REPORT 1.2.9

BEST PRACTICE REPORT ON METHODS, SKILLS AND COMPETENCES IN RELATION TO STONE PRODUCTS

CONSTRUCTION PROCESS OF PAVERS ON SAND BED

Consortium members: Deutscher Naturwerkstein-Verband E.V (DNV), Asociatia Romania Green Building Council (RoGBC), Colegio Oficial de Arquitectos de la Región de Murcia (COAMU), Asociación Empresarial de Investigación Centro Tecnológico del Mármol, Piedra y Materiales (CTM), Klesarska Skola Pucisca (KLESARSKA)

Content

1. INTRODUCTION

The BIMstone project was born from the fusion of three lines of action whose convergence is a consolidate a didactic material base for the training in the stone sector. These three lines of actions are:

- BIM (Building Information Modeling).
- LCA (Life Cycle Assessment).
- Digitisation of stone products placement methodologies.

The European Commission is focused on the construction sector on the criteria of smart growth (knowledge and innovation-based development and economy) and inclusive growth (ensuring social and territorial cohesion through employment).

According to the above context, the general aim of BIMstone project is to increase the skills of workers in the field of placing the stone products particularly in placing different type of floors and walls in buildings and urban environments, in order to increase the quality of the final work, the permanence of the work and the environmental sustainability, by using methods without non-recyclable and/or eco-friendly materials. For that reason, it is necessary to define and compile the most suitable execution systems and placement methods for stone products.

The first task of the BIMstone project "O1. *Establishment of common learning outcomes on stone placing methods, Life Cycle Analysis (LCA) and regulations*" encompasses a number of specific tasks among which we find the elaboration of this report.

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

Of all the natural stone construction elements selected in this project, this report focuses on the construction of pavers on sand bed, describing in detail some of their characteristics, both constructive and environmental, and the construction process to be followed to achieve an optimum result.

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 "***Tiles and Slabs from natural stone***" include natural stone products which main function is for ornamental use to cover interior and exterior surfaces, such as floors, walls, facades, stairs, etc. and has been verified and published at https://ibu-epd.com.

The EPD of Tiles and Slabs from natural stone has been carried out according to the LCA methodology with quantified environmental information of its entire life cycle. That is to say, the EPD of these materials is of the "cradle to door" type, as can be seen in the following table, which includes the life cycle stages considered.

DESCRIPTION OF THE SYSTEM BOUNDARY (X = INCLUDED IN LCA; MND = MODULE NOT DECLARED)																
PRODUCT STAGE			CONSTRUCTION PROCESS STAGE		USE STAGE							END OF LIFE STAGE				BENEFITS AND LOADS BEYOND THE SYSTEM BOUNDARIES
Raw material supply	Transport	Manufacturing	Transport from the gate to the site	Assembly	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-construction demolition	Transport	Waste processing	Disposal	Reuse-Recovery-Recycling-potential
A1	**A2**	**A3**	**A4**	**A5**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**C1**	**C2**	**C3**	**C4**	**D**
X	X	X	X	MND	MND	X	MNR	MNR	MNR	MND	MND	MND	MND	MND	X	MND

Source: IBU - Institut Bauen und Umwelt e.V.

This EPD has been developed and verified according to the EN 15804 and EN ISO 14025 standards and the Product Category Rules (PCR) for marble and limestone slabs used in the building construction.

This EPD refers to 1 ton of tiles and slabs from natural stone.
Results refer to a weighted average of EUROROC member companies, therefore also averaging the three major stone groups. The average thickness of the product is 0.04 m.
It means 1 ton of product is equal to 9.11 m².

Natural stone units are produced from thin tiles with 10 mm thickness up to massive slabs with more than 100 mm thickness. Therefore this EPD is declared for average thickness of 0.04 m.

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Technical Data:

Name	Value	Unit
Compressive strength acc. to /EN 1926/	a) 100 - 300	N/mm²
	b) 20 - 240	N/mm²
	c) 100 - 280	N/mm²
Flexural strength acc. to /EN 12372/	a) 5 - 25	N/mm²
	b) 1 - 20	N/mm²
	c) 5 - 40	N/mm²
Water absorption acc. to EN 13755	a) 0.1 - 1	M.-%
	b) 0.1 - 10	M.-%
	c) 0.3 - 2	M.-%
Gross density acc. to EN 1936	a) 2.000 - 3.000	kg/m³
	b) 1.700 - 2.900	kg/m³
	c) 2.600 - 3.000	kg/m³
Thermal conductivity	1.2 – 3.4	W/(mK)
Wear resistance acc. to DIN EN 14157	14 - 35	mm
Specific heat capacity	0.92	kJ/kgK

Source: IBU - Institut Bauen und Umwelt e.V.

Declared unit:

Name	Value	Unit
Declared unit	1	t
Gross density	2744	kg/m³
Conversion factor to 1 kg	0.0003644	m³/kg

Source: IBU - Institut Bauen und Umwelt e.V.

Transport to the building site (A4):

Name	Value	Unit
Litres of fuel [truck]	0.00135	l/100km
Litres of fuel [train]	0,00474	L/100km
Transport distance	411	km
Capacity utilisation (including empty runs)	85	%
Gross density of products transported	2744	kg/m³

Source: IBU - Institut Bauen und Umwelt e.V.

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The results of the LCA – Environmental Impact are:

RESULTS OF THE LCA - ENVIRONMENTAL IMPACT: 1 ton tiles and slabs from natural stone

Parameter	Unit	A1 - A3	A4
Global warming potential	[kg CO_2-Eq.]	2.55E+2	2.05E+1
Depletion potential of the stratospheric ozone layer	[kg CFC11-Eq.]	5.81E-8	3.58E-10
Acidification potential of land and water	[kg SO_2-Eq.]	7.25E-1	1.3E-1
Eutrophication potential	[kg $(PO_4)^{3}$ - Eq.]	6.75E-2	3.12E-2
Formation potential of tropospheric ozone photochemical oxidants	[kg Ethen Eq.]	4.17E-2	-4.69E-2
Abiotic depletion potential for non fossil resources	[kg Sb Eq.]	3.2E-5	7.64E-7
Abiotic depletion potential for fossil resources	[MJ]	3.39E+3	2.83E+2

RESULTS OF THE LCA - RESOURCE USE: 1 ton tiles and slabs from natural stone

Parameter	Unit	A1 - A3	A4
Renewable primary energy as energy carrier	[MJ]	5.52E+2	1.11E+1
Renewable primary energy resources as material utilization	[MJ]	0.0E+0	0.0E+0
Total use of renewable primary energy resources	[MJ]	5.52E+2	1.11E+1
Non renewable primary energy as energy carrier	[MJ]	3.88E+3	2.84E+2
Non renewable primary energy as material utilization	[MJ]	0.0E+0	0.0E+0
Total use of non renewable primary energy resources	[MJ]	3.88E+3	2.84E+2
Use of secondary material	[kg]	0.0E+0	0.0E+0
Use of renewable secondary fuels	[MJ]	0.0E+0	0.0E+0
Use of non renewable secondary fuels	[MJ]	0.0E+0	0.0E+0
Use of net fresh water	[m³]	8.29E-1	1.23E-2

RESULTS OF THE LCA – OUTPUT FLOWS AND WASTE CATEGORIES: 1 ton tiles and slabs from natural stone

Parameter	Unit	A1 - A3	A4
Hazardous waste disposed	[kg]	8.44E-2	0.0E+0
Non hazardous waste disposed	[kg]	5.23E+2	3.68E-2
Radioactive waste disposed	[kg]	1.96E-1	3.95E-4
Components for re-use	[kg]	0.0E+0	0.0E+0
Materials for recycling	[kg]	0.0E+0	0.0E+0
Materials for energy recovery	[kg]	0.0E+0	0.0E+0
Exported electrical energy	[MJ]	0.0E+0	0.0E+0
Exported thermal energy	[MJ]	0.0E+0	0.0E+0

Source: IBU - Institut Bauen und Umwelt e.V.

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3. CONSTRUCTIVE CONSIDERATIONS

A surface with pavers is a stable load-bearing area that transfers loads individually.

The stone paving is made up of a series of layers prior to the placement of the paving stones. And one of these layers is a sand bed on which the paving stone will rest. This sandy bed has several important functions. The first of these is to support and transfer weight. This layer will also mitigate the possible differences between the different thicknesses of the paving stones.

In addition to the characteristics described above, the sandy bed also has a drainage function. For this function, the sand grains must be between 2 and 6 millimetres in size. This substrate also has a considerable influence on the operability of the pavement, specifically on the size of the different deformations caused in the paving.
The initial thickness of this sand bed should be between 3 and 5 centimetres. Ideally, it should never be less than 2 centimetres. It has been proven that angular-grained sands perform better than round-grained sands.

The sand composing this base must be clean and properly washed sand. Either natural or synthetic sand is suitable, but in both cases, there must not be more than 3 % clay. Harmful salts and other foreign matter should also be avoided. In this way, this layer will remain stable and water absorption will be avoided. The sand must be completely dry when it is spread to form this layer.

It should be borne in mind that other elements such as cement, mortar or lime should never be added, as this may cause the sealing system to fail. Also, the use of limestone sands is not recommended because of their excessive dust content, in which case the surface of the paving may tarnish.

Although the constitution of this substrate with sand alone is recommended, in certain circumstances it may be advisable to add some other element to help compact the base and reinforce the sealing capacity. In areas where there is a steep slope of more than 9 % and where heavy rainfall is frequent, it is preferable that this sandy bed be reinforced.

The importance of this sand bed will influence numerous aspects related to paving, both in its functional and aesthetic components. Among other aspects, it determines the uniformity of the paving surface, both longitudinally and transversally. This regularity has a direct impact on the comfort of users.

It also influences the rapid evacuation of water on the surface of the paving, and therefore, when paving with stone pavers, the sand bed plays a very important role in the performance of the paving.

4. CONSTRUCTION PROCESS

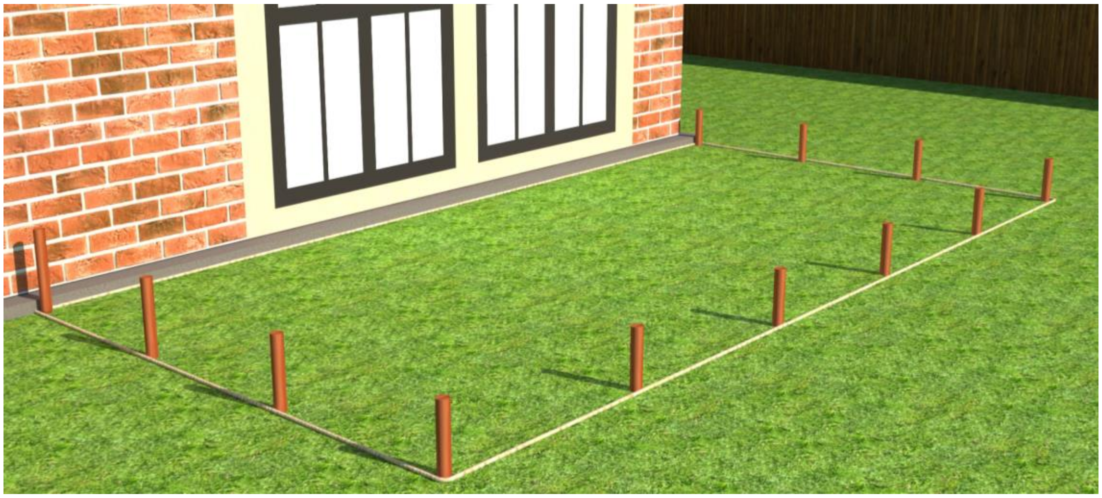
4.1. Stake out the area to be covered with the new paving

Surfaces built with stone pavers generally need to be delimited with a stable border to prevent horizontal displacements. It is advisable to specify the distances according to the width of the product to speed up the work.

Source: BIMstone project website.

4.2. Delimitation of the area with a rope and stakes

Delineate the area with string and stakes to draw the outline and use triangles to make neat corners.



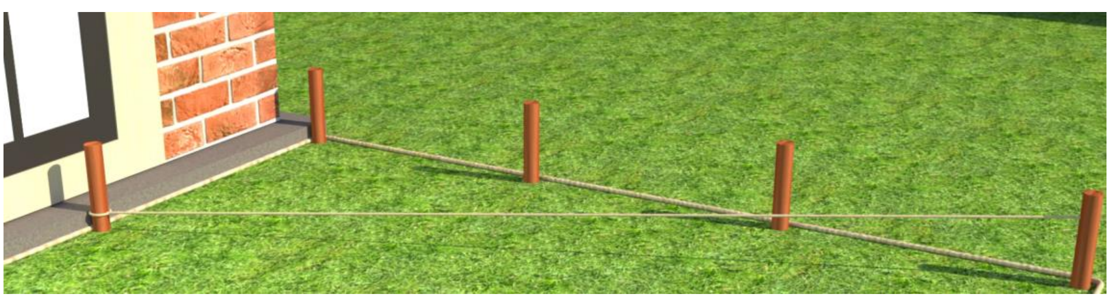
Source: BIMstone project website.

4.3. Make triangles to make neat corners and give the right inclination to the strings

To prevent water from pooling in the paver, the paver should be slightly above the surrounding ground surface at all points. When measuring the slope, start with what will be the highest point.

Place a stake at the highest point and mark the correct height where the paver meets the door or structure. Tie a rope around the stake at that height.
Placing a stake at the outer boundary of the sketch. This will be the lowest point. Tie a level line to the rope and then tie the loose end of the rope around the stake placed at the outer boundary at the height where the level line indicates that the entire rope is level.

Tie transverse lines along the length of the project to mark the correct depth.



Source: BIMstone project website.

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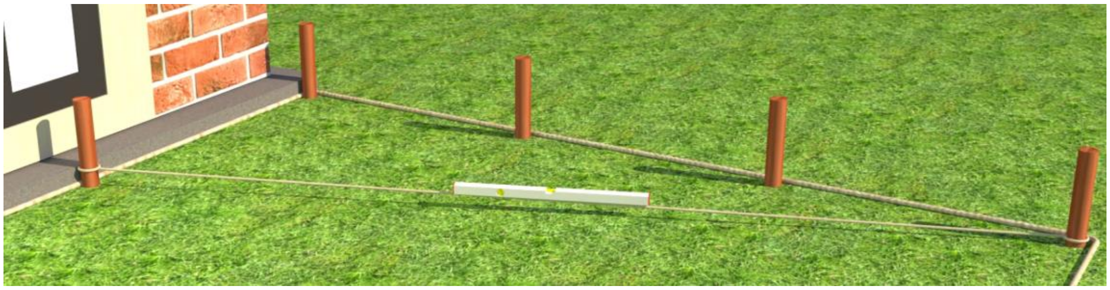

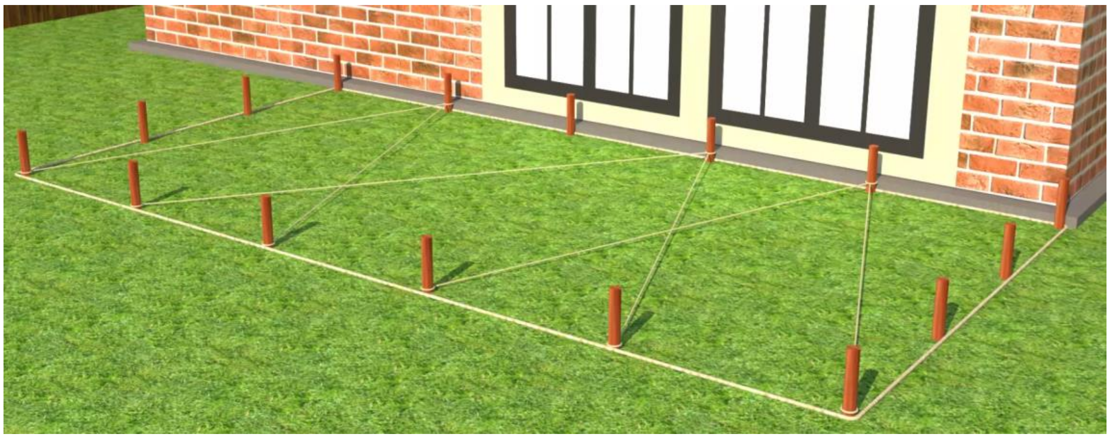

Source: BIMstone project website.

4.4. Excavate the installation area to a height of 15-30 cm below grade

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

Soil strength, water table and prepared surface levelling must be known for proper pavement construction.

The sum of the depth of the base, sand and pavers is the depth of excavation to be done in the area. Be sure to excavate 15 cm to 30 cm beyond the project limits in order to have enough space to install the containment edges.

Also, try to level and smooth the ground where the paver edging will go.
Measure the depth of the excavation from the string used to measure the slope, not from the ground surface.

Once the required depth has been reached, moisten the soil.

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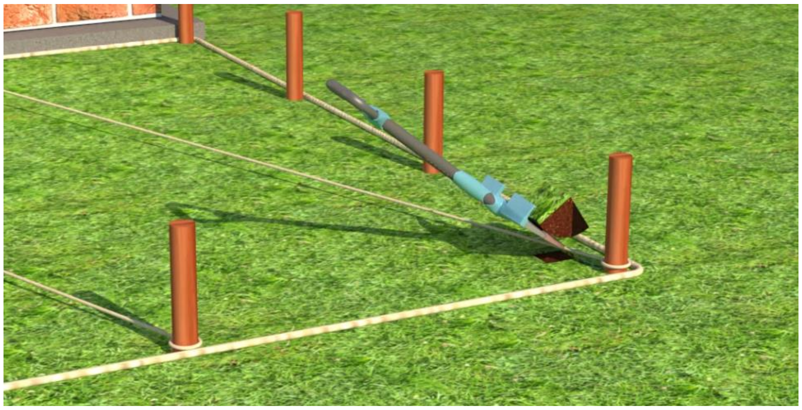
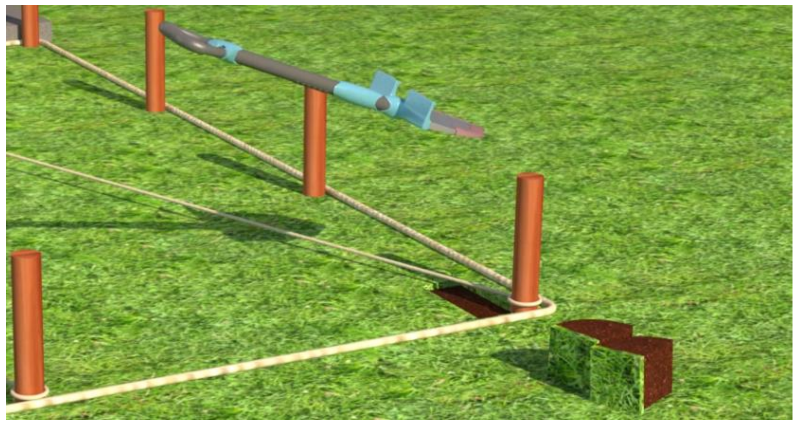
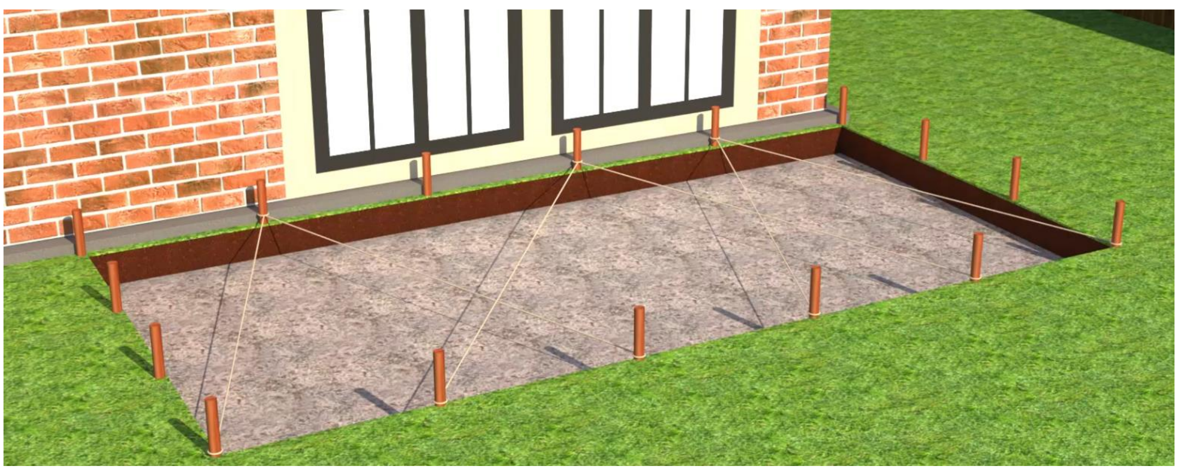




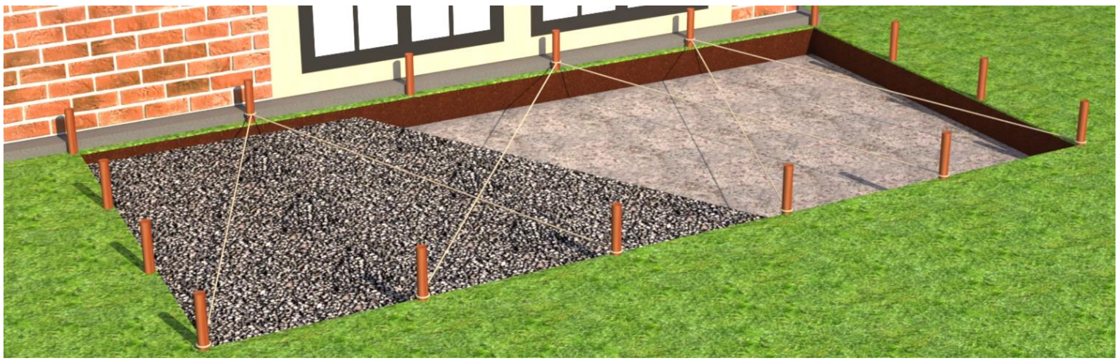


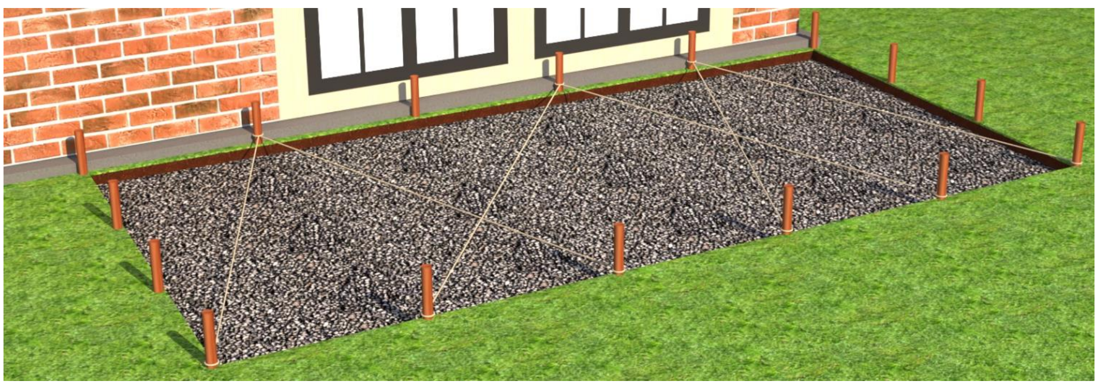
Source: BIMstone project website.

4.5. Spread the base layer (10-15 cm)

The two most important properties that the base material must have are that it remains firm when compacted (to serve as a base for the pavers) and that it has adequate drainage. Structural integrity and weak drainage can ruin the whole project completely.

Laying of the base with no more than 15 cm of base material at the same time over the entire excavated area, which is then compacted with a rammer.





Source: BIMstone project website.

4.6. Compact with the metal plate compactor

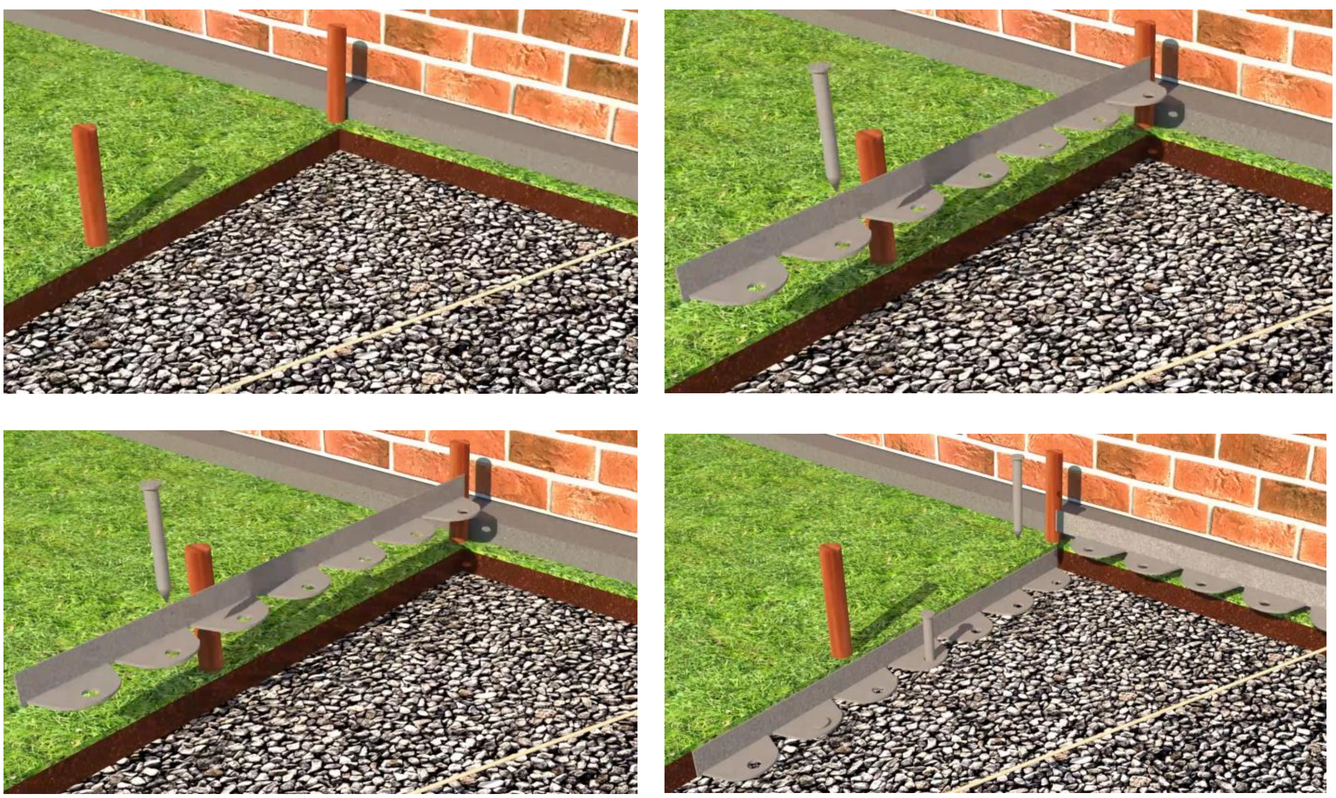
It is very important that the base is well compacted. Repeat the process until the base has the correct depth. This is the last opportunity to correctly adjust the height of the finished project, as well as the time to ensure that there are no voids or potholes.
Base material should be placed beyond the intended limits of the pavers, giving more stability to the whole.

Proceed by placing base material and compacting every 5 cm until a depth of about 7.5 cm of the desired final height is reached.

Source: BIMstone project website.

4.7. Install the containment edges to maintain the design of the project

Installation of retaining walls. Bunds help maintain and extend the life of the design. The location of these borders, usually plastic, aluminium or steel, around the perimeter of the project, should be secured to the ground with 30 cm stakes. If the design is irregular in shape, it will be necessary to trim the borders to fit the edges of the design.



Source: BIMstone project website.

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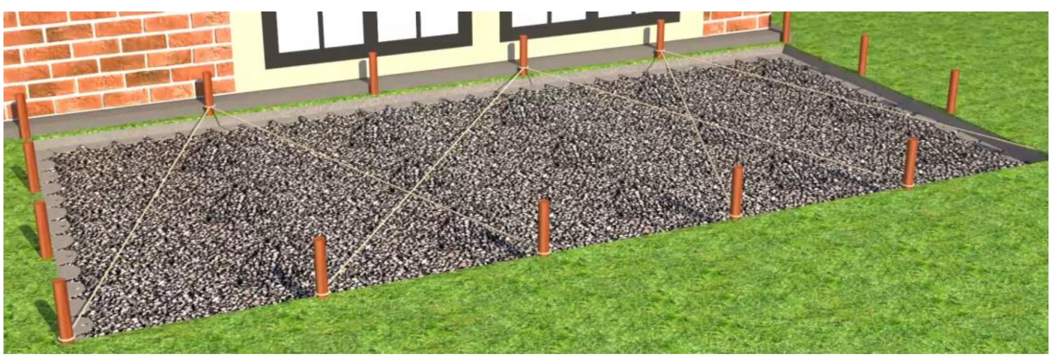
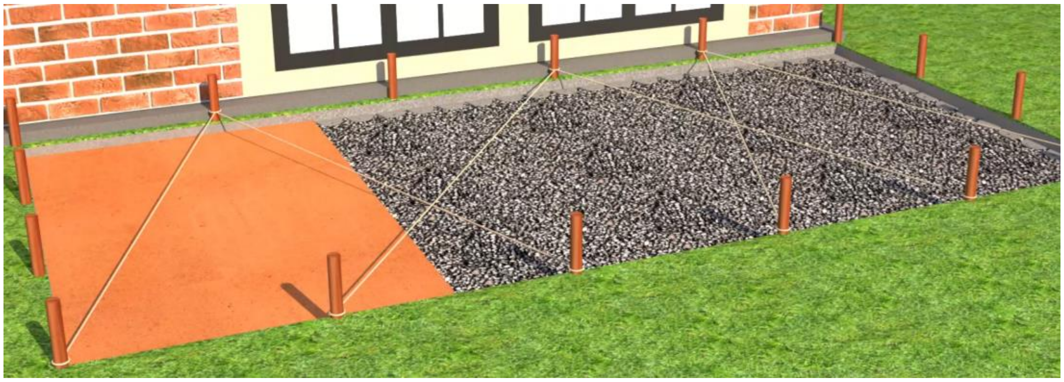
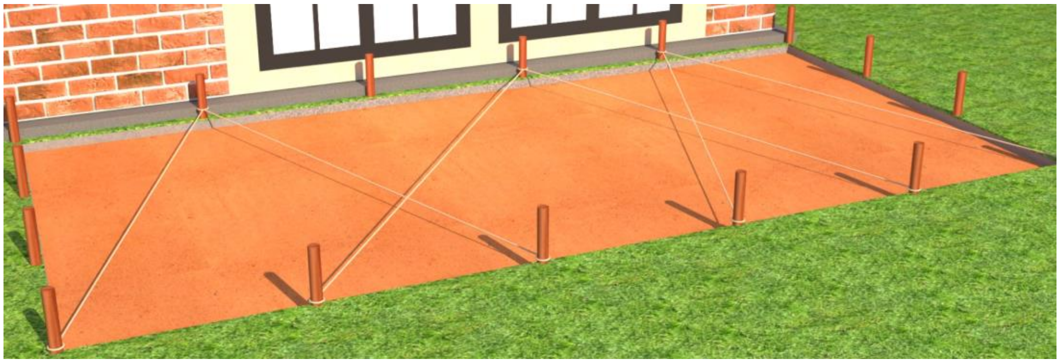


Source: BIMstone project website.

4.8. Place a layer of sand of at least 3 cm

Laying of sand layer. Sand is the material that holds the pavers in place. Use coarse sand, spreading it gently to a uniform depth of at least 3 cm but no more than 5 cm.





Source: BIMstone project website.

4.9. Lay the pavers first on the longest straight side and at right angles

First lay the pavers on the longer straight side. First lay the pavers on a corner with a right angle, preferably one that rests on another structure and continue laying the pavers on the longest straight side.

Continue working in this manner, keeping the pavers in straight lines. Lay the pavers by placing them straight on the sand, not tilted on the ground or forcibly pushed into the sand. Each paver is slid directly against the edge of the adjacent paver, keeping the pavers as close together as possible. If there are wide spaces between pavers, much more polymeric sand will be needed to fill them. Periodically check to make sure the pavers are flat, using a string or level to check the straightness of each row of pavers.

Source: BIMstone project website.

4.10. Trim the paving blocks to fit the contour of the area to be paved

Cut the pavers according to your needs. Some pavers will need to be trimmed to fit the corners. Do not try to curve the pavers to fit the ends. Instead, lay as many pavers as you can in a row and then trim some to fit the ends. Use a saw or guillotine-style splitter to get even and neat cuts.

Source: BIMstone project website



Source: BIMstone project website.

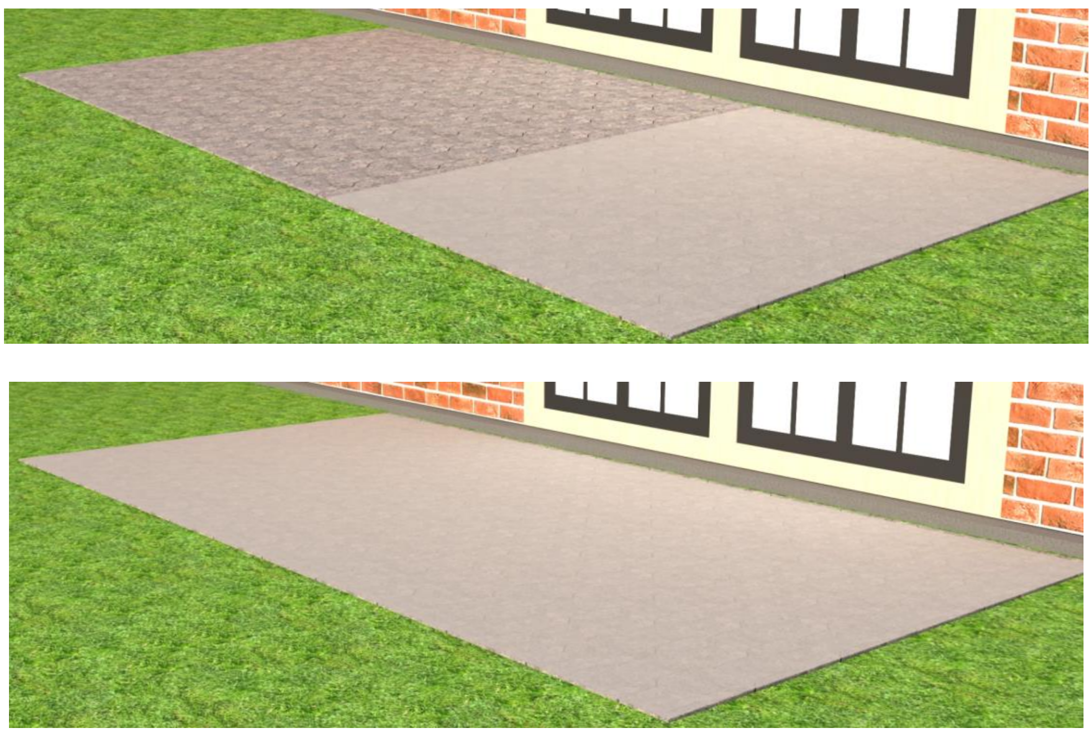
4.11. Once all the pavers have been laid, use the plate compactor to tamp the pavers into the sand (use a protective cover to avoid scratching the pavers)

Compact the pavers in the sand. Once all the pavers have been placed according to the design, use a plate compactor to tamp the pavers into the sand. Use the compactor at least three times to ensure that they are pressed firmly into the sand.
If there is any space between the pavers, add polymeric sand at the joints until they are half full. This will prevent the pavers from shifting position when the slab is compacted. If the pavers are loose when compacted, they may become uneven.

Source: BIMstone project website.

4.12. Add sand in the spaces between the pavers

Place sand in the spaces between the pavers. Fill the joints between the pavers with coarse sand as used above or slightly finer sand.



Source: BIMstone project website.

4.13. Pour with a broom so that all joints are completely covered

Pour it into the pavers and push it into the cracks using a broom until the gaps are completely filled. The sand holds the pavers in place. Make sure the sand is dry.

Use a large broom for a large area, or a small broom for a small area. Add in many different directions.

Source: BIMstone project website.

5. SUMMARY. STEPS TO FOLLOW IN THE CONSTRUCTIVE PROCESS

The construction processes of laying pavers on sand bed:

1. Stake out the area to be covered with the new paving.
2. Delimitation of the area with a rope and stakes.
3. Make triangles to make neat corners and give the right inclination to the strings.
4. Excavate the installation area to a height of 15-30 cm below grade.
5. Spread the base layer (10-15 cm).
6. Compact with the metal plate compactor.
7. Install the containment edges to maintain the design of the project.
8. Place a layer of sand of at least 3 cm.
9. Lay the pavers first on the longest straight side and at right angles.
10. Trim the paving blocks to fit the contour of the area to be paved.
11. Once all the pavers have been laid, use the plate compactor to tamp the pavers into the sand (use a protective cover to avoid scratching the pavers).
12. Add sand in the spaces between the pavers.
13. Pour with a broom so that all joints are completely covered.

6. REFERENCES

1. BIMstone project website. www.bimstoneproject.eu/bimstone-products

2. Tiles and Slabs from natural stone. EUROROC - European & International Federation of Natural Stone Industries. IBU – Institut Bauen und Umwelt e.V.

3. Laying of paving stones. https://es.wikihow.com/poner-adoquines

4. Video “09. Pavers on sand bed” of BIMstone project. https://www.youtube.com/watch?v=buGFJTKXutM