Concrete Segmental Paving

A Look at The Development of Concrete Segmental Paving

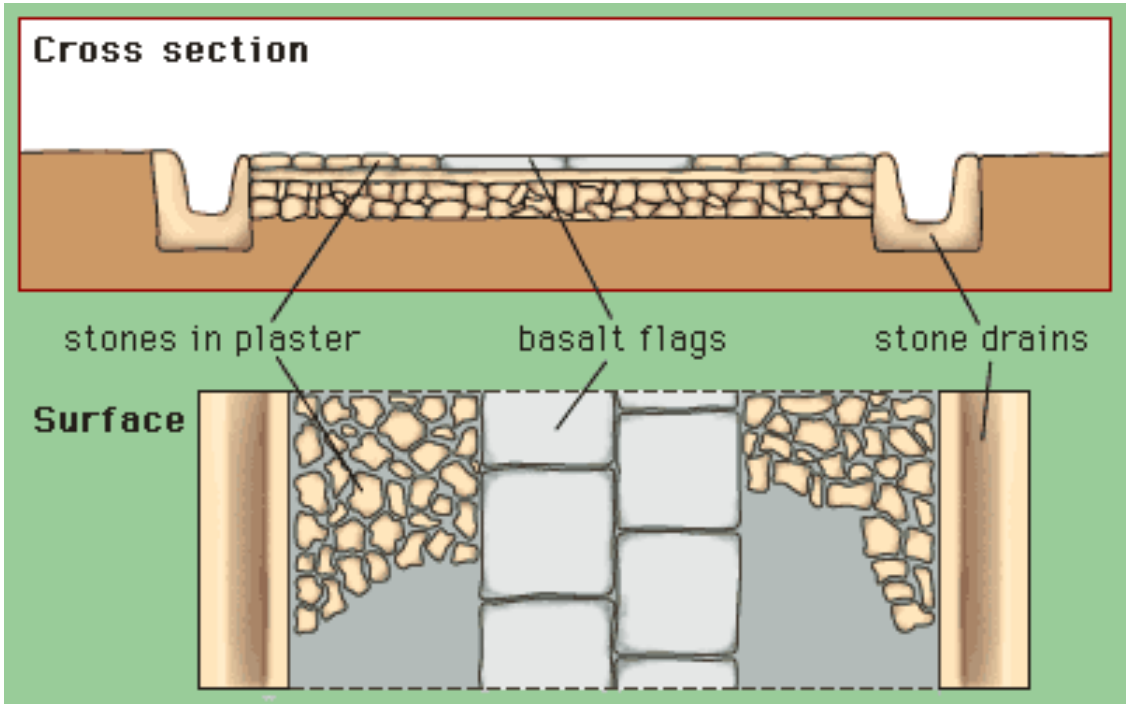
John Fifield

"Sir, hell is paved with good intentions“ Samuel Johnson

We can trace the history of segmental paving back to 2000BC

When the Minoeans constructed the first roads with segmental paving in their palaces on the island of Crete.

The construction method included central flagstones, interlocking stones, and stone drains.



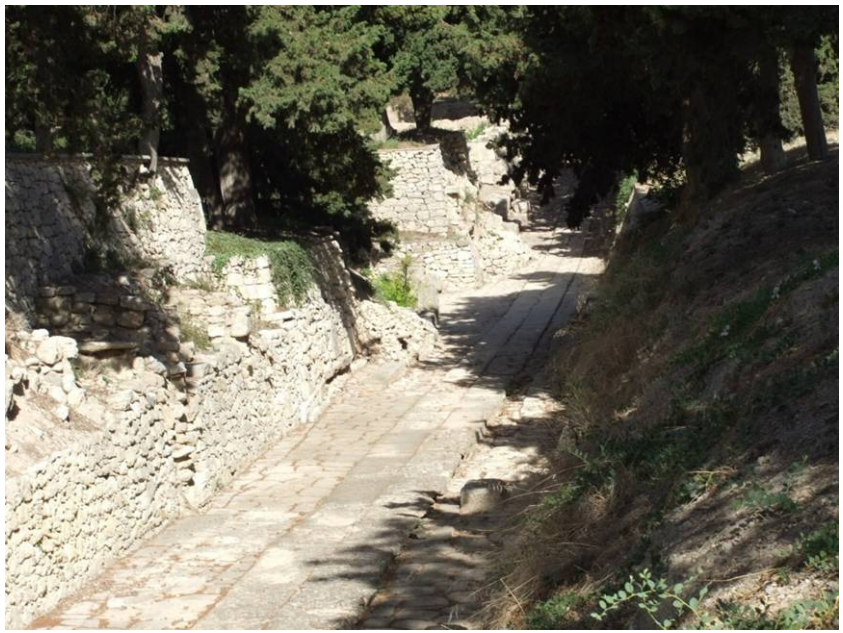
Minoan Roads

The Minoans then paved roads to connect the towns of Crete.

Many of these paved roads were constructed in the Neopalatial era 1700-1600BC, and reached impressive density during the Postpalatial period 1200BC.

Today, these ancient paved roads are difficult to identify in the countryside, but several well preserved examples appear in the Minoan ruins of Gournia and other Minoan palaces.

Gournia



Knossos

Minoan Roads

Minoans were able to "satisfy their enthusiasm for chariot-riding" by building an intricate system of roads.

However, this civilization was interrupted by Greek urban culture which supplanted the Minoan people in about 900 BC. The Greek culture depended heavily on sea travel and did not have the same cultural tendencies towards chariots. Consequently the roads that the Minoans had left were neglected by the Greeks.

Sources state that "Greece in the thirteenth century BC probably had a better system of roads than it did in the third."

The Greek neglect of the Minoan roads is an example of how culture will ultimately choose which technologies to pursue. Although the road as a technology is a major advance in a civilization, it had no real use to the Greeks and was therefore not developed in their society.

Persian Roads

On the other hand, the Medes and Persian civilizations had an intricate system of paved roads in the first millennium BC. Both cultures depended on horses for transportation, communication, and military operations. Paved roads were essential to these cultures and as such they made major technological innovations in the field.

The Persian Royal Road was an ancient highway reorganized and rebuilt by the Persian king Darius I in the 5th century BC. Darius built the 1677 mile long road to facilitate rapid communication throughout his very large empire from Susa to Sardis.

Persian Royal Road at Sardis

Concrete Segmental Paving

The Persian Royal Road joined and became part of one of the major silk routes linking the Mediterranean with China.

Concrete Segmental Paving

Roman Roads

Rome made a great deal of money from trade in Europe. Some of this trade involved transport by sea but more frequently the Romans used roads. With so much of Western Europe conquered by the Romans they needed roads to move their troops around quickly and poorly built roads would not help this.

When the Romans began their conquest of Celtic Britain in 43AD they found a haphazard collection of roads and paths mostly connecting local fields and hamlets. But there was also some longer distance trade routes (e.g. along the North Downs in Kent, and the Icknield Way along the Chilterns into Norfolk).

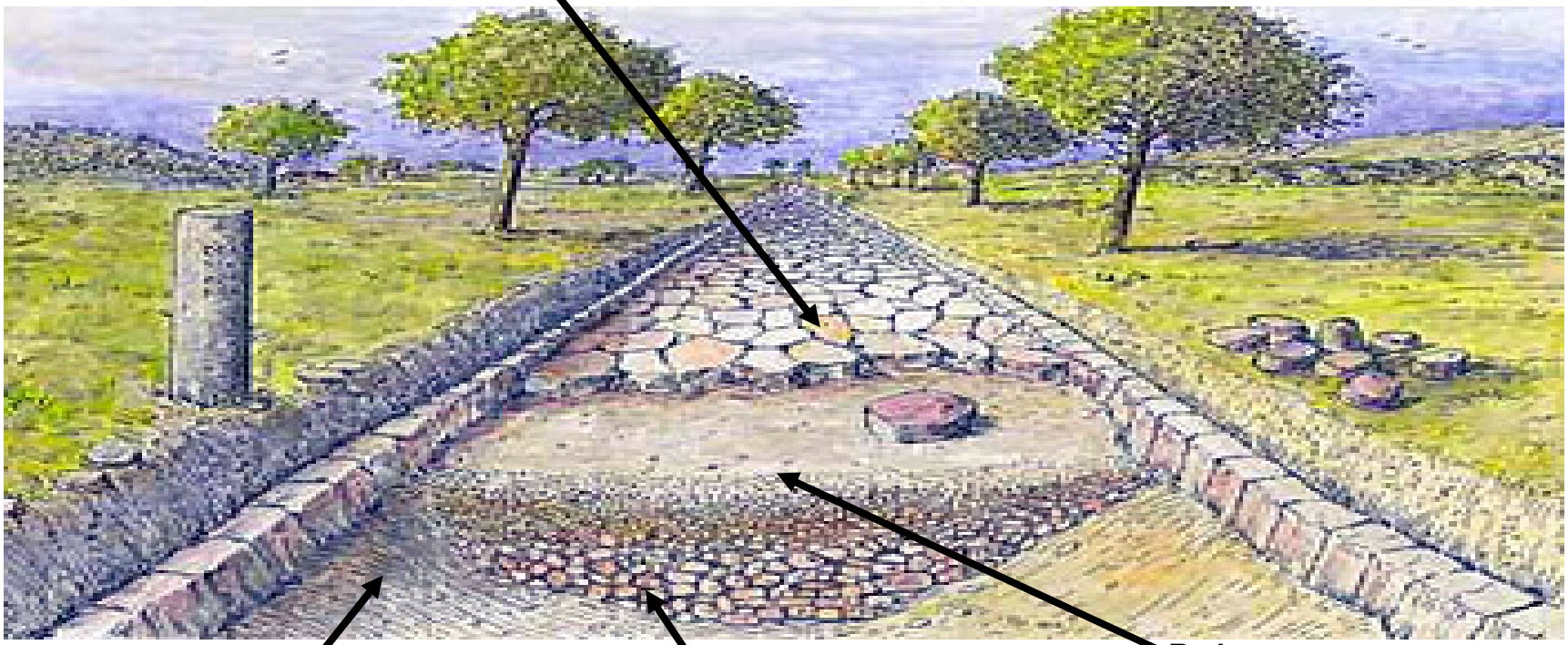
The Roman administration needed a better network of roads to connect its new towns and army posts and to speed the flow of both trade goods and troops. In building their network of roads the Romans mostly ignored the Celtic paths, partly because the Roman towns and forts were built on new sites away from the Celtic settlements.

Concrete Segmental Paving

Roman Roads

Summum Dorsum

Polygonal blocks of stone that were 150mm or more thick and carefully fitted atop the still moist concrete



Pavimentum

The foundation of lime mortar or sand was laid to form a base

Statument

Rubble stones of about 125mm diameter

Rudus

400mm of lime concrete filled with shards of pottery or stone.

Atop this layer was the nucleus, a concrete made of gravel or sand and lime.. This layer was 250mm at the sides and 350mm at the crown to allow good drainage

Concrete Segmental Paving

Roman Roads

Concrete Segmental Paving

Roman Roads

Roman roads remained in use as core trunk roads for centuries after the Romans withdrew from Britain in 410 AD.

By the 17th century traffic along the medieval routes had increased to such an extent that the roads, often unsurfaced, were in a state of collapse.

In 1663 the first of the Turnpike acts was passed with powers to collect tolls and buy lands for road improvements.

Toll houses were located nearby roads so that they could see the traffic coming from a distance.

Hexagonal Toll House in Shropshire

Roman Roads

Systematic construction of paved highways did not resume in England until the 18th century.

The best unaltered examples of Roman roads in Britain today exist at Wheeldale Moor (North Yorkshire), Holtye (Sussex), and Blackstone Edge (near Littleborough, Greater Manchester).

Roads in the Netherlands

In the Netherlands the lack of natural stone led to the use of clay pavers to create their roads. Standard pavers (225x50x90) were used, laid on edge in a thin 4x4 herringbone format.

Concrete Blocks and Pavers

The first solid concrete block patent was granted in 1832 in England.

But much of the development of concrete pavers occurred in Germany.

It was quickly recognized that the concrete pavers provided better uniformity than the stone setts and that they obviated the need to dress any of the faces of the block before laying.

The first significant test of concrete brick paving appears to have been at Neuss in 1936. Here rectangular wet cast units 240 x 120 x 80 mm were successfully tested under heavy traffic.

However, prior to World War II concrete pavers were seen largely as a substitute for stone setts.

Concrete Pavers

The main impacts for the development of concrete block paving occurred in post war Holland when in the 1950's there was a substantial growth in the Dutch population.

This, coupled with the needs of war damage reconstruction, resulted in a large increase in the demand for new houses.

This led to a shortage in bricks and manufacturers were required to switch much of their production and pavers were reluctantly accepted as a substitute for bricks.

The Dutch government sought a manufacturer to competitively produce a concrete substitute for the clay paver:-

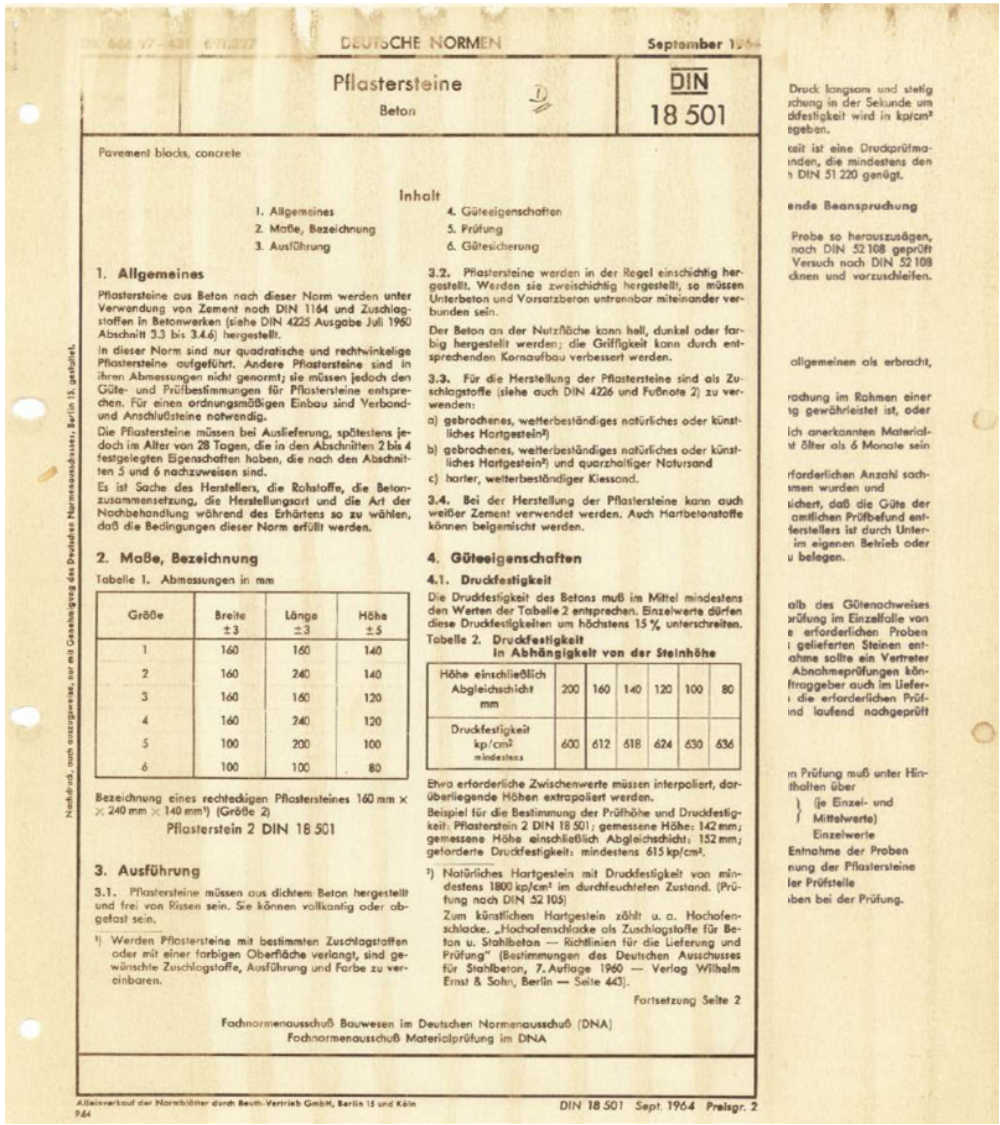
this challenge was met in 1951 by a Mr Holland who owned the then Holland Beton in Westervoort:- now a Struyk Verwo (CRH) company.

Concrete Segmental Paving

Concrete Pavers

The success of the concrete pavers in the Netherlands quickly spread to Germany and in September 1964 the Germans produced the first National Standard for concrete pavers:-DIN 18 501

This product was by now generically known as the Hollandstone paver as a rationalised the size of 200x100x80mm.



DEUTSCHE NORMEN — September 19

Pflastersteine
Beton

DIN 18 501

Pavement blocks, concrete

Inhalt

1. Allgemeines

Pflastersteine aus Beton nach dieser Norm werden unter Verwendung von Zement nach DIN 1164 und Zuschlagstoffen in Betonwerken (siehe DIN 4225 Ausgabe Juli 1960 Abschnitt 3.3 bis 3.4.6) hergestellt.

In dieser Norm sind nur quadratische und rechtwinkelige Pflastersteine aufgeführt. Andere Pflastersteine sind in ihren Abmessungen nicht genormt; sie müssen jedoch den Güte- und Prüfbestimmungen für Pflastersteine entsprechen. Für einen ordnungsmäßigen Einbau sind Verband- und Anschlußsteine notwendig.

Die Pflastersteine müssen bei Auslieferung, spätestens jedoch im Alter von 28 Tagen, die in den Abschnitten 2 bis 4 festgelegten Eigenschaften haben, die nach den Abschnitten 5 und 6 nachzuweisen sind.

Es ist Sache des Herstellers, die Rohstoffe, die Betonzusammensetzung, die Herstellungsart und die Art der Nachbehandlung während des Erhärtens so zu wählen, daß die Bedingungen dieser Norm erfüllt werden.

2. Maße, Bezeichnung

Tabelle 1. Abmessungen in mm

Größe	Breite ±3	Länge ±3	Höhe ±5
1	160	160	140
2	160	240	140
3	160	160	120
4	160	240	120
5	100	200	100
6	100	100	80

Bezeichnung eines rechteckigen Pflastersteines 160 mm × × 240 mm × 140 mm[1]) (Größe 2)

Pflasterstein 2 DIN 18 501

3. Ausführung

3.1. Pflastersteine müssen aus dichtem Beton hergestellt und frei von Rissen sein. Sie können vollkantig oder abgefast sein.

[1]) Werden Pflastersteine mit bestimmten Zuschlagstoffen oder mit einer farbigen Oberfläche verlangt, sind gewünschte Zuschlagstoffe, Ausführung und Farbe zu vereinbaren.

3.2. Pflastersteine werden in der Regel einschichtig hergestellt. Werden sie zweischichtig hergestellt, so müssen Unterbeton und Vorsatzbeton untrennbar miteinander verbunden sein.

Der Beton an der Nutzfläche kann hell, dunkel oder farbig hergestellt werden; die Griffigkeit kann durch entsprechenden Kornaufbau verbessert werden.

3.3. Für die Herstellung der Pflastersteine sind als Zuschlagstoffe (siehe auch DIN 4226 und Fußnote 2) zu verwenden:

a) gebrochenes, wetterbeständiges natürliches oder künstliches Hartgestein[2])
b) gebrochenes, wetterbeständiges natürliches oder künstliches Hartgestein[2]) und quarzhaltiger Natursand
c) harter, wetterbeständiger Kiessand.

3.4. Bei der Herstellung der Pflastersteine kann auch weißer Zement verwendet werden. Auch Hartbetonstoffe können beigemischt werden.

4. Güteeigenschaften

4.1. Druckfestigkeit

Die Druckfestigkeit des Betons muß im Mittel mindestens den Werten der Tabelle 2 entsprechen. Einzelwerte dürfen diese Druckfestigkeiten um höchstens 15 % unterschreiten.

Tabelle 2. Druckfestigkeit in Abhängigkeit von der Steinhöhe

Höhe einschließlich Abgleichschicht mm	200	160	140	120	100	80
Druckfestigkeit kp/cm² mindestens	600	612	618	624	630	636

Etwa erforderliche Zwischenwerte müssen interpoliert, darüberliegende Höhen extrapoliert werden.

Beispiel für die Bestimmung der Prüfhöhe und Druckfestigkeit: Pflasterstein 2 DIN 18 501; gemessene Höhe: 142 mm; gemessene Höhe einschließlich Abgleichschicht: 152 mm; geforderte Druckfestigkeit: mindestens 615 kp/cm².

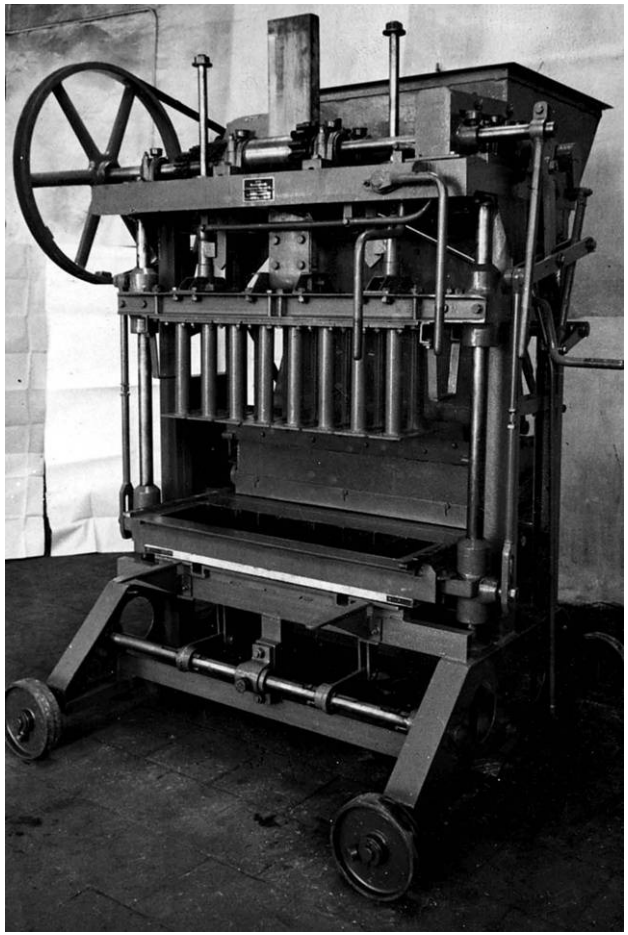
[2]) Natürliches Hartgestein mit Druckfestigkeit von mindestens 1800 kp/cm² im durchfeuchteten Zustand. (Prüfung nach DIN 52 105)
Zum künstlichen Hartgestein zählt u. a. Hochofenschlacke. „Hochofenschlacke als Zuschlagstoffe für Beton u. Stahlbeton — Richtlinien für die Lieferung und Prüfung" (Bestimmungen des Deutschen Ausschusses für Stahlbeton, 7. Auflage 1960 — Verlag Wilhelm Ernst & Sohn, Berlin — Seite 443).

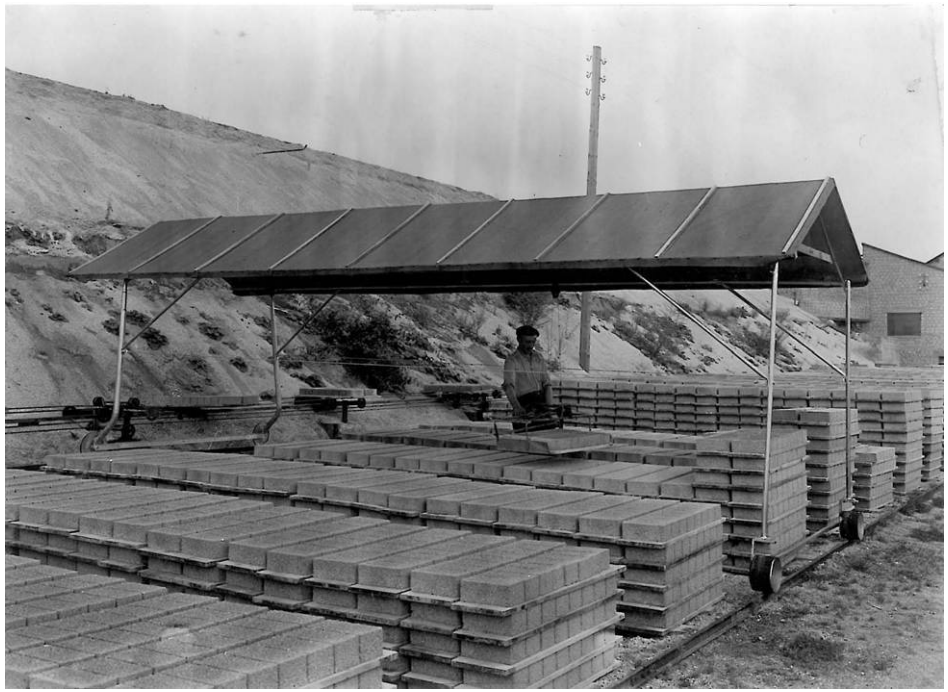
Fortsetzung Seite 2

Fachnormenausschuß Bauwesen im Deutschen Normenausschuß (DNA)
Fachnormenausschuß Materialprüfung im DNA

Alleinverkauf der Normblätter durch Beuth-Vertrieb GmbH, Berlin 15 und Köln
9.64

Concrete Pavers

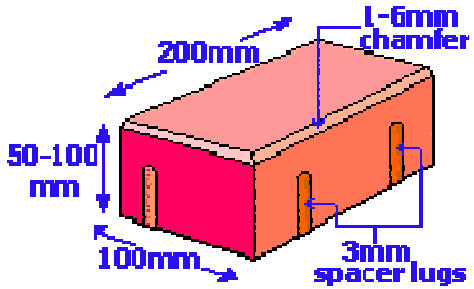




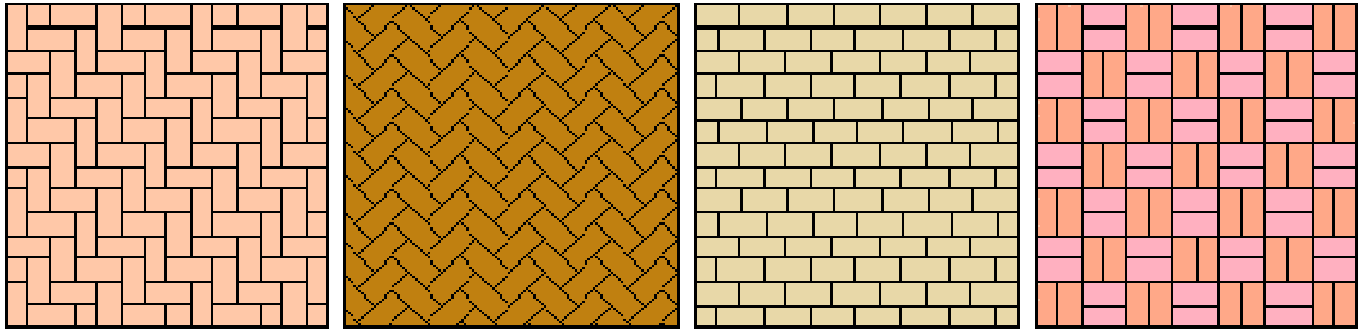
An early concrete paver machine and typical storage for curing prior to packaging.

Concrete Segmental Paving

Hollandstone



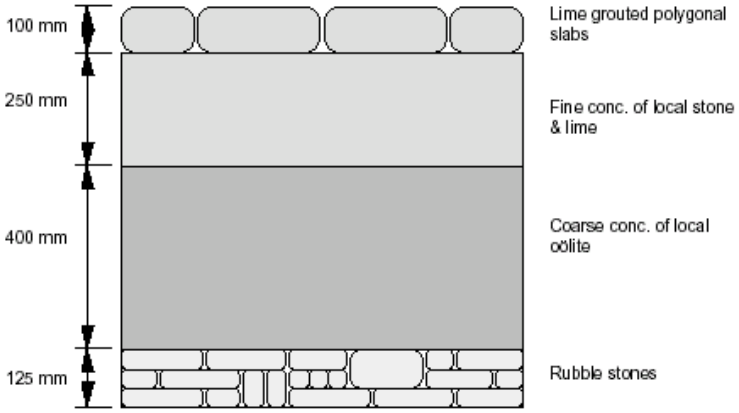
Being a 2 by 1 format it was easy to install in several patterns

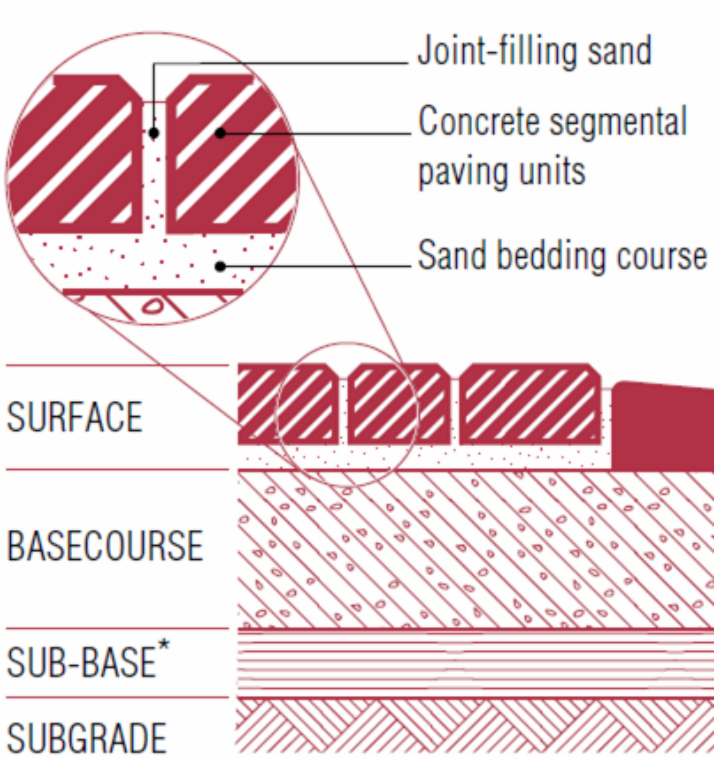


Concrete Segmental Paving

Hollandstone

The installation of these modern concrete pavers is remarkably similar to the Roman road.

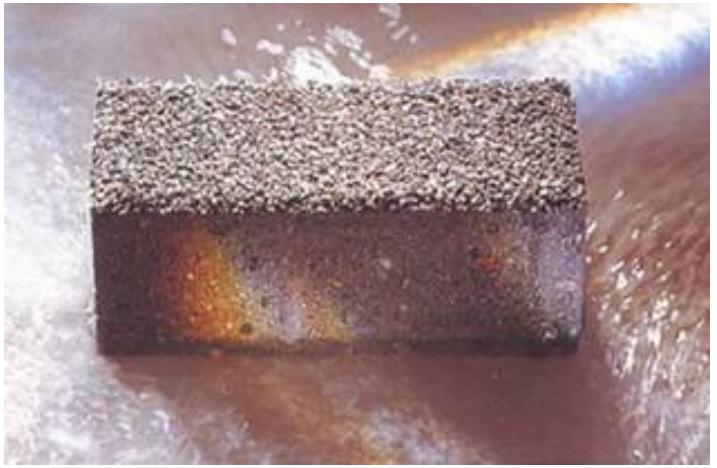




Hollandstone in Herringbone format

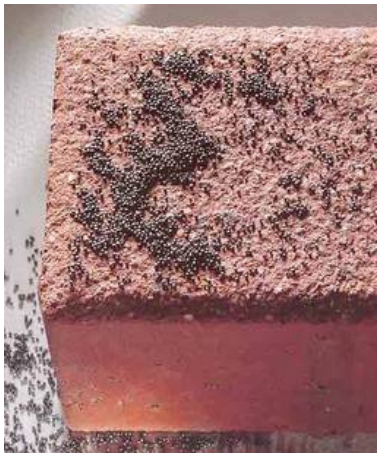
But it was not long before manufacturers added some new shapes that were mostly easy to install.

Then to improve appearance, decorative aggregates were used and exposed by washing.



As washed pavers became less fashionable, other surface treatments evolved.

Shotblasting exposes the aggregate surfaces



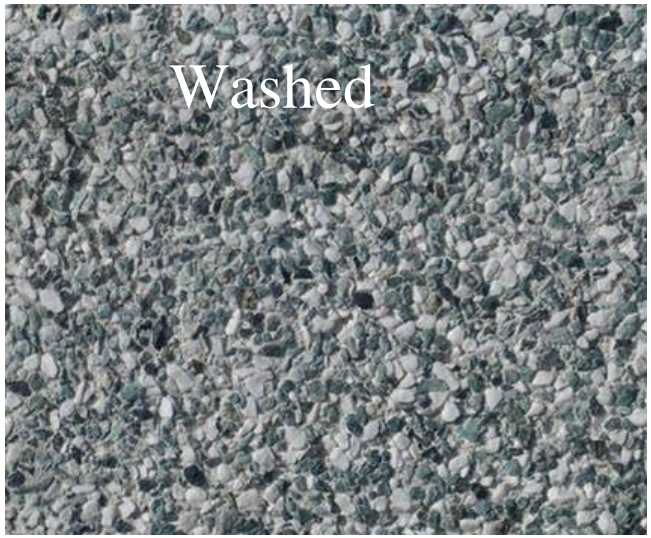
Concrete Segmental Paving

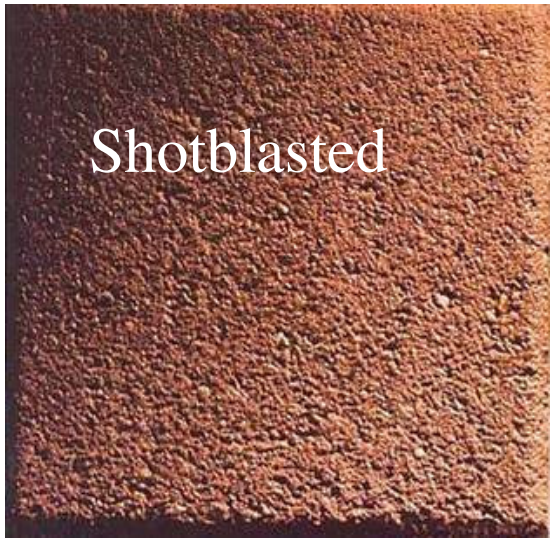
Bush Hammering both exposes the aggregate and fractures its top surfaces

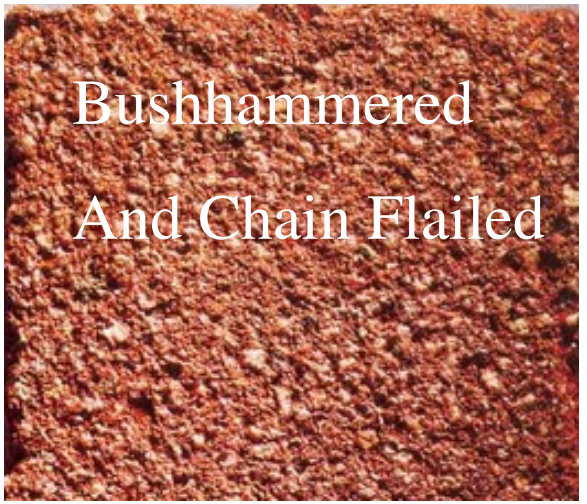
Similar finishes to bush hammering have been achieved by chain flailing

Concrete Segmental Paving

Creating a choice of surface finishes







Concrete Segmental Paving

To add more choice, more shapes evolved.

:- But many of these new shapes were difficult to install, especially in a rectangular area.

Concrete Segmental Paving

The Symetry paver is one of the most beautiful, and it can be installed in several ways

:- but it is difficult to install

So there was a trend to revert to simpler shapes but with varying stone sizes

Concrete Segmental Paving

Creating some beautiful installations:-

Then in the 1990's there evolved a preference for pavers that better replicated natural stone. The first ageing method was to put the concrete pavers in a concrete mixer, then this was improved by tumbling in an inclined revolving tube.

The term rumbled stone was applied to these pavers.

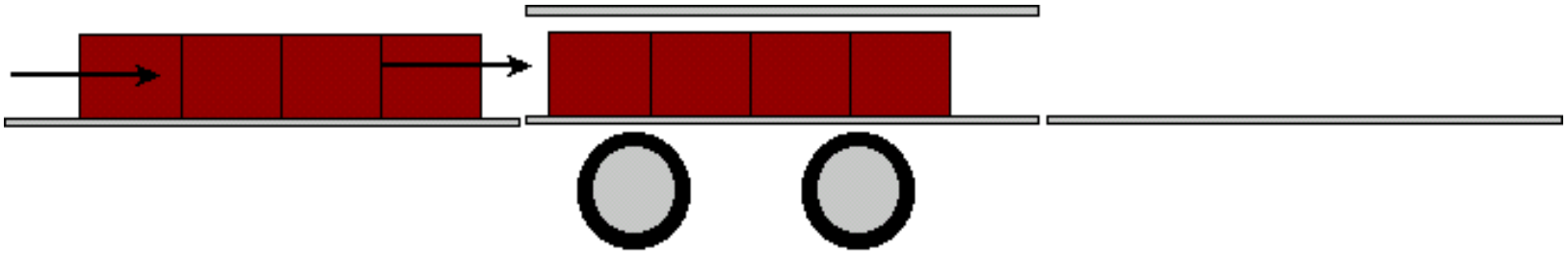
Initially the tumbled stones had to be hand packed but there is now some automated repackaging systems.

A state of the art tumbling equipment from Vena

Then in 1999 the Ebema Company in Belgium invented the first truly in-line ageing system

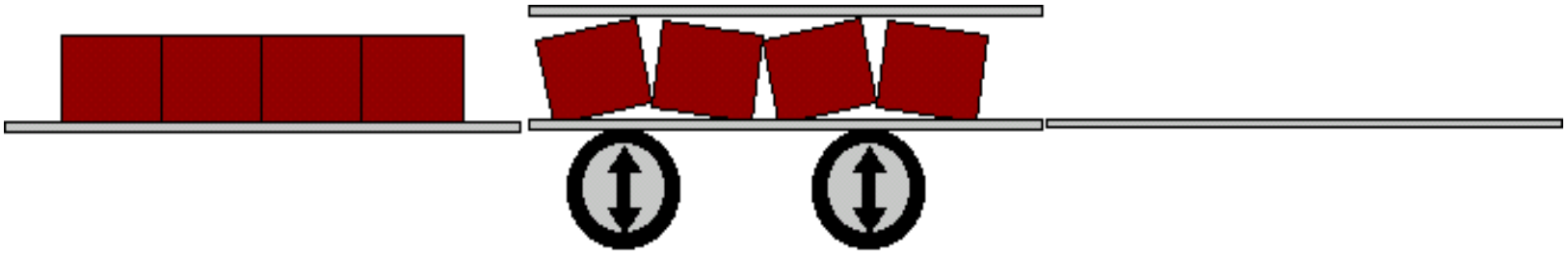
How did it work?

First:- Push a drop in between the plates



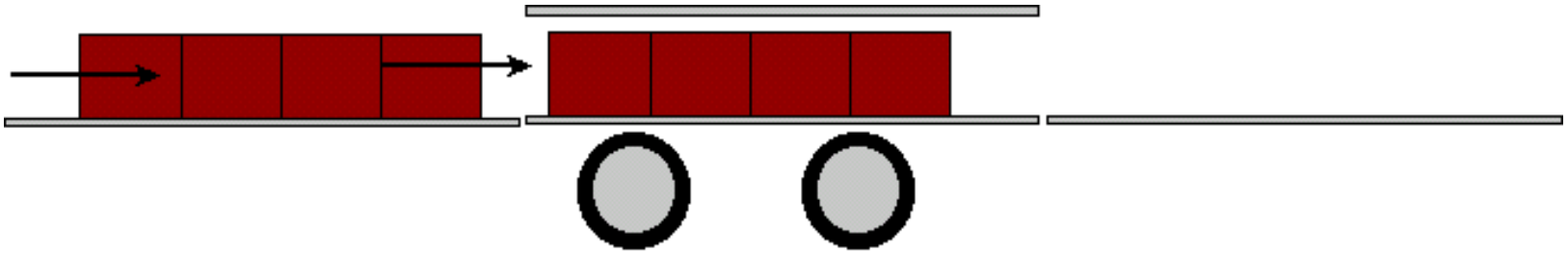
How did it work?

Then: Turn on the Vibrators



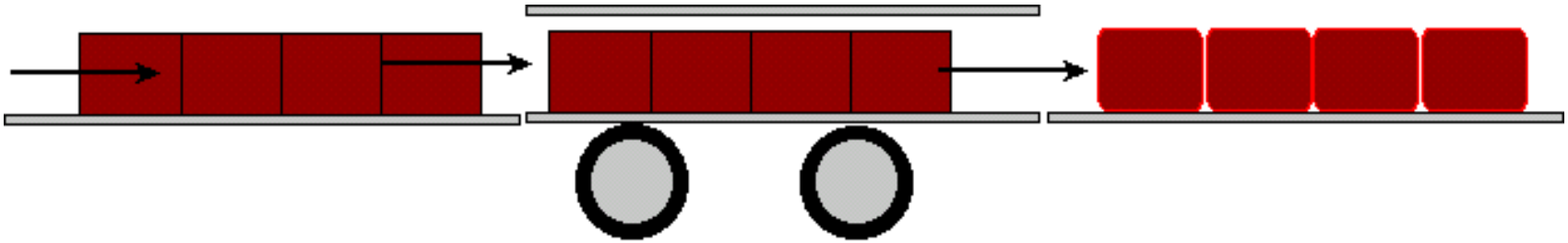
How did it work?

Then: Turn off the Vibrators



How did it work?

Then: Push in the next drop



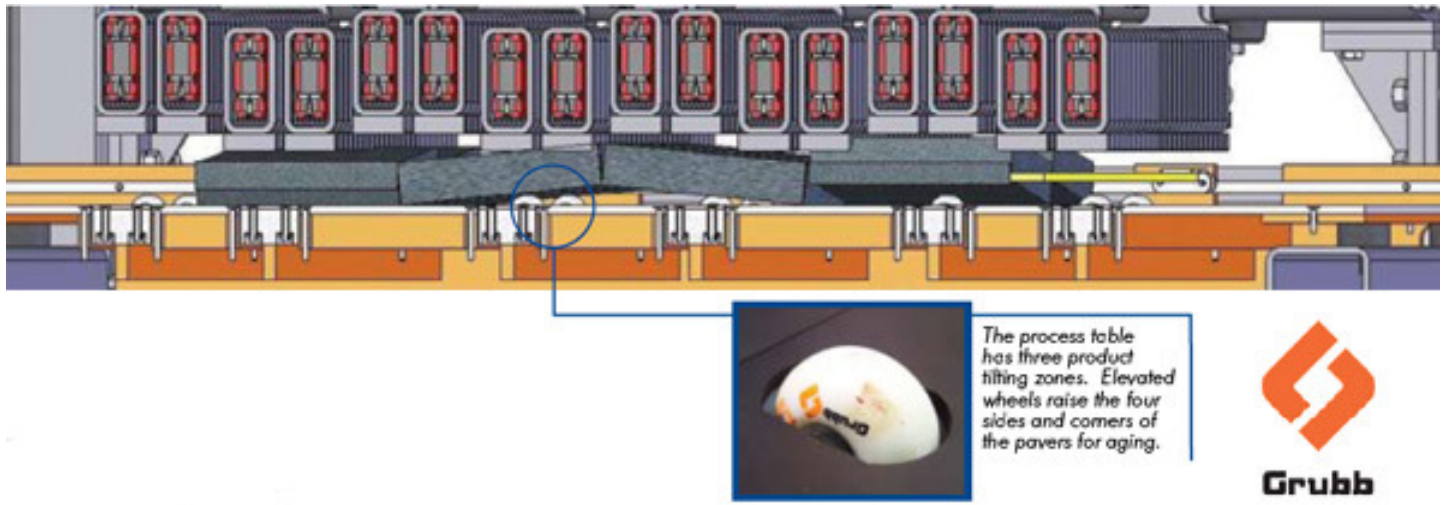
Concrete Segmental Paving

The finished product.

In line ageing had many advantages

- No need to yard product prior to rumbling
- The system keeps up with production rate
- No need to rearrange for cubing
- Light or heavy rumbling possible
- Low maintenance costs
- Low processing costs

Several commercial in-line ageing machines have followed:-



In-line machine from Grubb, sold via Besser

Concrete Segmental Paving

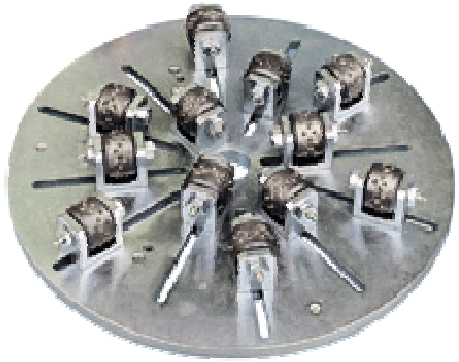
In-line machine from KBH

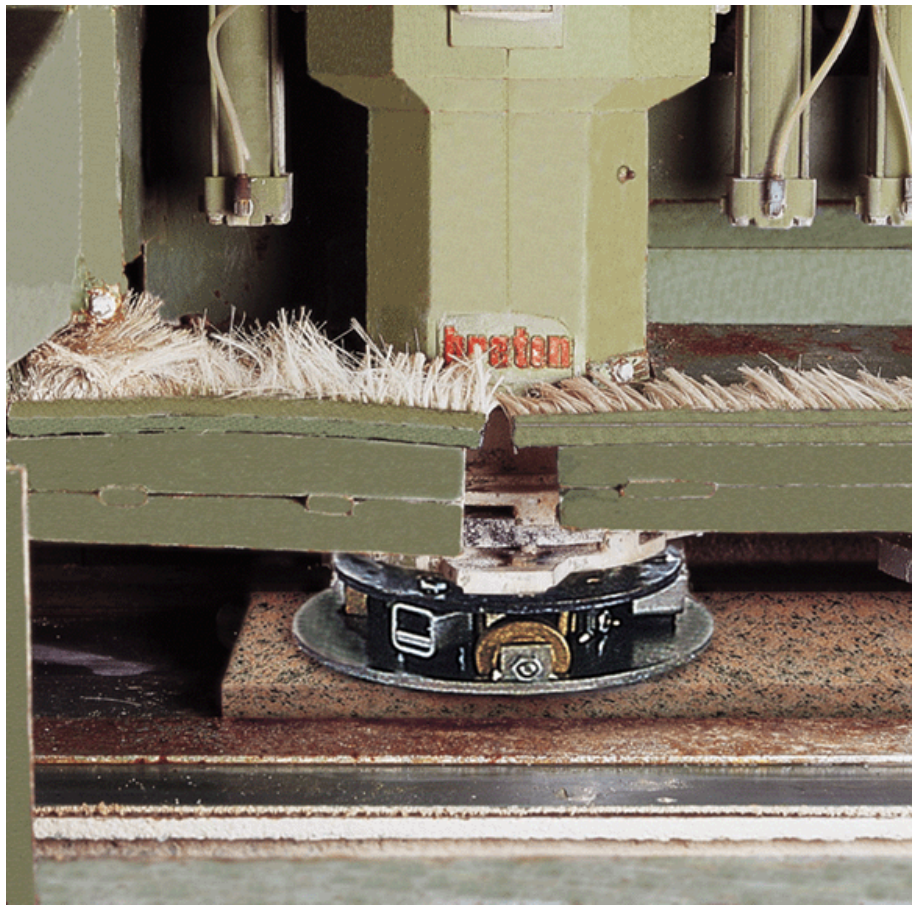
Heavy Treatment

Light Treatment

Concrete Segmental Paving

And surface ageing
from Italmonte



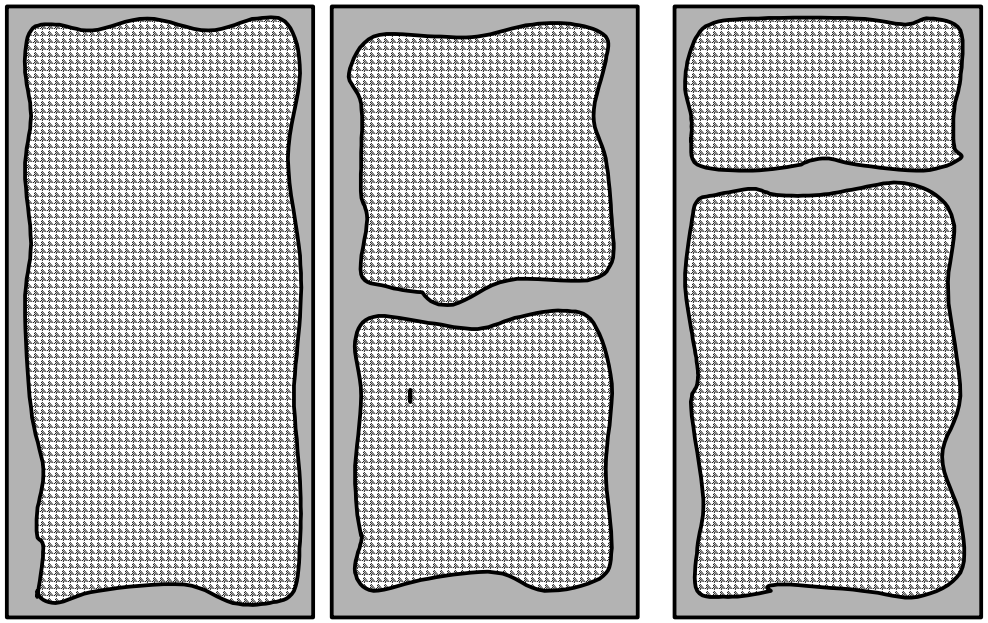


These in-line procesors are now widely used to create desired aesthetics

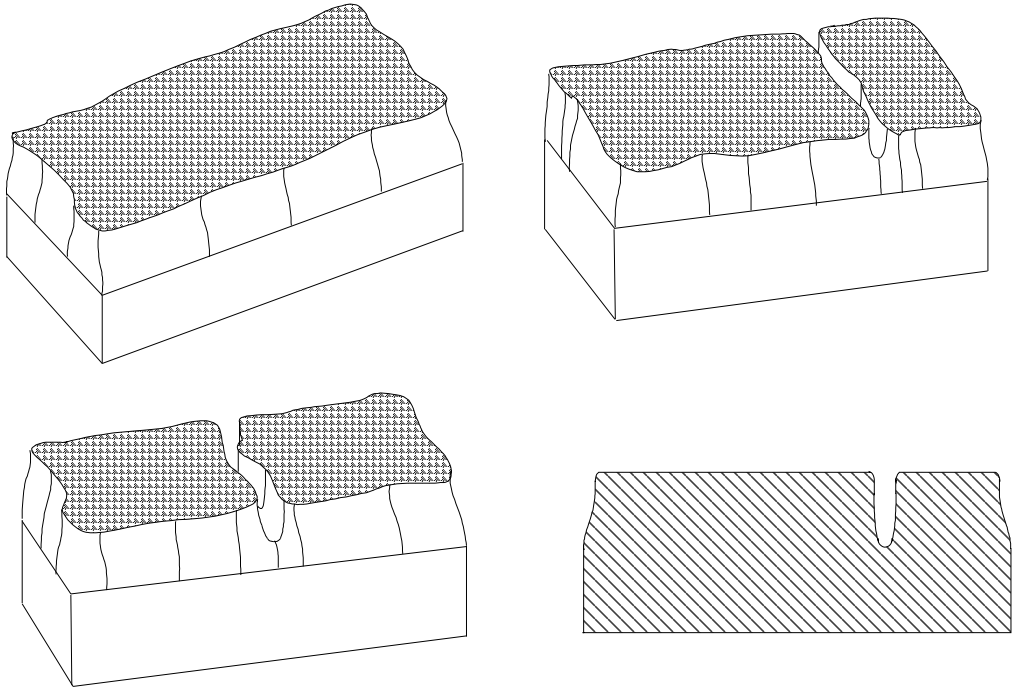
To offer a simple to lay random stone paver

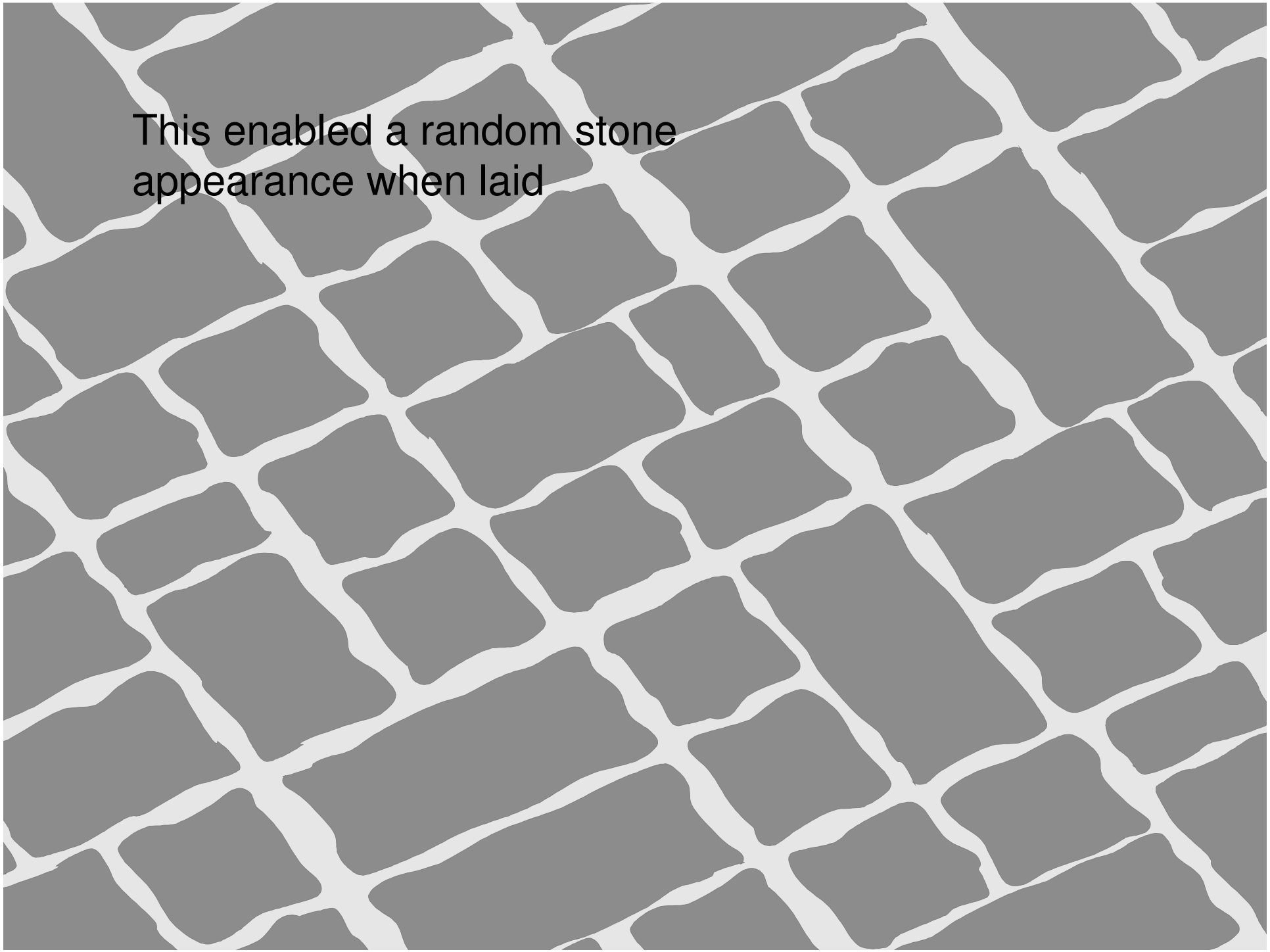
Back in 2000 Oldcastle in the USA patented a series of three concrete pavers.

Three “Top” Shapes over Hollandstone bases



These pavers had deep mock joints and by being a 2 by 1 format could be laid in several formats and each stone could be used in four orientations.




This enabled a random stone
appearance when laid

Using the same principle the Four Cobble Paver with deep joints evolved

Oldcastle, USA

4 Different Textures
Unit Dimensions: 200 x 200 x 50
Unit Coverage: 25 stones/m^2

And the Canvas Paver

Oldcastle, USA

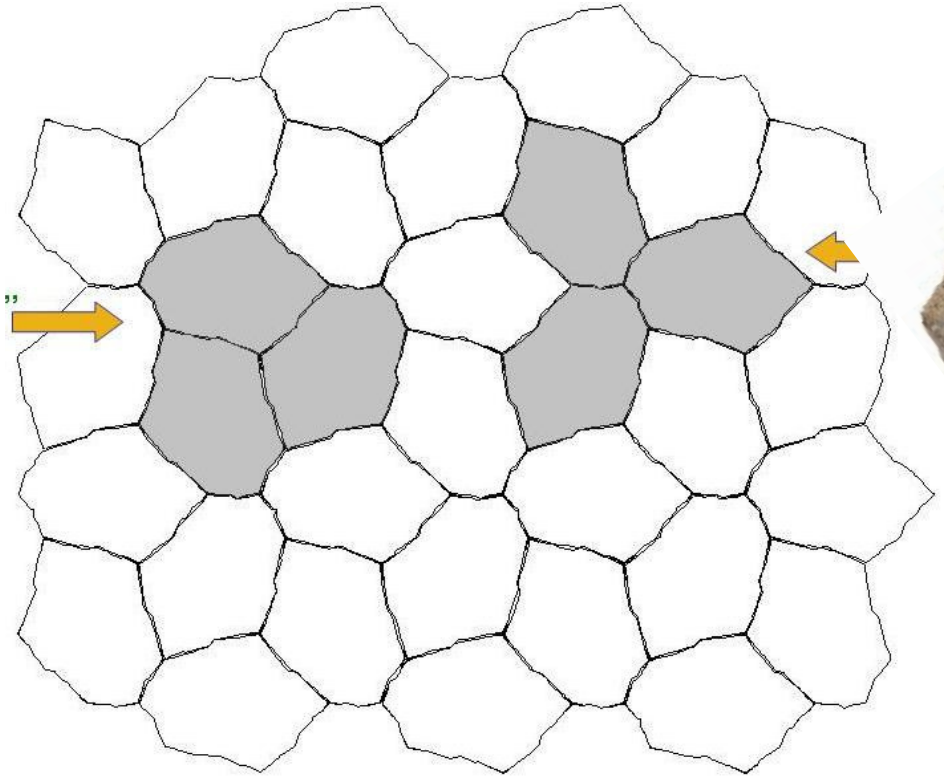
Canvas Paver

Oldcastle, USA

Concrete Segmental Paving

The Interlocking Stepping Stone

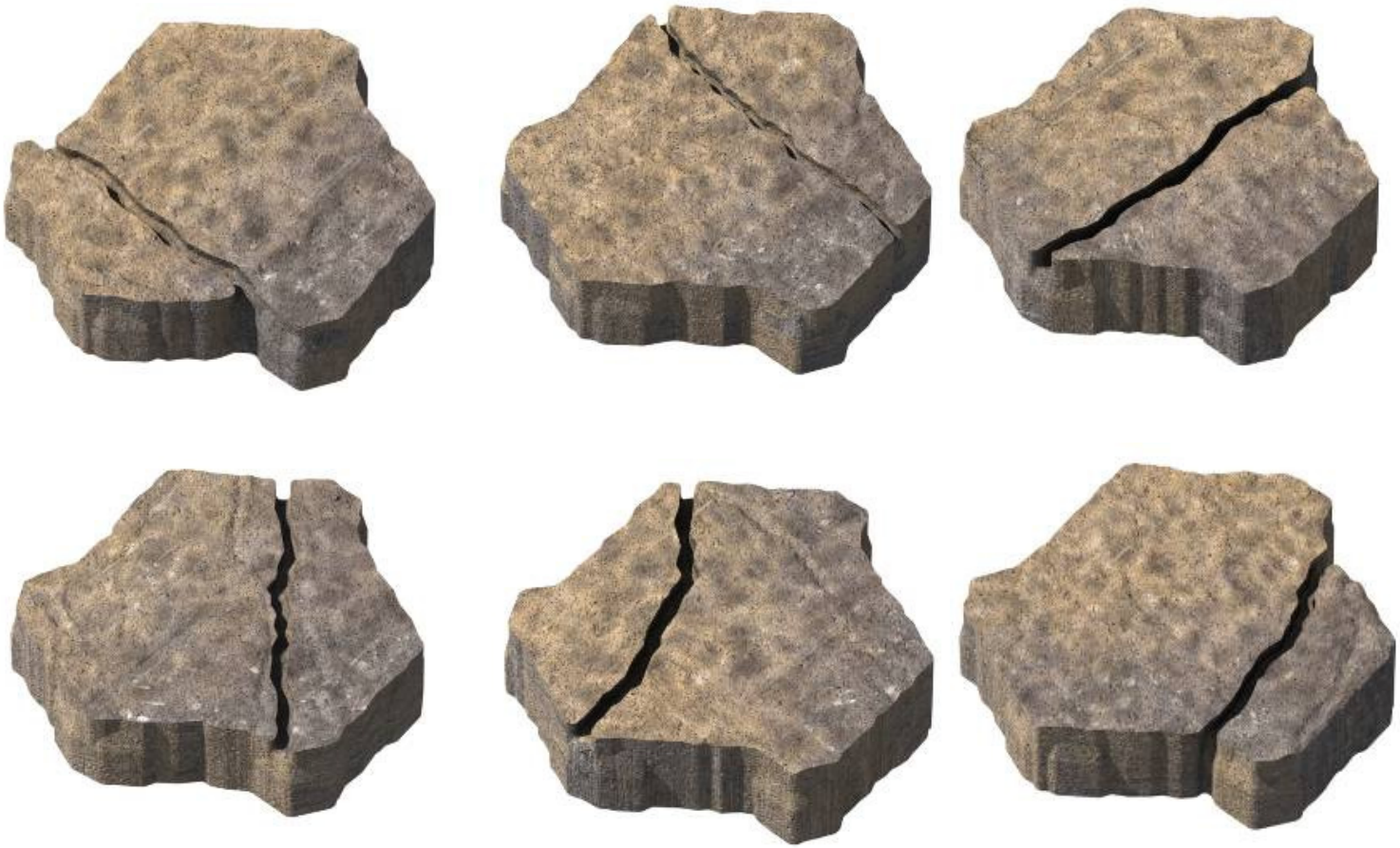
Developed into the Portage Stone and Belgard Arbel Pavers



Oldcastle, USA

Concrete Segmental Paving

One Basic Shape
Six different stones

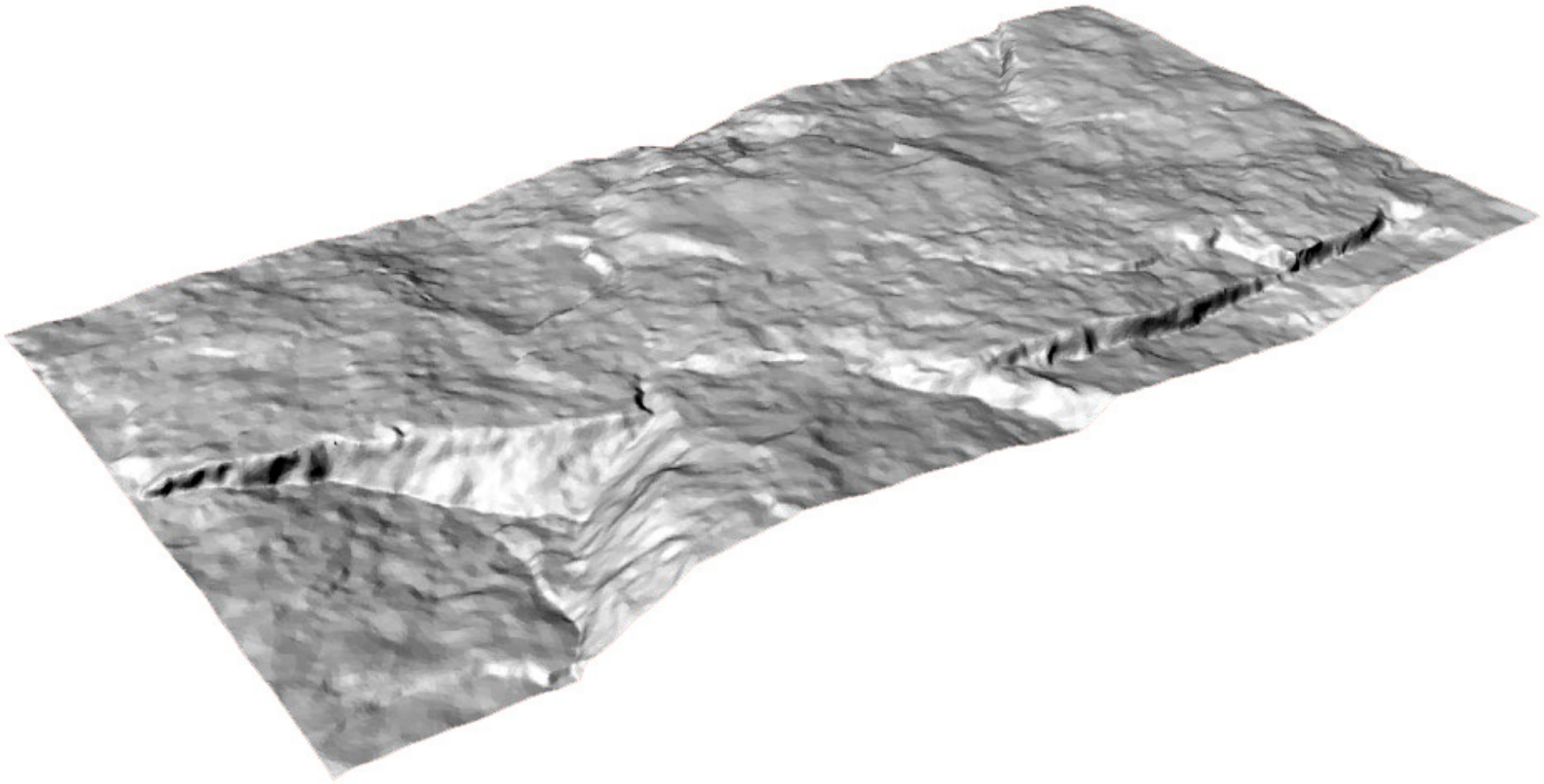


Concrete Segmental Paving

Then as the desire to replicate natural stone continued:-

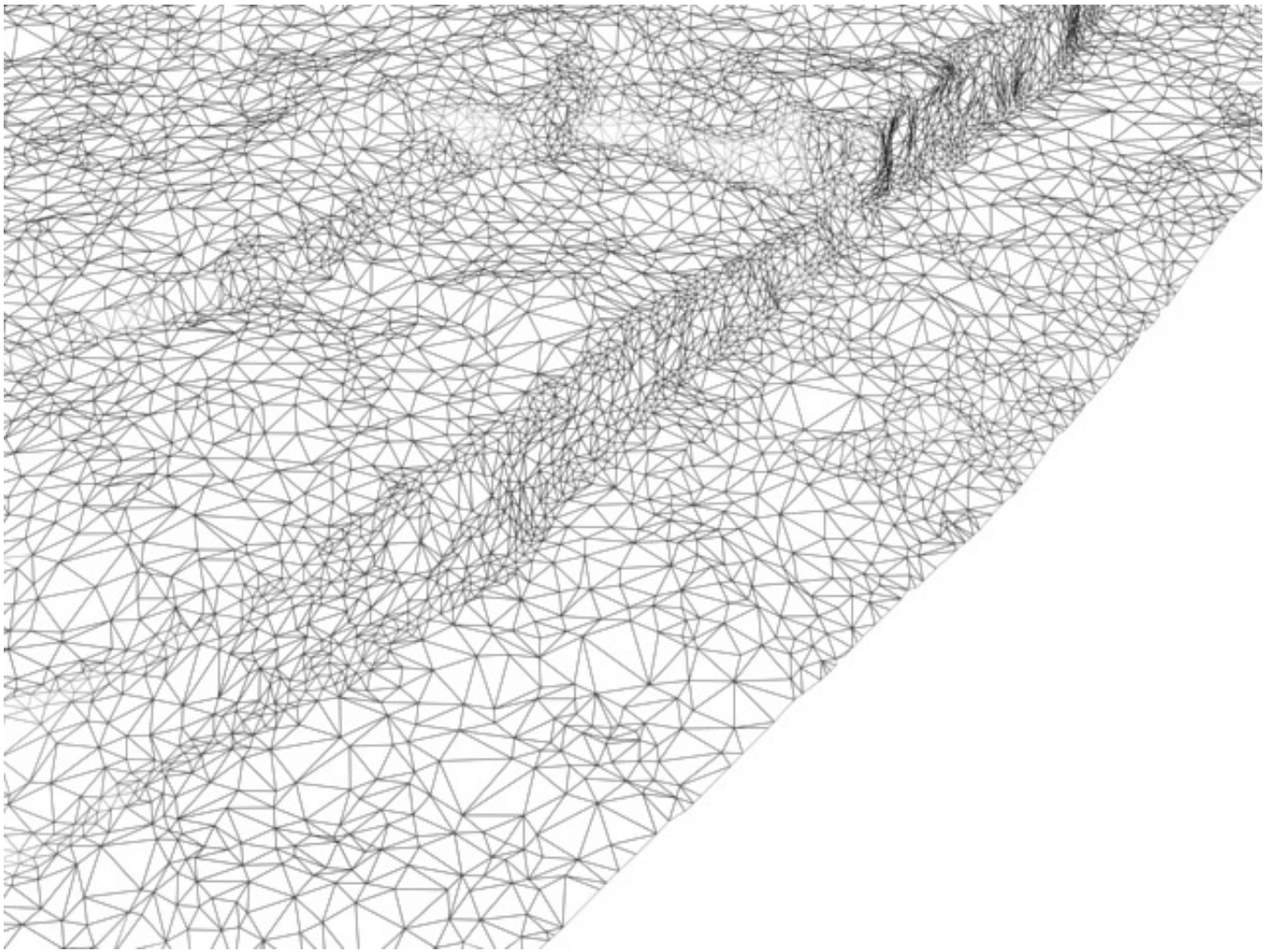
Concrete Segmental Paving

The surface of stones are digitally mapped



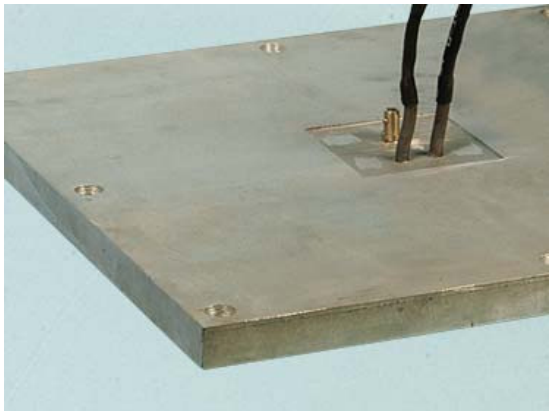
Concrete Segmental Paving

And stored as a computer file



To create tooling to make concrete pavers replicating real stones.

These tools use either heated shoes or by covering the shoe with flexible rubber material



Terr Turana Concrete Paver

EHL (Germany)

Concrete Segmental Paving

Advantages: Natural stone looking

Technical standards and installation as concrete paving

15 x 15 x 8 cm

40 different elements in one mould

Concrete Segmental Paving

Decorative portion in face mix only

A Paved Area

The same stones but shotblasted

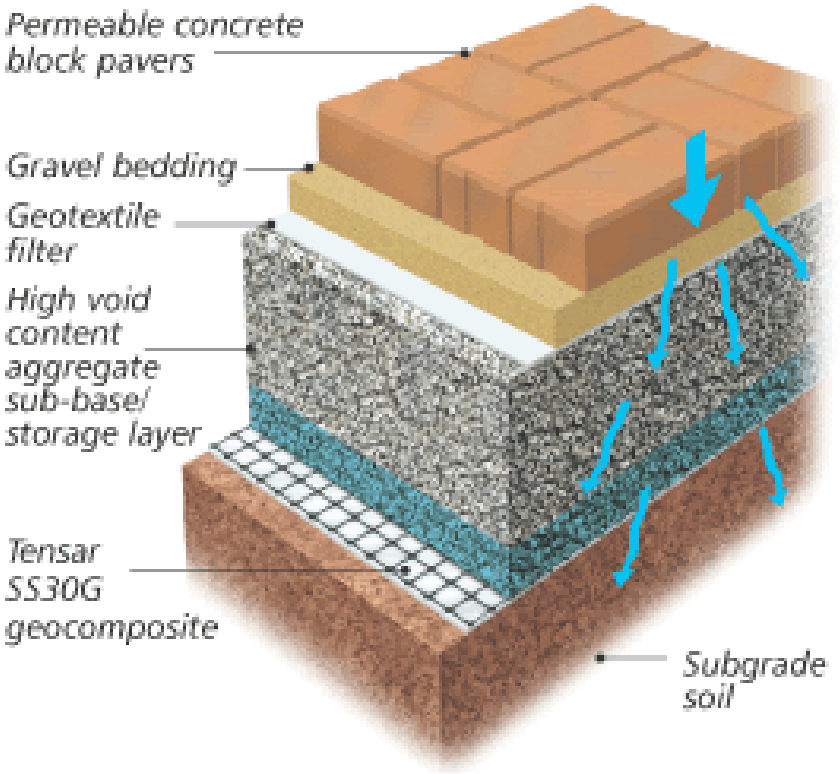
Environmental Developments

In the past decade there has been development of concrete paving that has environmental benefits:-

- **Stormwater Control**
- **Air Purifying**

Concrete Segmental Paving

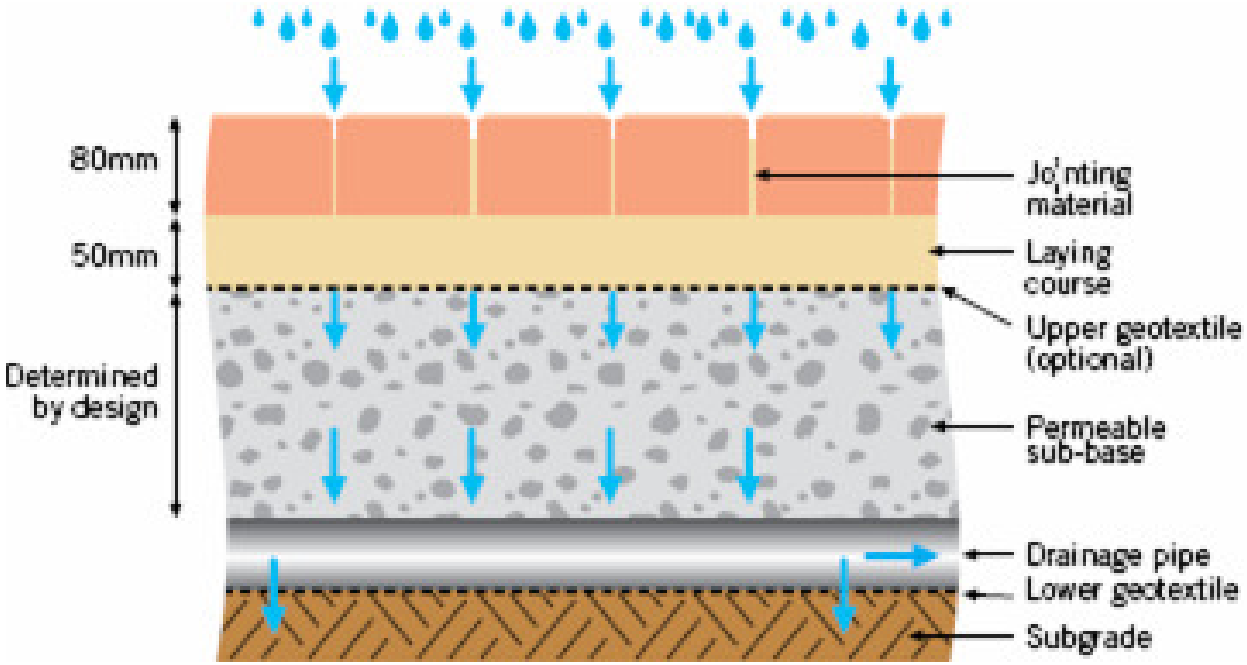
Stormwater Control



Tensar Systems

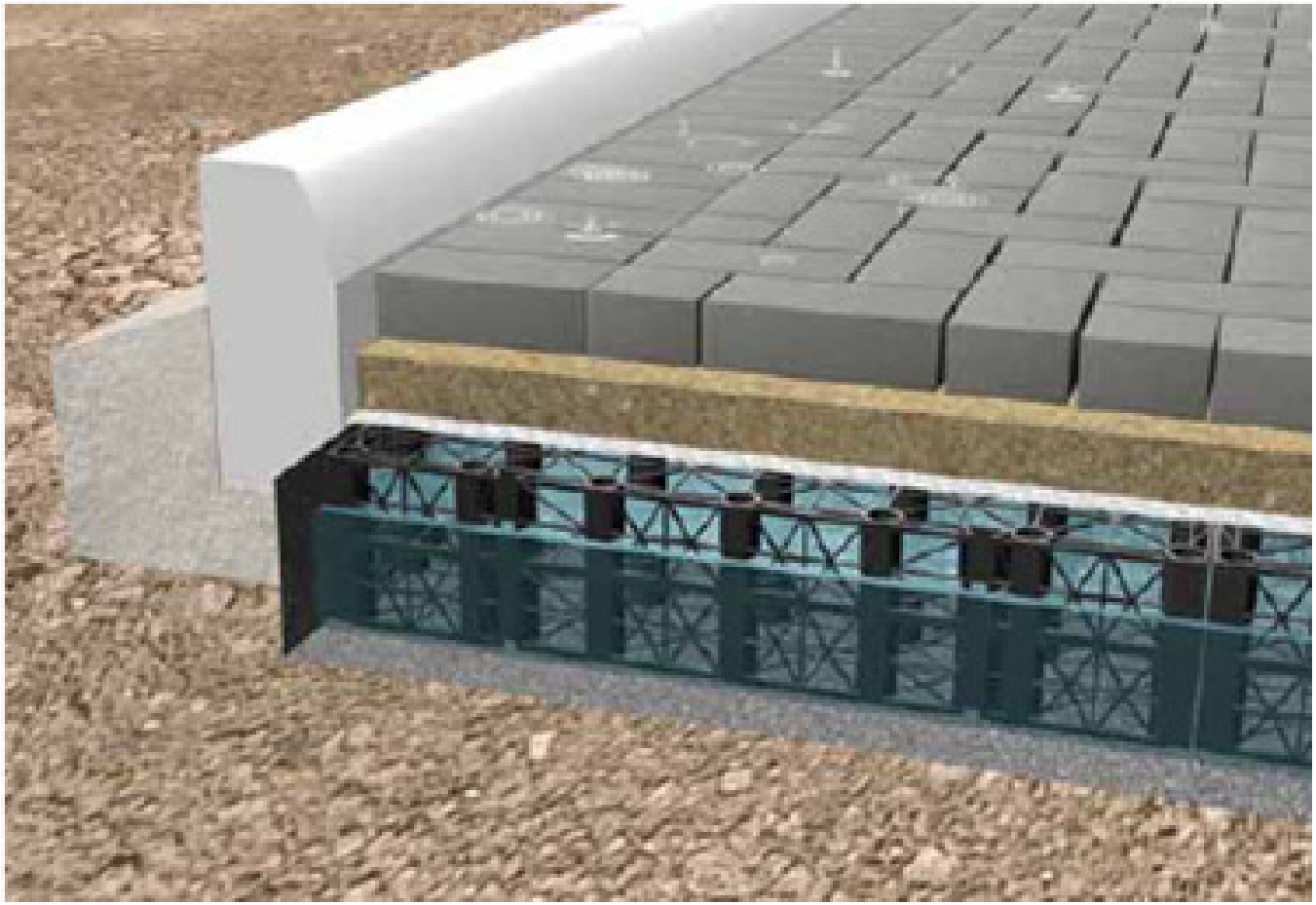
Concrete Segmental Paving

Stormwater Control



INTERPAVE:- *GUIDE TO THE DESIGN,CONSTRUCTION AND MAINTENANCE OF CONCRETE BLOCK PERMEABLE PAVEMENTS EDITION 5*

Stormwater Harvesting



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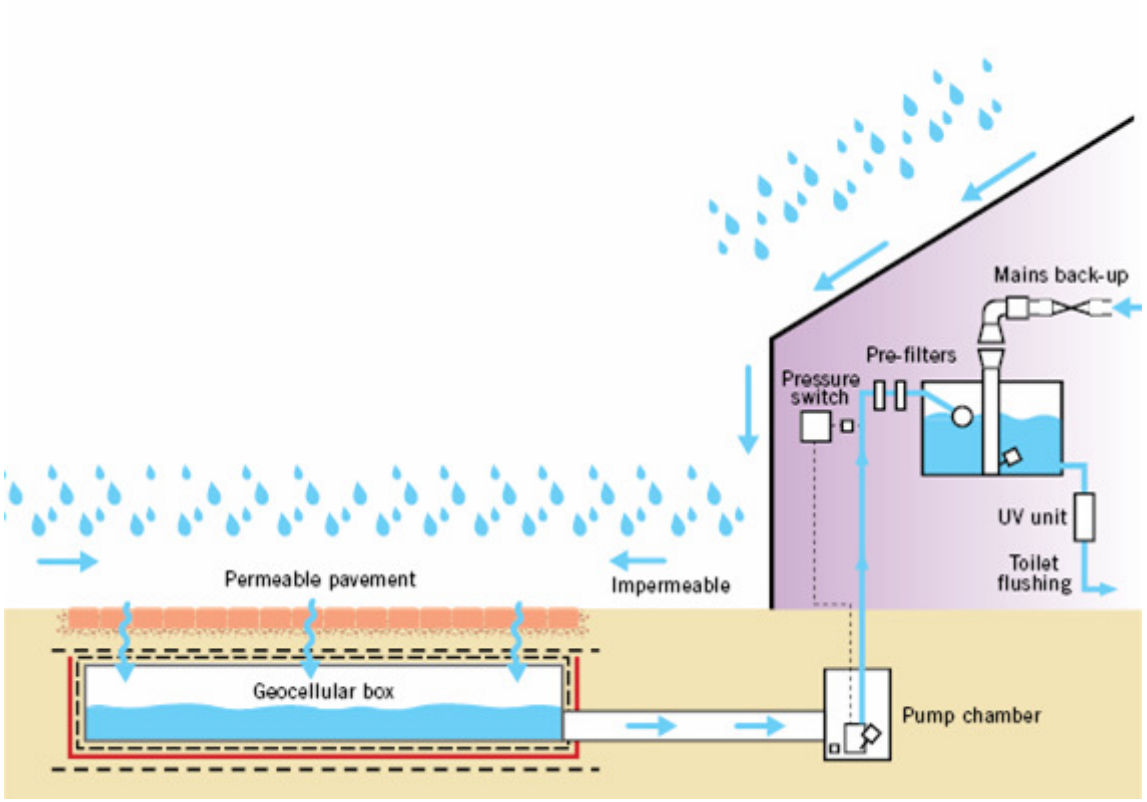
Stormwater Harvesting



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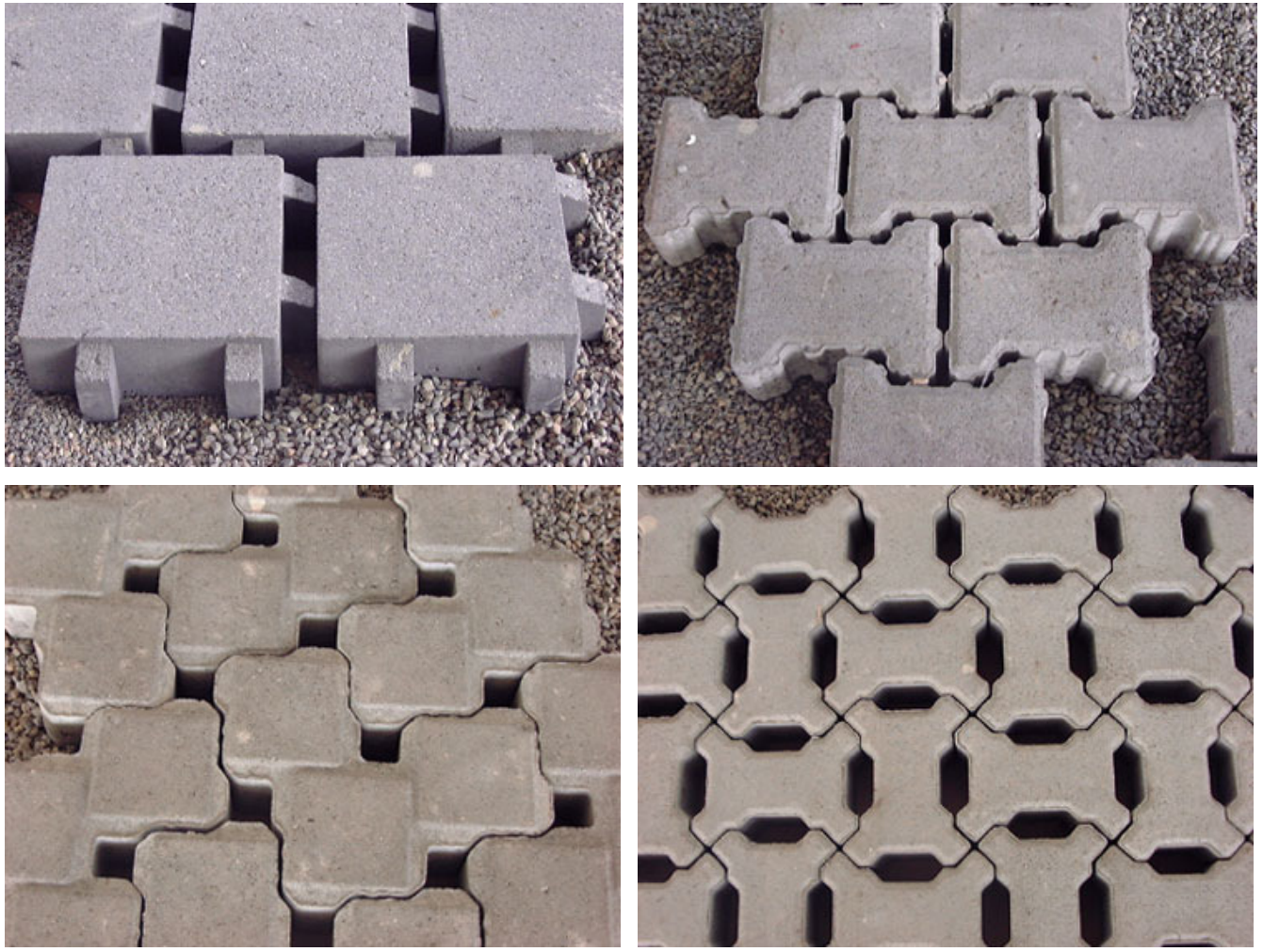
Concrete Segmental Paving

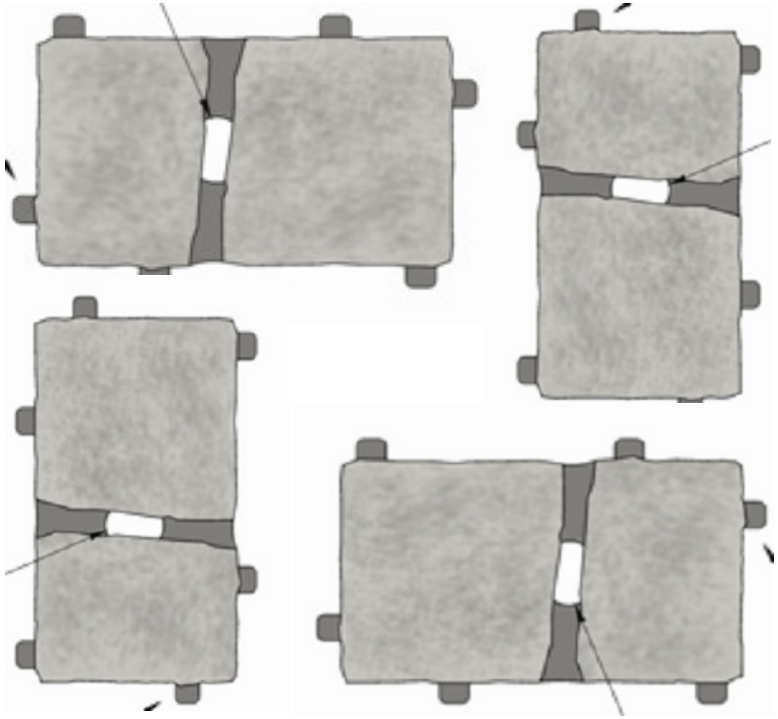
Stormwater Harvesting



Some of the many porous paver shapes

Concrete Segmental Paving

Stormwater Harvesting



Porous Paver with Deep Joints

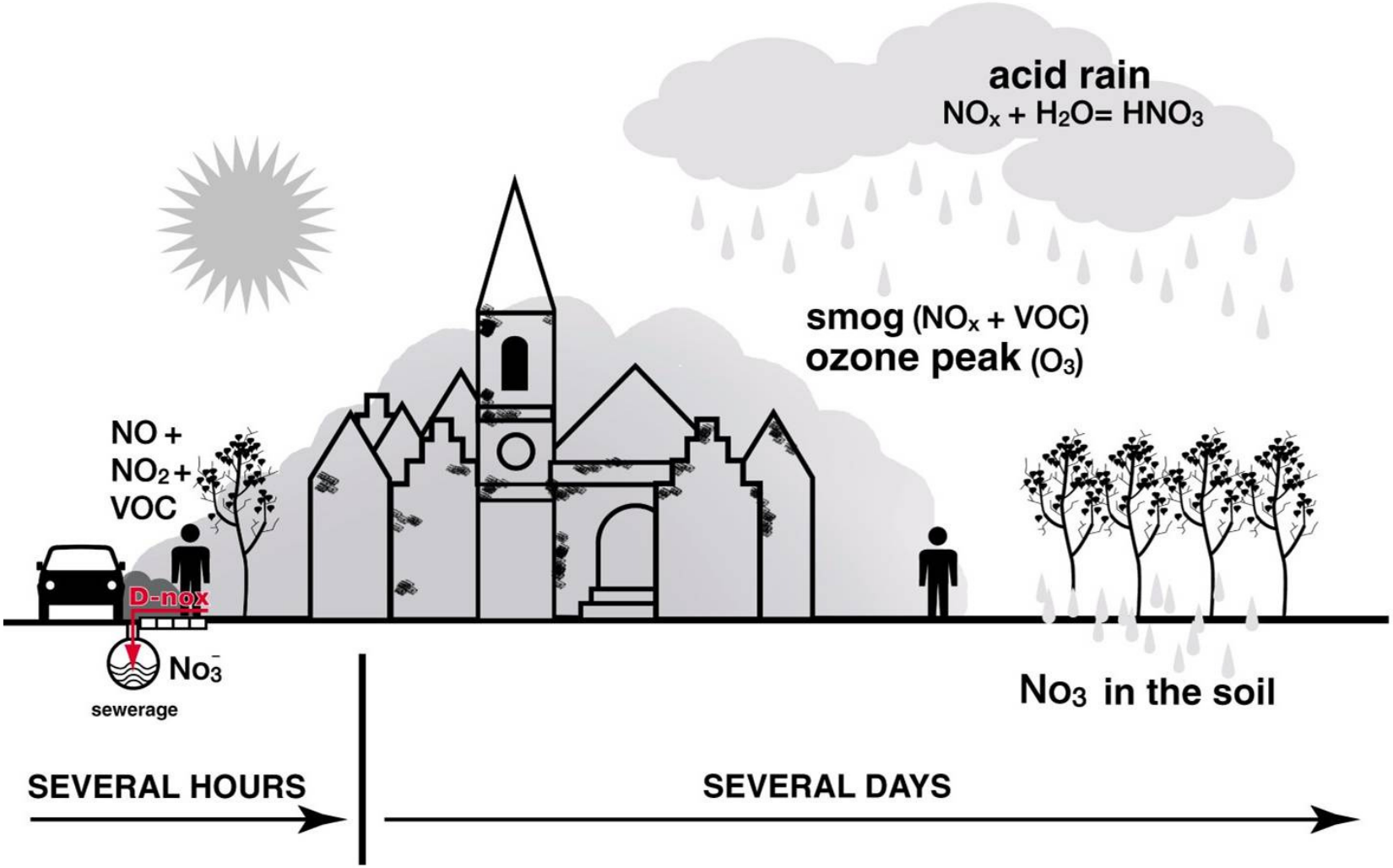
Each paver has four orientations

Concrete Segmental Paving

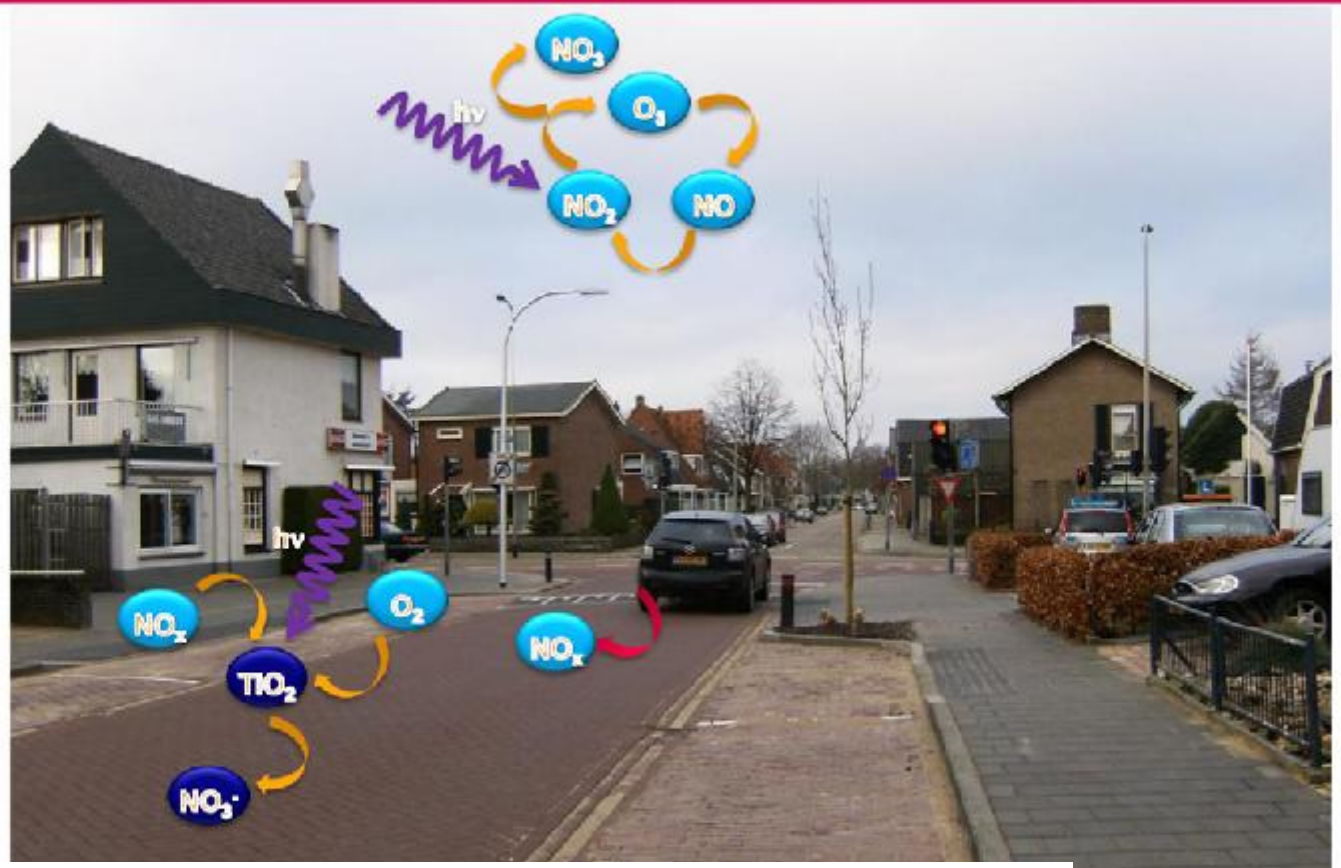
Allows good random visual effect

Concrete Segmental Paving

NO_x and the Environment



DeNOx Process



- Under the condition of uv radiation anataese TiO_2 transforms the nitrites and sulphites into sulphates and carbonates at the surface of the pavers or wall. This is a photocatalytic reaction.
- The end products will be washed out by the rain.

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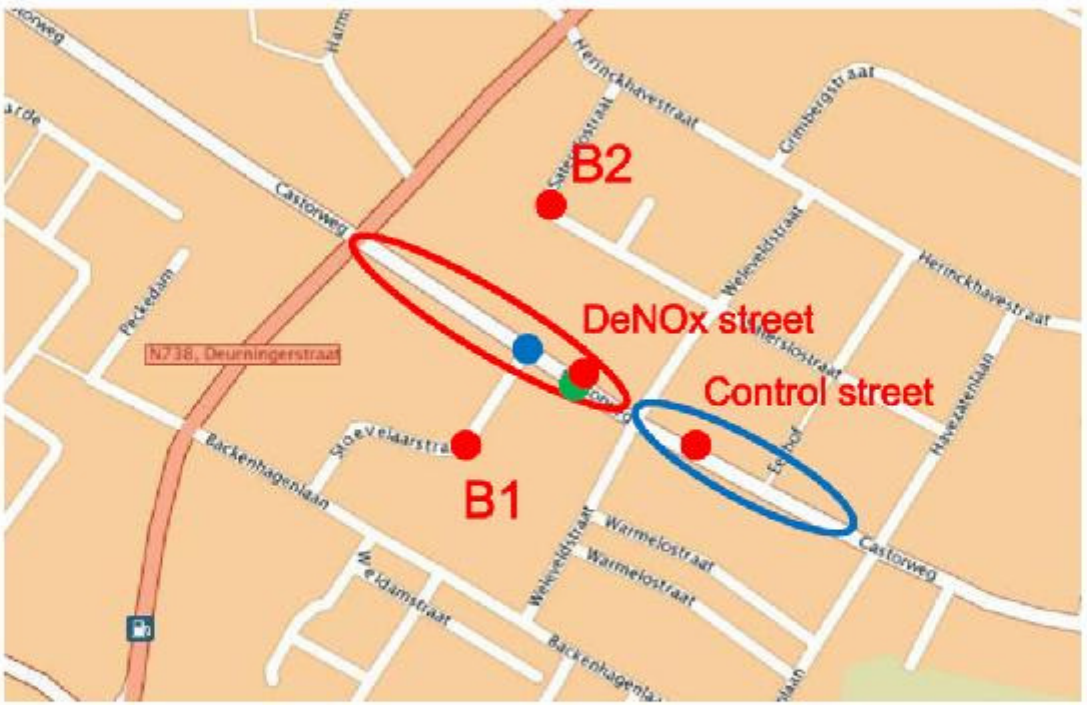
Concrete Segmental Paving

Sampling Places



● NO_x analyzers, O_3 analyzer and radiometer
● Weather station ● Traffic volume counter

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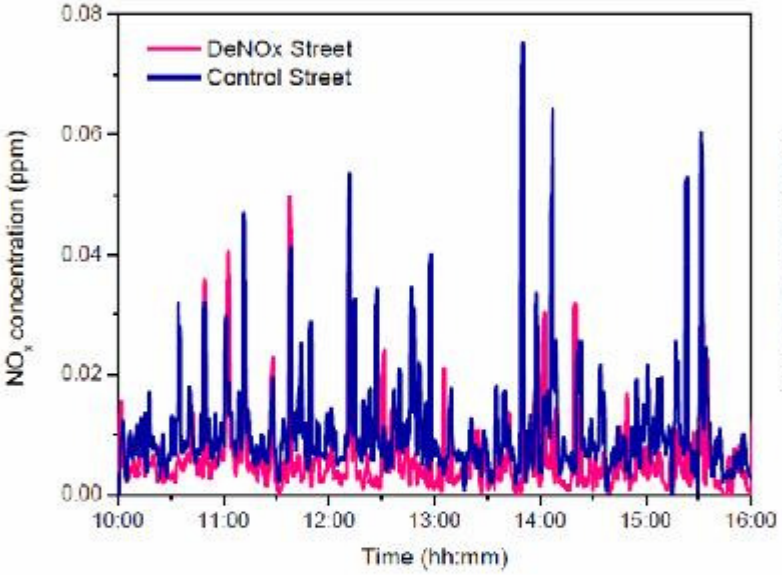
Location

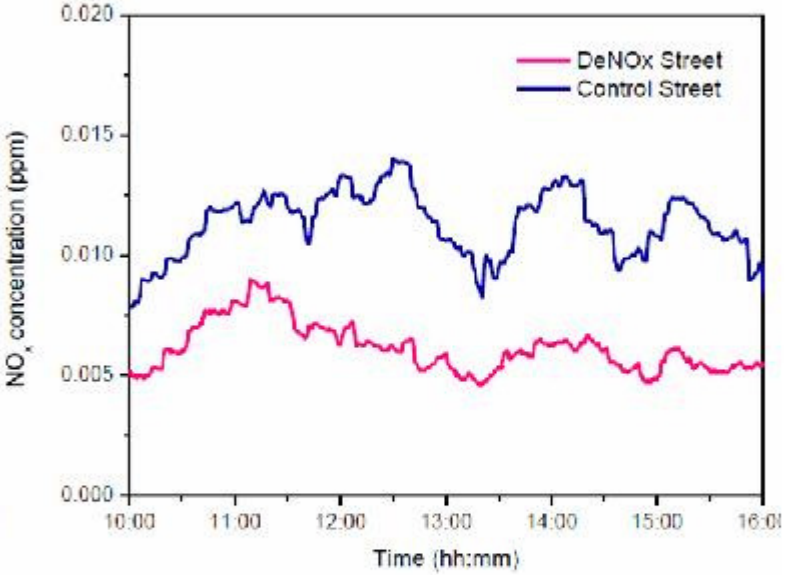
Before modification

After modification
(Nov 2009)

Concrete Segmental Paving

Outdoor Measurement 03-06-2010





Average NO_x reduction: 45 %

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Summarising the history of segmental paving

3000BC:- Minoeans construct the first road with segmental paving

500BC:- The Royal Road from Turkey to Damascus built

Early AD:- Romans build a road from Newcastle to Damascus

1800 late:- First concrete pavers made in Germany

1936:- First road from concrete pavers (Neuss)

1951:-First concrete pavers made in Holland to substitute clay (Hollandstone)

1964:- First national standard for concrete pavers

1970:- First concrete pavers made on a concrete block machine

2000:- 4000th anniversary of segmental pavers

2009:- First catalytic pavers laid in the Netherlands

Concrete Segmental Paving

Thank you!

John Fifield

"They Paved Paradise, put up a parking lot":- Jodi Mitchell