernido ponderal acumulado (% en masa)			
Abertura Tamices UNE-EN 933-2 (mm)	Tipo de zahorra natural *		
	ZN40	ZN25	ZN20
50	100	-	-
40	80 – 95	100	-
25	60 – 90	75 – 95	100
20	54 - 84	65 - 90	80 – 100
8	35 - 63	40 - 68	45 - 75
4	22 - 46	27 - 51	32 - 61
2	15 – 35	20 – 40	25 – 50
0,500	7 - 23	7 - 26	10 - 32
0,250	4 - 18	4 - 20	0 - 11
0,063	0 - 9	0 - 11	0 - 11
* La designación del tipo de zahorra se hace en función del tamaño máximo nominal, que se define como la abertura del primer tamiz que retiene más de un diez por ciento en masa.			

Source: Manual para el Uso del Adoquín Cerámico

The material shall be non-plastic and its sand equivalent greater than 30 (EA > 30).

The support capacity of the material shall be such that it has a CBR index greater than 20.
Once the material has been spread on site, it will be adequately humidified to be compacted. The density reached after compaction will be greater than 95% of the maximum obtained in the modified Proctor test.

When elaborating the base, special care will be taken to level the project surface, avoiding possible deviations as much as possible. Otherwise there may be discontinuities in the sand bed that affect the homogeneous performance of the paving, especially during the compaction process.

Any of the following materials can be used, properly dimensioned:

a) Artificial gravel.

It is best to use material from crushing and crushing quarry stone or natural gravel. The fraction retained by the sieve 5 UNE must contain at least 50% by weight of elements with two or more fracture faces. It must be free of organic matter, dust, clays and any other harmful matter. The material shall be non-plastic and its sand equivalent shall be greater than 35 for heavy traffic and 30 for all other cases.

The particle size curve of the aggregates shall be adapted to one of the following spindles defined by PG-3:

Cernido ponderal acumulado (% en masa)			
Abertura Tamices UNE-EN 933-2 (mm)	Tipo de zahorra artificial *		
	ZA25	ZA20	ZAD20
40	100	-	-
25	75 - 100	100	100
20	65 - 90	75 - 100	65 - 100
8	40 - 63	45 - 73	30 - 58
4	26 - 45	31 - 54	14 - 37
2	15 - 32	20 - 40	0 - 15
0,500	7 - 21	9 - 24	0 - 6
0,250	4 - 16	5 - 18	0 - 4
0,063	0 - 9	0 - 9	0 - 2
* La designación del tipo de zahorra se hace en función del tamaño máximo nominal, que se define como la abertura del primer tamiz que retiene más de un diez por ciento en masa.			

Source: Manual para el Uso del Adoquín Cerámico

Once the material has been spread, it shall be suitably moistened for compaction, which shall reach 100% of the maximum density obtained in the modified Proctor test. Sometimes it is advisable to receive sand and its compaction to avoid later losses of the sand bed, or to interpose a sheet of geotextile material.

b) Gravel-cement.

The aggregates to be used in the mixture will come from the crushing of quarry stone or natural gravel. The granulometry will be adapted to one of the spindles defined in PG-3:

Cernido ponderal acumulado (% en masa)		
Abertura Tamices UNE-EN 933-2 (mm)	Tipo de gravacemento	
	GC25	GC20
40	100	-
25	76 - 100	100
20	67 - 91	80 - 100
8	38 - 63	44 - 68
4	25 - 48	28 - 51
2	16 - 37	19 - 39
0,500	6 - 21	7 - 22
0,063	1 - 7	1 - 7

Source: Manual para el Uso del Adoquín Cerámico

The aggregates used shall be non-plastic and their sand equivalent greater than 30 (EA > 30). They shall be free of organic matter and the proportion of clods of clay shall be less than 2% by weight.

The cement to be used shall be type II class 32.5 (N/mm2). The dosage of cement shall not exceed 4.50% by weight in relation to the total of aggregates.

The compressive strength of seven-day specimens manufactured on site with the modified Proctor mould and compaction shall not be less than 35 kg/cm2.

The work will be carried out following the recommendations of PG-3, with special care in the adequate humidification of the support and in avoiding segregation of the mixture during transport. It is necessary to guarantee the continuity of the work and, in the event of major interruptions, the appropriate working joints will be carried out.

The compaction will be carried out in a single pour, it being recommended to reach 100% of the maximum density of the modified Proctor of the mixture with cement, and in no case less than 97%.

Once the compaction is finished, the gravel-cement layer will remain wet and later it is advisable to apply an irrigation with bituminous binder on which 0 - 5 mm of sand will be sprinkled.

Source: BIMclay project website.

c) Concrete.

It is recommended the use of mass concrete with a characteristic resistance of not less than 10 N/mm2, being able to use aggregates with a maximum size of 40 mm. that comply with the specifications of the EHE instruction.

The wetting of the support or the interposition of plastic membranes that avoid the dehydration of the mixture will be taken care of during the execution. The surface should be smoothed "a pass-rule", avoiding protrusions or re-sinking of importance, but without smoothing it completely. Appropriate expansion and working joints should also be provided. Finally, the concrete should be cured properly using the methods deemed appropriate.

3. Base layer dosing and roller compaction.

For the pavement to be properly laid, it is necessary that, prior to laying the ceramic pavers, the confinement edges or perimeter kerbs have been laid, in order to have the alignment and support necessary for laying the pavement, containing the external thrust produced by the pavement and preventing the sand from dispersing.

By means of the execution of the confinement edges, the displacement of the pieces, the opening of the joints and the loss of interlocking between the pavers of fired clay are avoided.

If the option of constructing the confinement edges after laying the paving stone were chosen, the loads on the pavement would have to be limited to a margin of approximately 1 metre,

counted from the unconfined end. In this case, prior to the construction of the edge, the correct condition of the end cobblestones should be checked and, if necessary, they should be replaced.

In order to ensure the necessary fixation, the confinement edges must be supported at least 15 cm below the lower level of the pavers.

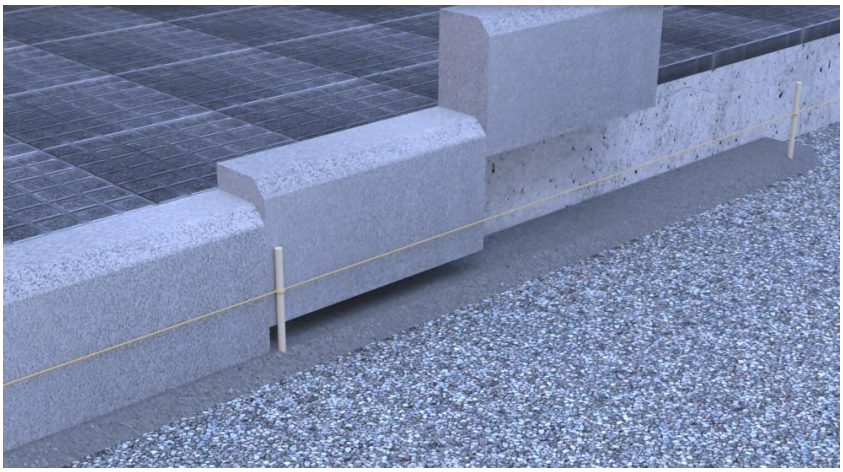
Care should also be taken to seal the vertical joints between the adjacent elements to prevent sand from escaping (sand layer or sealing sand).

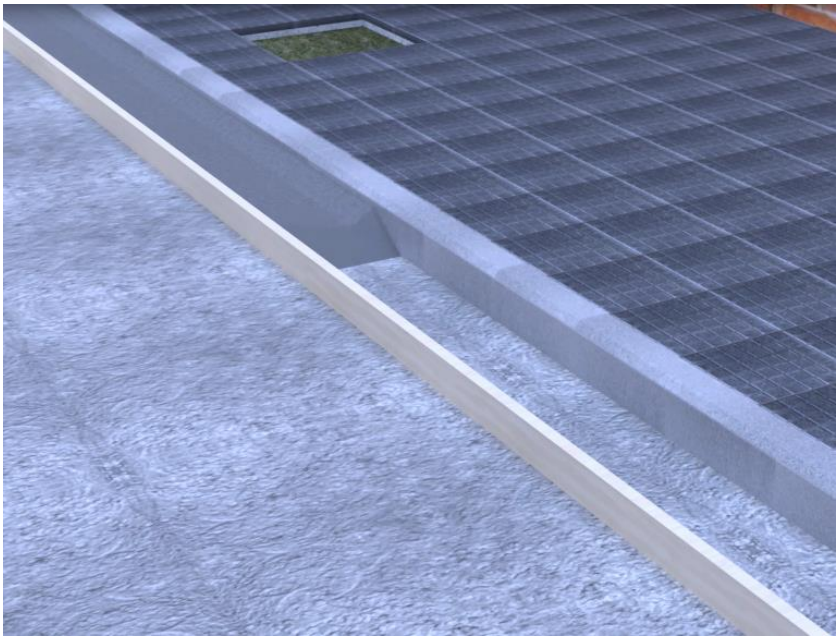
There are several types of kerbs: special pieces of fired clay edge, wall, concrete block, stiff, natural stone, ...

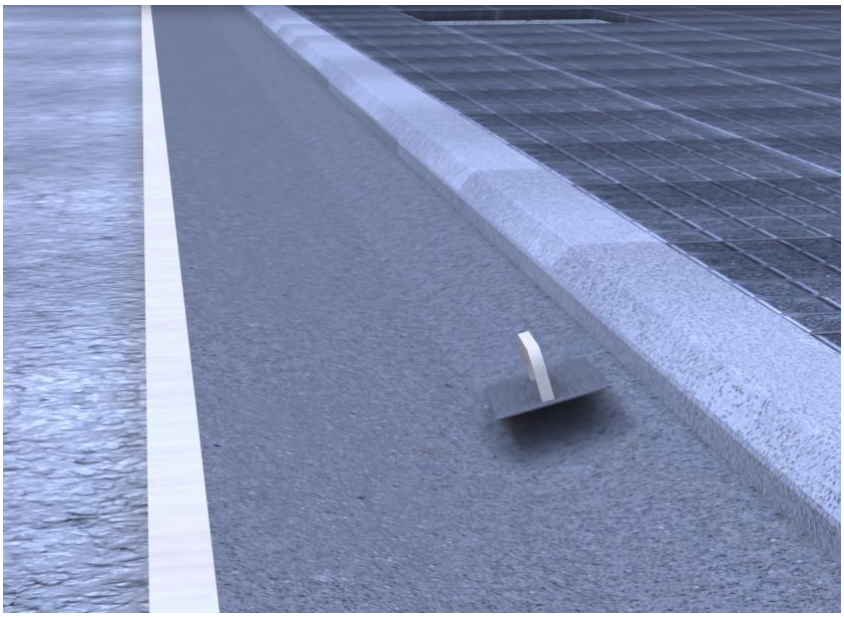
4. Placing of the confinement edges.

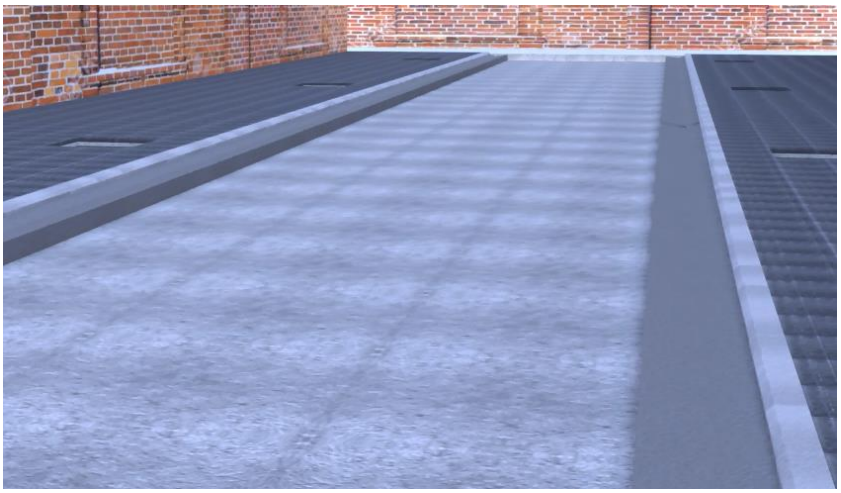
The thickness of this layer will be between 3 and 5 cm once the ceramic pavers have been laid and the pavement has vibrated.

Before paving the sand in an area, all the kerbs and other containment elements of the pavement have been laid, as well as the necessary drains, if necessary, to evacuate filtration water.







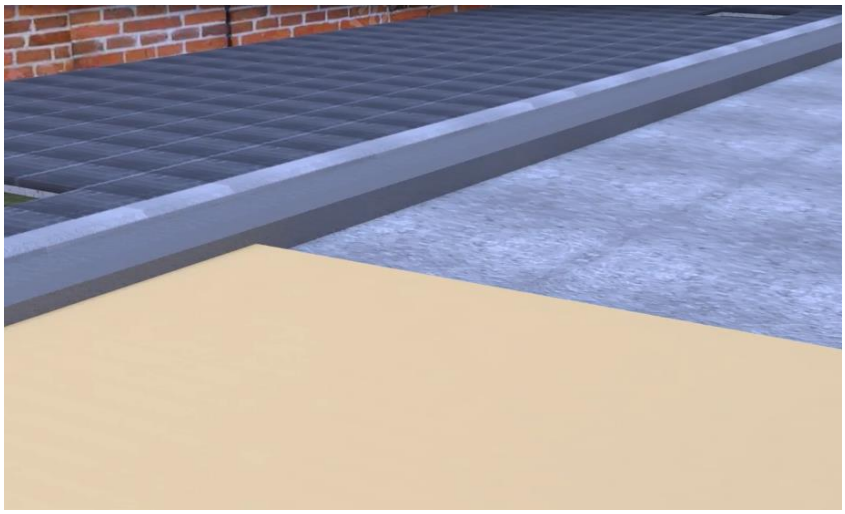


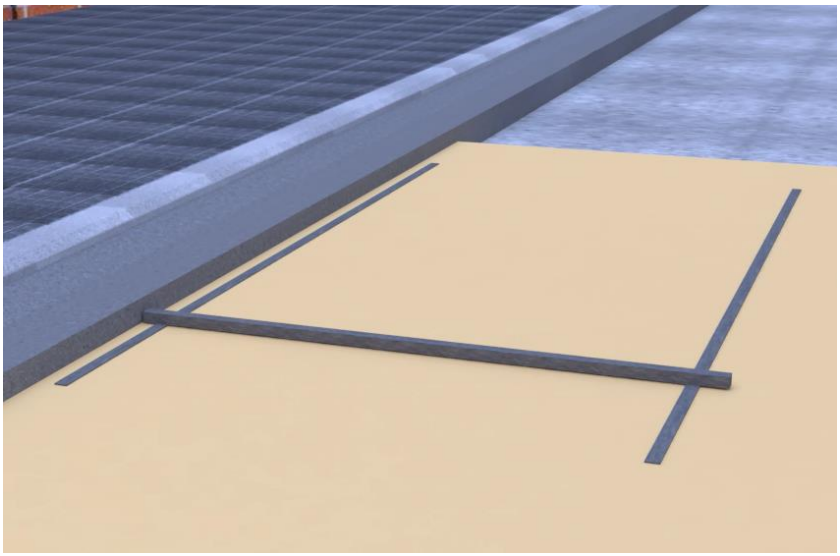
Source: BIMclay project website.

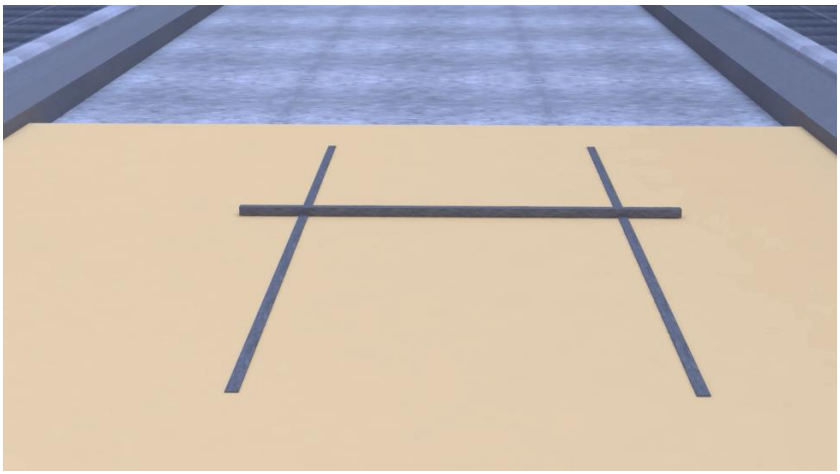
In order to avoid wasting material, it is not advisable to spread sand over very large sections at the same time, which implies a correct organisation of the work by means of sections of 3 or 4 metres.

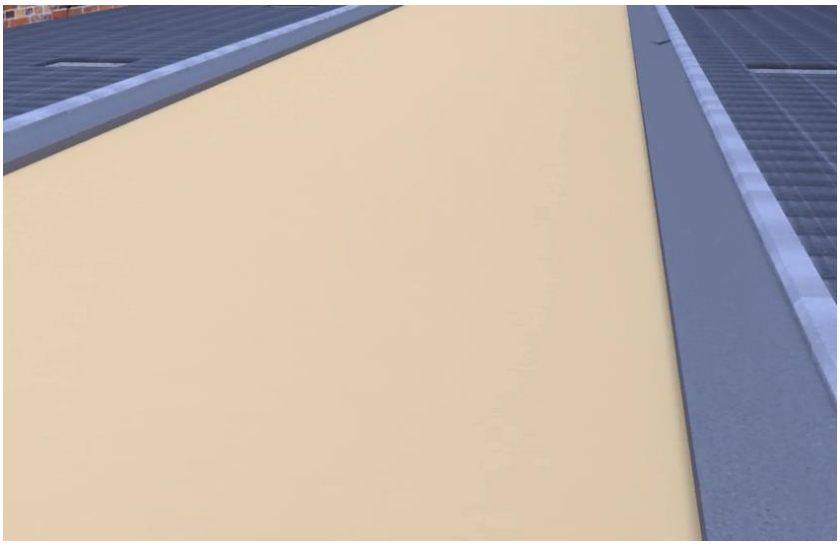
Flexible ceramic pavements end up performing as waterproof pavements, since dust and dirt end up completely clogging the sores, preventing water infiltration through them, so they will be projected with elements of surface drainage. In any case, in order to avoid possible saturation of the sand bed in the first stage of use, when the base is impermeable, drainage can be foreseen in that stage. In these cases, the precaution of interposing geotextile-type membranes between the sand and the drainage element should be taken in order to avoid seats due to loss of sand.

The sand will be spread in a uniform layer, loose and without compacting, until the necessary height to obtain, once compacted, the fixed levels. The usual system for scraping this layer is the use of continuous rules on masters in which the scrapes have been recorded.









Source: BIMclay project website.

Another system that can be used for paving this layer, improving yields, is to scrape the sand using vibratory rules.

The sand is pre-compacted using roller tamping machines or vibrating trays.

It is always preferable to add less sand when spreading and recreating, if necessary, once the layer has been pre-compacted, compacting again when the added quantity has a certain importance.

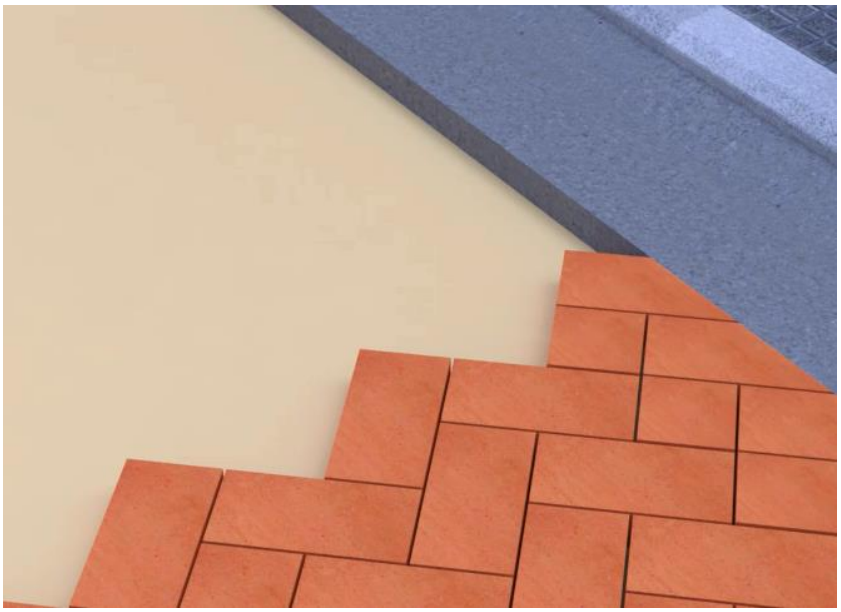
5. Laying the ceramic pavers on the sand bed.

Once the sand layer has been grazed and pre-compacted, the ceramic pavers will be laid on it in accordance with the projected rigging.

There are a multitude of possibilities for the design of ceramic pavements, combining the different equipment possible for each model, the different formats and colours.

When designing flexible pavements with ceramic paving stones, adequate provision will be made for slopes and surface drainage elements. In order to achieve adequate drainage, the transverse slopes must be at least 2% and the channel slopes approximately 1%. When projecting sections with slopes greater than 9%, the use of rigid pavement solutions is recommended.

It is advisable to take ceramic pavers from several shovels simultaneously, and in vertical and non-horizontal layers. In this way, the pavement will present a mixture of pleasant tones and a great aesthetic effect.

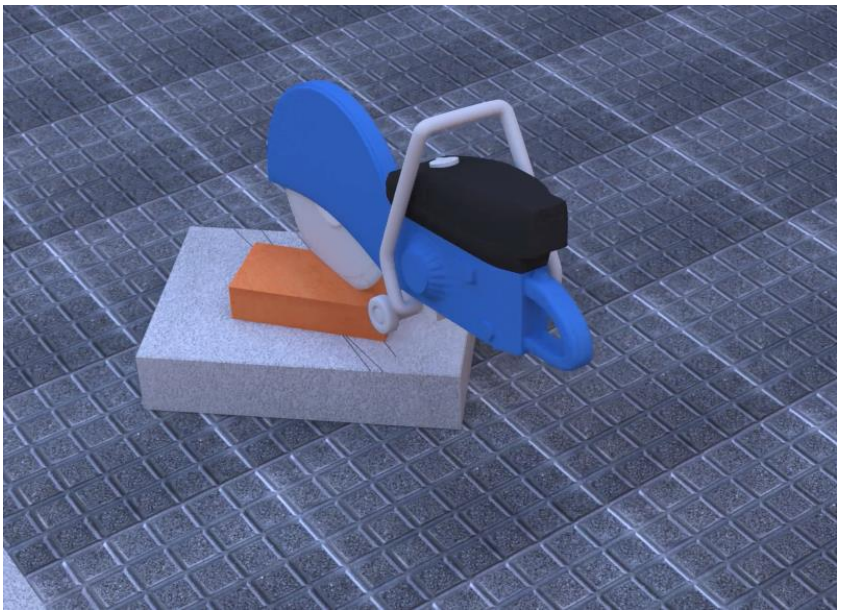


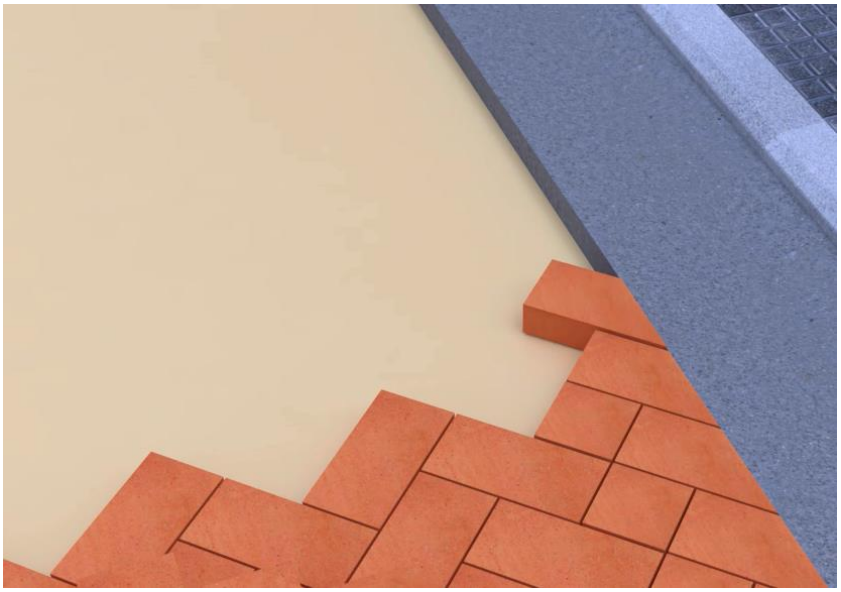
Source: BIMclay project website.

It is essential to carry out a perfect staking out of the pavement; to achieve this, the necessary pieces will be taken and presented in the place where they are going to be placed, with the separation of the real joint, in order to adjust the containment edges as much as possible to

measures of complete pieces; carrying out this operation correctly will avoid unnecessary cuts of pieces that make the execution more expensive and diminish the quality of the finish.

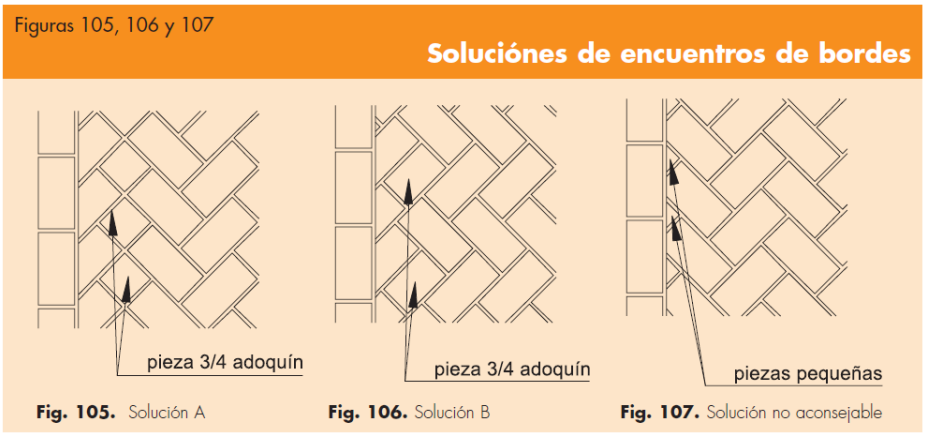
In case of having to cut the ceramic pavers, it will be done with a suitable disc or shear.





Source: BIMclay project website.

It is not advisable to place pieces of a size smaller than 1/4 of the paving stone, being able to solve the edge joints with the inclusion of half pieces or pieces at 3/4. If the distance between the paving stone and the edge is less than 4 cm, the corresponding gap can be filled with mortar (4:1 sand - cement ratio). Figures 105, 106 and 107 show some possibility of solving this problem.



Source: Manual para el Uso del Adoquín Cerámico

When there are elements inside the area to be paved, such as corks, pillars of structures, manholes, etc., the adjustments of the pavers will be made in the same way as with the confinement edges.

The ideal joint between paving blocks should be between 3 and 5 mm. Under no circumstances should butt joints be used. On these dimensions, the layer can make slight modifications in order to maintain the correct alignments. These alignments shall be systematically checked, by means of rules, the sufficient number of axle ropes or any other appropriate system. Likewise, the levelling points of the pavement will be monitored, for which the levelling points will be recorded in the masters, which will serve as a reference for running threads or rules.

The laying of the ceramic paving stone will be carried out avoiding stepping on the layer of sand, for which work will be done on the already laid part of the pavement, trying not to concentrate loads due to stacking of material (laying of paving stones one metre behind the main working edge) or to the same operators near the working edge.

Do not lay paving stones on waterlogged or excessively wet sand beds. In order to avoid problems in case of rain, it is advisable not to spread layers of sand on surfaces much higher than those that can be covered in a working day. Ideally, at the end of each day, the levelling layer should protrude approximately 1 metre from the pavement.

The laying sequence of the ceramic pavers must be planned in order to achieve a good performance of the work. The pavement must always start with a kerb line, which is the natural guide. In order to maintain the projected design, the ceramic paver must follow the correct sequence. Figures 108 and 109 explain examples of herringbone laying at 45º and 90º.

Figura 108

Ejemplo adoquinado espina de pez a 45°

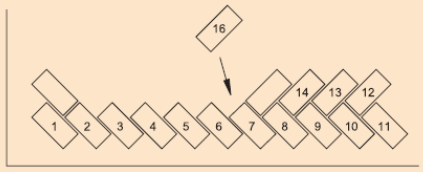
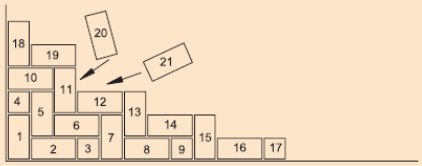


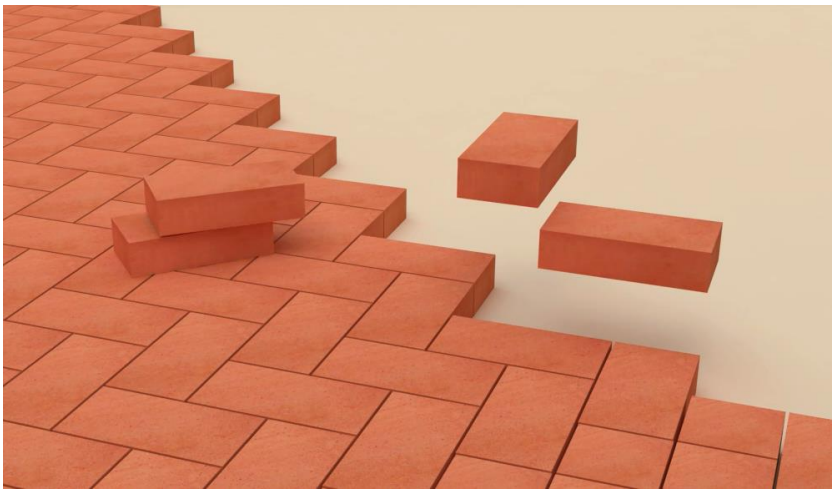
Figura 109

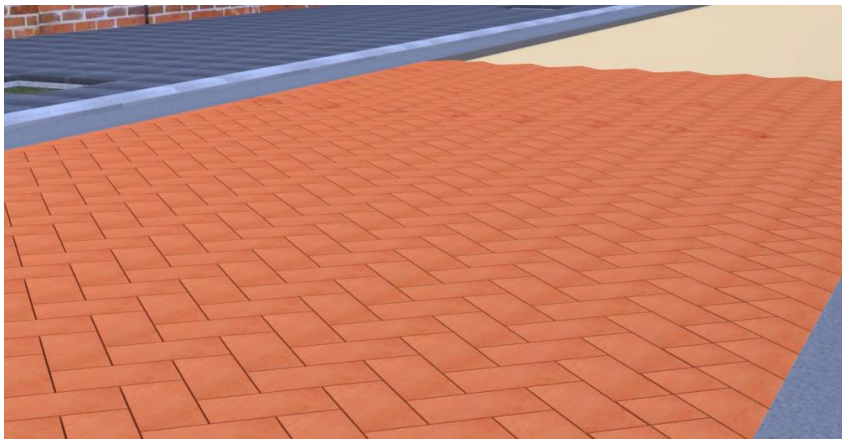
Ejemplo adoquinado espina de pez a 90°



Source: Manual para el Uso del Adoquín Cerámico

With the herringbone design at 45º only one bricklayer can work; at 90º more than one. The linearity of the joints has to be continuously checked: 90º cords will mark the good execution of the pavement.





Source: BIMclay project website.

One of the great advantages of flexible flooring is the speed of its construction. In order to improve performance, we recommend the following recommendations:

- Once a section of two to three meters has been advanced, the deviations of the complete section are corrected by placing a plank against the edges of the free edge and hitting with a flowerpot (hammer with a head with two equal mouths and a short handle) until the pieces are brought to the required alignment. For herringbone rigging, edge trim pieces can be provisionally placed to achieve a straight line on which to support the plank or to prepare a wood with the shape of the sawtooth that fits into the holes.

- When it is intended to correct alignments in cloths fitted between already executed confinement edges and it is not possible to follow the previous method, or to align pieces in rigs where some of the joints is run and in the direction of this one, can be used nails and levers, that introduced in the joints will easily move the yarns to the correct position; in this case it is only necessary to be careful to fit these useful ones so that they do not chip the edges of the pieces.

- When the pieces are placed by several operators at the same time, especially if the rig is in herringbone, it is advisable to alternate their positions. In this way the differences between the cuts are corrected.

With these systems, not only is the rhythm of execution increased, but the final result will be visibly improved by absorbing the slight differences in the calibre of the pieces and the imperfections in their placement.

It is also not necessary to check the exact levelling of the flooring piece by piece, as long as they are placed on a bed of well-flush sand, as any minor irregularities that may exist will be corrected

in the subsequent compacting process. However, it is advisable that the pieces are not too "nodded", which is easily achieved by hitting the edges with a rubber mallet that protrude abnormally before compacting; this way we avoid breaks in the tamping.

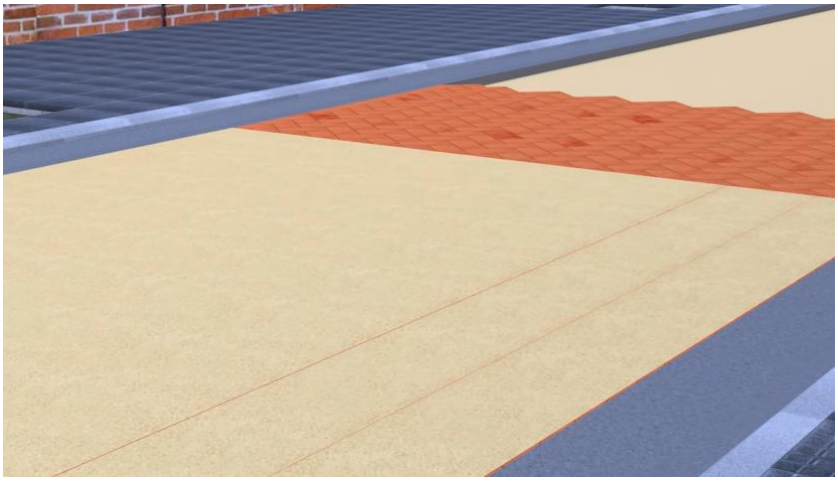
The paving performance can vary between 15 m2/man/day and 25 m2/man/day, depending on the characteristics and organisation of the work. The use of mechanised or automated procedures in which it is not possible to establish an ideal joint between paving stones of between 3 and 5 mm is discouraged.

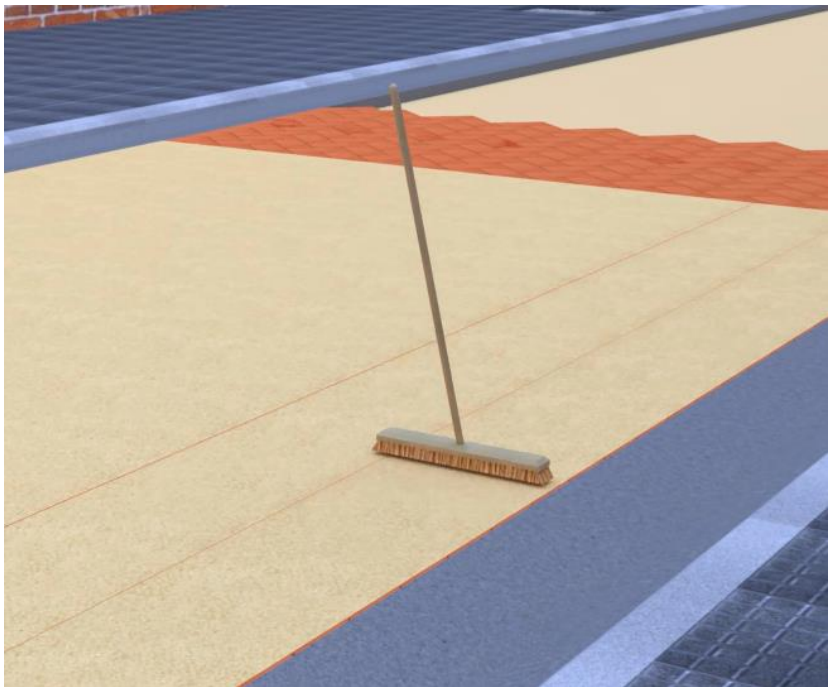
6. Grouting joints the sand and compacting.

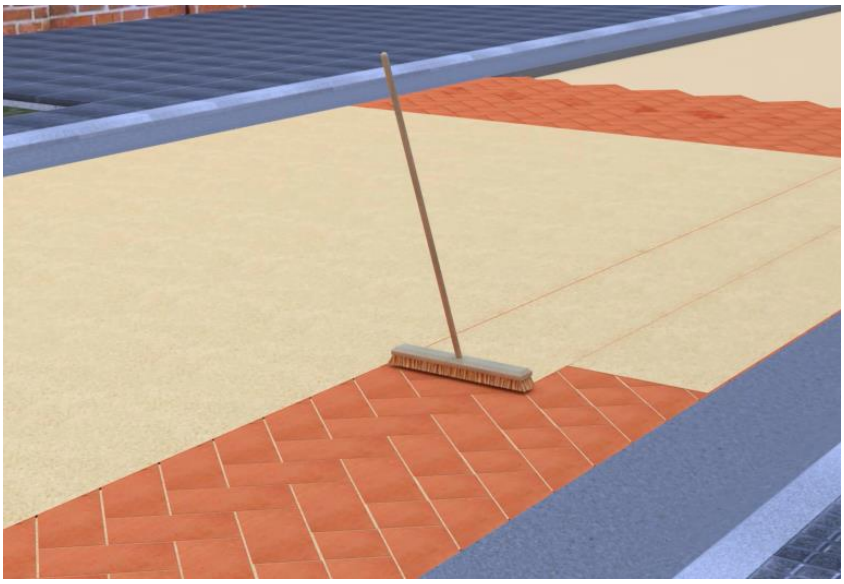
- Grouting the joints.

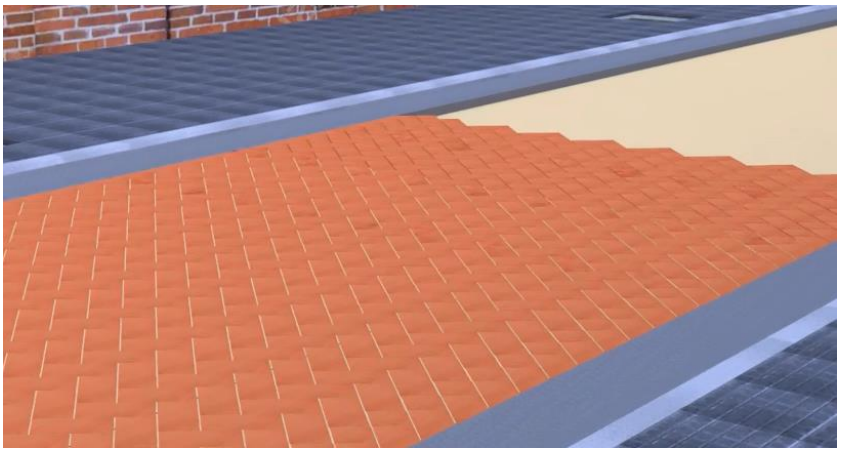
Once a sufficient surface of ceramic pavers has been laid, the joints will be filled.

The sand is spread over the pavement and then swept over until the joints are filled satisfactorily; the excess sand is removed from the surface to be compacted by sweeping and not by washing with water.









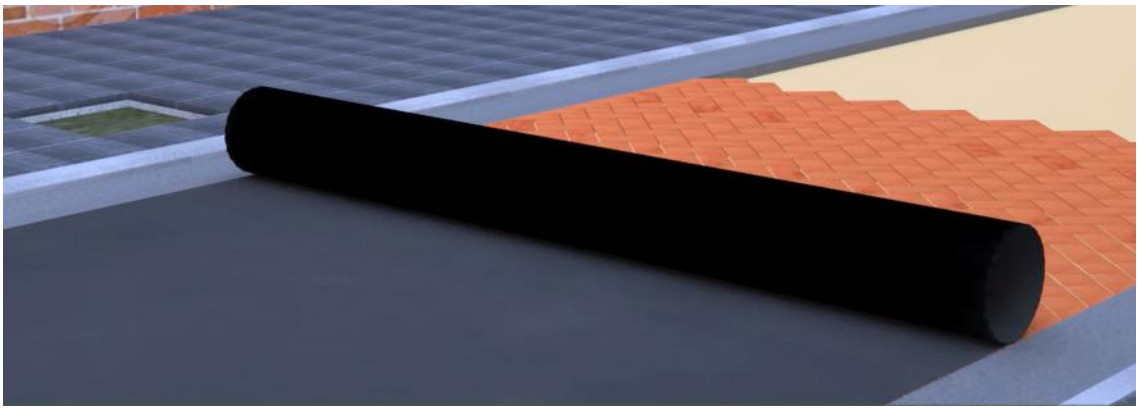
Source: BIMclay project website.

- Compacting.

Before compacting, the joints between the paving blocks and the fastening elements must be fully finished and they must not be compacted at a distance of less than 1 metre from the edges without containing the pavement.

The type of compactor to use will depend on the dimensions of the work. For reduced surfaces, vibrating trays (normally with an area of 0.2 - 0.4 m2) can be used, provided with neoprene soles or other material that cushions impacts on protruding corners, which could chip the edges of the pavers.

For larger surfaces the performance is increased by using vibrating roller compactors; in these cases the precaution should be taken to spread on the pavement, as a carpet, a felt sheet or any other material that reduces direct impacts; it will be necessary in any case to check the useful force that the roller must transmit to obtain the required compaction without damaging the pieces. For large extensions, they can be used together with vibrating rollers of metallic rim, compactors of rubber wheels.



Source: BIMclay project website.

The elements used must transmit a useful force between 50 and 75 kN/m2 at frequencies between 60 and 100 Hz. Usually two or three passes with the rammers are required to achieve the proper compaction. After each of the passes the state of the joints will be checked, adding sand as it is introduced into the sores.

Source: BIMclay project website.

Once the compaction has been completed, the levels of the paving will be checked, rectifying, if necessary, the pieces that have been left off grade. The joints that are not filled will be received. Once the excess sand has been removed, as in the filling of joints, it should be removed by sweeping and not by washing with water, it is advisable to water the pavement to facilitate the caking of the aggregate. After this operation, the pavement will be ready to be used.

Source: BIMclay project website.

CONSTRUCTION OF RIGID PAVEMENTS

1. Preparation of the surface.

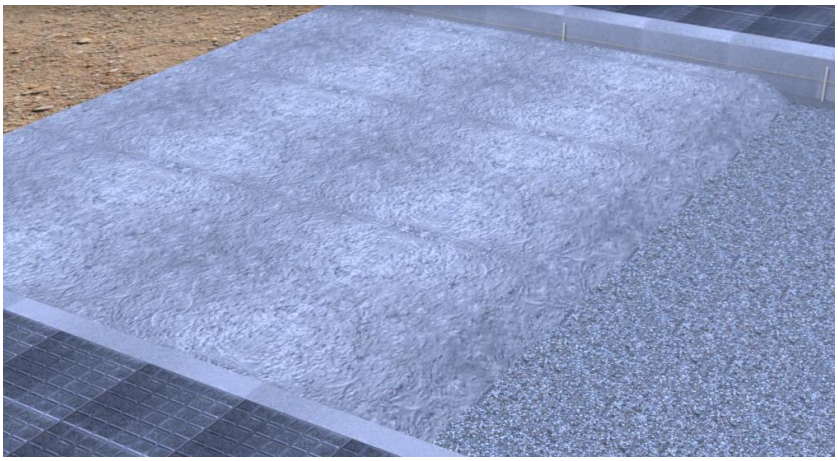
The preparation of the surface procedure for rigid pavements is the same as for flexible pavements, so the instructions explained in this section can be followed.

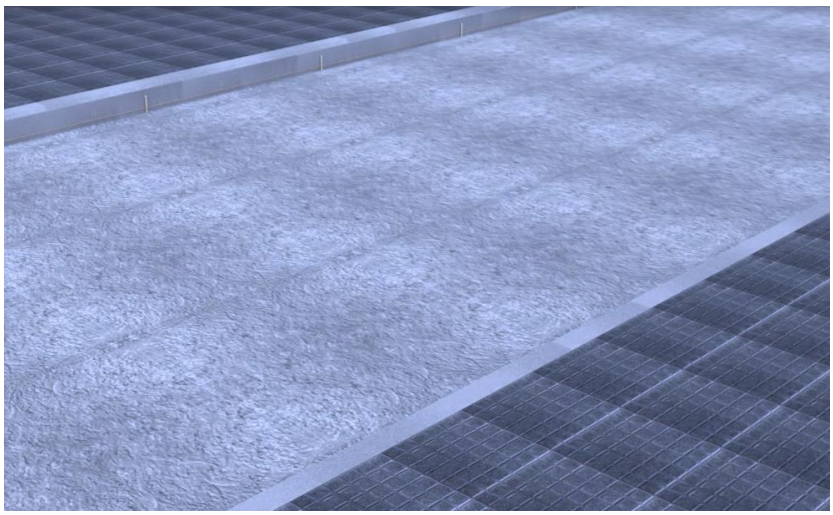
2. Gravel sub-base layer dosing and roller compaction.

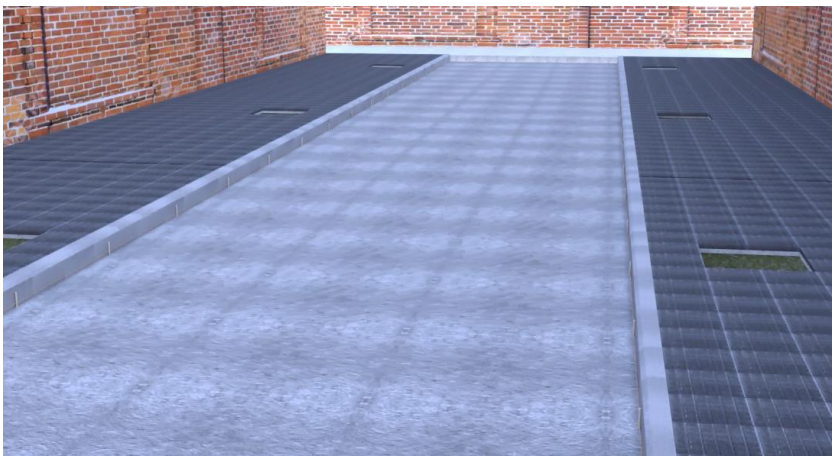
The procedure for gravel sub-base layer dossing and roller compaction is the same for rigid and flexible pavements, so the instructions explained in this section can be followed.

3. Laying of the base.

A mass concrete floor screed shall be used as the base of the pavement, the section of which shall depend on the foreseen loads, and a distribution reinforcement may be added when deemed necessary. It is important to respect gradients with minimum tolerances.







Source: BIMclay project website.

Expansion joints should be provided for the entire perimeter whenever the dimensions of the sides exceed 5 m, the spacing between expansion joints should not exceed the same distance of 5 m, and care should be taken to ensure that the resulting cloths are of substantially equal sides; in areas exposed to strong temperature variations, it may be necessary to reduce these dimensions to 4 m. Care should be taken to match the joints of the flooring with those of the base. It is also necessary to place joints at the joints with rigid elements, such as manholes, lanterns, pillars and any element anchored to the base.

4. Spreading of mortar layer.

A layer of mortar of about 3 cm will be spread over the concrete floor of the base. It is advisable to use an M-15 mortar (with a dosage of 1:3 or 1:1/4:3 if lime is to be added). The mortar will be placed with a hard consistency; sometimes dry consistency mortars are used; their hydration being completed by watering as the pieces are placed. This last solution, however, is not appropriate due to the doubts that the correct hydration of the mortar can offer and, therefore, the homogeneity of its performance.

Existen otros métodos para conseguir pavimentos semi-flexibles, en los que se utilizan bases de mortero pobre, con lo que pueden espaciarse a mayor distancia las juntas de dilatación, aunque no se aconseja su empleo, por los problemas que comportan, especialmente de limpieza.

Basically, they consist of laying the pavers on a layer of poor, dry mortar; in these cases, the pieces are usually compacted and scraped using rubber mallets, although they could also be used, provided that the mortar has not yet begun to set, vibrating trays with rubber soles or rollers of small or medium size, in this case, protecting the pieces from direct impacts by interposing felts or another suitable sheet. The mortar is then hydrated by abundant watering. Once the surface is dry, the joints are filled, using a mixture of sand and dry cement, which is introduced by sweeping with brushes in the joints, then the surplus is removed and proceeds to its irrigation, taking care not to wash the mixture of the joints.

With this method the remains of cement stain the surface of the pavement and the cleaning of it is difficult, since the low resistance of the material with which the sore is filled can cause its detachment and dragging in this cleaning process. On the other hand, it is difficult to achieve a homogeneous hydration of the mortar, which can translate into variable behaviour of the flooring from one area to another.

5. Laying the ceramic pavers.

Once the mortar layer has been laid, the ceramic paving blocks are laid, without forgetting the need to carry out expansion joints throughout the entire thickness of the paving, every 5 x 5 m as a minimum.

Before inserting the elastic material into the expansion joint and sealing it, the following precautions must be observed:

- The joint cavity must be clean and free of mortar.
- The thickness of the joint must be constant (approx. 20 mm).
- Before sealing the joint, the floor will be dry.

It is advisable to protect the surface finish of the flooring before applying the sealant to prevent staining. The finish of the seal must be concave, following the manufacturer's instructions in its application.

The ceramic pavers to be used will not have spacer or separator spikes, as these would only serve to create a discontinuity in the mortar joint, in addition, for aesthetic reasons, it would favour the use of unbevelled edges, thus avoiding the formation of excessively wide joints. Therefore, the ceramic pavers will be separated only by a mortar joint of between 6 - 10 mm nominal.

It is recommended to mix pavers of several packages at the same time, taking them in vertical batches, to equal the slight differences of calibre or tone that could appear. A good preliminary stakeout, taking into account the real dimensions of cobblestones and sores, is essential to avoid cuts of unwanted pieces and to mark axes and level references that will serve as a guide to the layer.

For the seating of the ceramic pavers on the mortar layer, rubber mallets and metallic or wooden rules will be used, with which the pieces of each cloth will be equalized.

6. Grouting the joints and cleaning.

Once the ceramic pavers have been laid correctly aligned and levelled, the joints are filled using a mortar with the same dosage as the seat mortar, but with a soft or fluid consistency. In the latter case, containers can be used with pitcher-type mouths, which will allow for less soiling of the pavers.

The ceramic pavers should be stained as little as possible during the grouting task, cleaning as much as possible of the stains as the filling is carried out, using clean rags or scouring pads and without spreading the mortar on the face of the piece.

In spite of following these advices, it is foreseeable that remains of mortar remain on the surface of the ceramic, reason why it will be proceeded later to a cleaning of the pavement, once hardened sufficiently the mortar of the sores to avoid its detachment.

To clean the remains of hardened mortar, proceed as follows:

1. The surface to be treated will be watered with clean water, which will decrease the suction of the mortar sore.
2. Using a mixture of one-part commercial hydrochloric acid (strong water) and ten-parts water, clean the pavement, either by spraying it under pressure (faster method that gives more homogeneous results) or by rubbing it with root brushes.
3. Then water abundantly again with clean water to remove dirt and acid residues.

Once the cleaning has been completed and the minimum resistance of the mortar has been reached, the pavement will be ready to be used.

5. SUMMARY OF STEPS TO BE FOLLOWED IN THE CONSTRUCTION PROCESS

LAYING PROCESS OF CERAMIC PAVERS ON SAND BED:

Construction of flexible pavements

1. Preparation of the surface.
2. Gravel sub-base layer dosing and roller compaction.
3. Base layer dosing and roller compaction.
4. Placing of the confinement edges.
5. Laying the ceramic pavers on the sand bed.
6. Filling joints the sand and compacting.

Construction of rigid pavements

1. Preparation of the surface.
2. Gravel sub-base layer dosing and roller compaction.
3. Laying of the base.
4. Spreading of mortar layer.
5. Laying the ceramic pavers.
6. Grouting the joints and cleaning.

6. REFERENCES

1. *Manual para el Uso del Adoquín Cerámico*. HISPALYT – SECCIÓN ADOQUINES, 2004. https://www.hispalyt.es/es/productos-ceramicos/adoquines/publicaciones

2. Video "Laying process of ceramic pavers on sand bed". BIMclay Project. https://www.youtube.com/channel/UCm1KRHbAvQwXQ_ffRSPhE7A/playlists