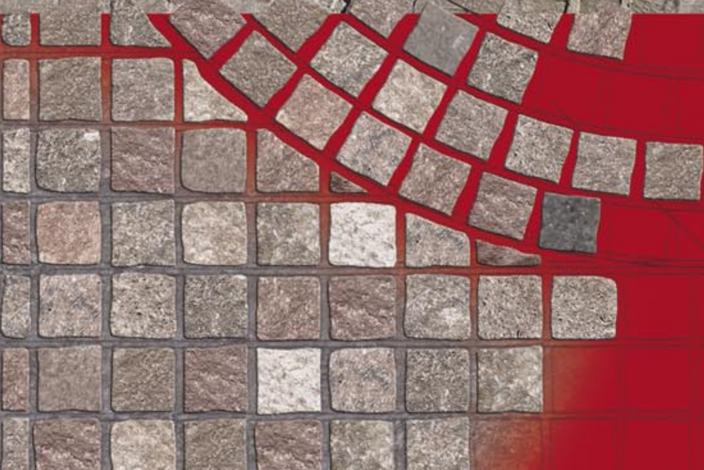
The Porphyry Manual



MEXICO PORPHYRY & STONES

THE PORPHYRY MANUAL

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Among the unique stones available, Porphyry can only be quarried in a limited number of places. It's a material that has been known and used since ancient times. Important relics and monuments in porphyry have been discovered at Assyrian-Babylonian, Egyptian and Roman sited, the cradles of civilisation.

Porphyry is type of volcanic, igneous rock, which along with granite and other rock formations make up approximately 95% of the world "crust". The material is composed of 70% silica, 14% alumina, followed by other elements. It provides a non-slip surface even when wet, and its surface can be quarry split, sawn, polished, rusticated and honed.

The company Mondial Porfidi has been involved in the mining, processing and laying of Porphyry since its establishment in 1968 in the porphyry-producing Trentino region in Italy.

Beside Italy, one of many large formations occurs in Guanajuato, Mexico and is recognized for its beautiful rusty red and gold-buff colours.

*That's why in 1995, Mondial Porfidi open a new quarry in Mexico. This new company is called **MEXICO PORPHYRY & STONES.***

*With **MEXICO PORPHYRY & STONES**, the company took a step to supply this stone more competitively to the North American market. The company is centrally located on 5,000 acres (2,000 h) in San Luis de la Paz, Guanajuato, which has access to ports on both sides of the country -Tampico in the east and Manzanillo in the west.*

The company has more than 60 workers. It currently owns 14 Steinex cutting machines, and 17 splitting machines and two computerized Zonato saws among others, for a production for over 100,000 m2 per year.

*Since 1996, **MEXICO PORPHYRY & STONES** has been a constant presence in Stone shows in America and Mexico as well. Porphyry now is been specified more and more for paving outside the buildings as well as many other applications such as walls and facades, thanks to the caracteristic of the stone to match with modern, elegant and rustic styles of architecture.*

With this manual, we want to provide you with the most completely explanations regarding the technical and physical properties of Porphyry, production methods and usage, photos of jobs made in Mexico, Europe and the US, with the aim of fully appreciating this natural stone.

For quotes and more information, please visit us at:
www.mexicoporphyry.com

PART ONE

EXTRACTION AND WORKING

Chapter 1

GEOLOGICAL SETTING PHYSICAL AND MECHANICAL PROPERTIES

1.1 ROCK MATERIAL

We thought it would be useful to start with some information about the mineralogy of porphyry in order to appreciate the specific characteristics of the material and to be able to compare it with other varieties of stone which are available on the market. For further information please refer to specialist texts. In particular we will consider the main technical properties so as to be able to evaluate the possibilities for using the material depending on the precise requirements.

GENERAL

Rocks are classified into 3 main categories depending on the origin of the material:

1. Igneous rocks;
2. Metamorphic rocks;
3. Sedimentary rocks.

Igneous rocks

Igneous, volcanic, eruptive or magmatic rocks are formed by the solidification of a magma, a fluid mass of volcanic origin with complex composition which is found at high temperatures within the earth's crust. They are called primary rocks because they are the first to be formed and are not derived from the transformation of other rocks. They represent 10% of the earth's surface, while in volume they make up to 95%.

Intrusive igneous rocks are the result of slow cooling of the magma mass deep in the earth's crust. As they have solidified under pressure and a high, stable temperature they have a very compact structure and are completely crystallized (granites, diorites, sienites, gabbros, serpentines, etc..). The igneous rocks which consolidated at greater depth have a less homogeneous structure, not crystalline but in part vitreous.

Extrusive igneous rocks, on the other hand, formed when the magmas were expelled into the lithosphere. Due to the effect of the reduction of pressure, rapid cooling and contact with the earth's atmosphere, the process of crystallization was halted.

The typical structure of extrusive rocks is the porphyritic structure i.e. fine grained or glassy ground mass with large single crystals (phenocrysts) scattered in it (porphyry, trachites, basalts).

Sedimentary rocks

Sedimentary rocks are formed by the transformation of rock material on the earth's surface during a later geological era than the one in which the igneous rocks were formed. They constitute 75% of the surface area of our planet, 1.1% by volume. Sedimentary rocks can be divided on the basis of the way they developed:

1. Rocks of clastic origin: originating from the action of physical elements (heat, wind, wave action, water erosion etc..) on the lithosphere (aranites, breccias, tuffs, etc..).

2. Rocks of chemical origin: formed due to the circulating solutions following the evaporation of the solvent, usually water, or precipitation of salts due to the loss of gas which is released (travertine, alabaster, peperino, pietra serena, etc..).

3. Rocks of organic origin: produced by the transformation of organic substances, animal or vegetable, in the marine environment, which contain calcium carbonate in their skeletons (calcites, amonitic limestone, dolomite, etc..).

Metamorphic rocks

Rocks, both of igneous or sedimentary origin, may undergo many processes of transformation due to modifying action produced within the earth's crust, such as pressure, and pressure combined with high temperature. Metamorphic rocks make up to 15% of the surface of the earth, 4% by volume.

The characteristics of metamorphic rocks may be partly or completely different from those of the original material. They have different structures and often a completely altered mineral composition.

Metamorphic rocks include gneiss (formed by the metamorphosis of igneous rock), slate, quartzite, crystalline marbles and saccaroid marbles (Carrara), crystalline dolomite, etc..

1.2 PORPHYRY

By the term **PORPHYRY** we mean the extrusive ignimbrite which in the Mexico area is dated in the Lower Permian. From a graphic, petrological point of view porphyry is the extrusive equivalent of granite and thus has a very variable composition. It passes from basic composition like porphyrites and trachytes, to the more acidic compositions of rhyodactites and rhyolites. As we have said, porphyry is an extrusive product originating in the Lower Permian, belonging to the Porphyric Atesina Platform. The rock is extremely varied as a direct consequence of extensive tectonic activity which resulted in linear eruptions along numerous fractures.

The geological situation was affected by prior erosion processes, demonstrated by the presence of basal conglomerates, which gave rise to decompression and facilitated the rise of the magma. The volcanic activity continued for millions of years with successive eruptive and stable phases. The eruptive structures were extremely varied including necks, dykes, sills, ignimbrites etc.. On the porphyry platform it is possible to find the results of reworking which indicate pauses in the phases of magmatic activity, and the presence of seams of predominantly rhyolitic material containing pink feldspar phenocrysts and larger crystal structures. These features document the rise of the magma after a stable phase. The eruptive activity lasted for tens of millions of years and was accompanied by a series of downward faulting and tectonic activity thus producing an extremely complex geological area. The area has a very varied morphology due to selective erosion, in particular associated with the more errodable rocks like tuffs and conglomerates, while the ignimbrites result in vertical cliffs or, after glacial erosion, "mouton" mounds. Among the extrusive rocks present, the "ignimbrites" are particularly important because from them we obtain the porphyry suitable for cutting and paving. The ignimbrites originate from the collation of extremely fluid liquid-gas mixtures at high temperature. Being rich in gas and having a more acid composition they are more viscous and so extend over a wide area. From this we can explain why the ignimbrites have a sub-vertical, slab-like structure with parallel strata. This slab effect contributes to the workability of porphyry. The thickness of a typical unit is between 100 - 200 meters, with an area of about 7,500 km2, of which only about a quarter outcrops while the rest has been covered by later deposits. The "stratification" of these rocks makes it possible to split them into slabs along the parallel planes which are sub-vertical or steeply inclined.

The chemical composition of the Mexican porphyry is as follows:

Silicon oxide (SiO_2): 73.68%
Aluminium oxide (Al_2O_3): 12.05%
Titanium dioxide (TiO_2): 0.05%
Iron oxide (Fe_2O_3): 2.62%
Calcium oxide (CaO): 0.63%
Magnesium oxide (MgO): 0.72%
Potassium oxide (K_2O): 5.77%
Sodium oxide (Na_2O): 2.06%
Loss on heating (PF): 1.95%

The mineralogical composition comprises principally quartz, sanidine and plagioclase, and as accessories biotite and vitreous material. The porphyric structure encourages stratification and improves the technical characteristics (high breaking load under pressure, high resistance to chemical attack, etc..). These characteristics make porphyry one of the most important materials for paving and cladding. As we have said before, throughout the Lower Permian volcanic activity occurred between periods of stability-this makes it possible to identify the difference between workable masses and unworkable masses from the variation in colour, composition, inclination and grain characteristics. In particular the colour is an important indicator for the identification of rock types which are suitable for being worked. In fact the colour varies from a pinky grey to a darker shade due to the absence of quartz. The first type are suitable for industrial use, the second rather less so, if they are not completely useless. This variation in colour is due to the variation in composition. The more basic composition is darker while the more acid is lighter in shade and more suitable.

1.3. TECHNICAL PROPERTIES OF ROCKS

UNI 9724 and UNI 9725 define the tests of the most important characteristics for the acceptance of rock material and its appropriate use depending on its properties and behaviour when in use. These tests include:

1. Petrological examination.
2. Dimensions and shape.
3. Apparent volumetric mass (weight/volume).
4. Compressive strength.
5. Resistance to deformation (bending).
6. Coefficient of thermal expansion.
7. Elasticity.
8. Impact test.
9. Knoop micro-hardness.
10. Absorption coefficient.
11. Freeze – thaw characteristics.
12. Resistance to abrasion.

The results of the physical and mechanical tests carried out on samples of rock defined as "porphyry" by the Department of Geology and Resources of the Polytechnic of Turin follow. In order to make them easier to understand the results are accompanied by a few notes summarising the techniques and apparatus employed, comments on the results and comparisons with other rock types.

1.3.1. Petrology

The rock is composed of a micro crystalline ground mass with phenocrysts of average size 0.5 – 1 mm (maximum 5 mm) contained in it.

In the phenocrysts the following principal constituents are found (in decreasing order)

• Feldspar, in rather muddy crystals with inclusions of opaque minerals and sheet silicates;
• Quartz, in normally clear crystals, larger than average;
• Chloritized biotite, with abundant opaque inclusions.

The rock could even be called a rhyolite or, based on slightly old-fashioned terminology still in use, a quartzite porphyry.

1.3.2. Dimensions and shape.

For this information please refer to the chapter regarding extraction and wording techniques.

1.3.3. Apparent volumetric mass: UNI 9724/2

The apparent volumetric mass gives and indication of the maximum compactness of the rock. It is the ratio, expressed in kg/m3, between the mass and the apparent volume (determined by geometric measurements), i.e. the volume delimited by the external area, of samples of regular shape.
The weight of the unit of rock is linked to the mineralogical composition and its fabric. In a compact rock this may coincide with the "real specific weight" (unit volume of the rock form which is subtracted the volume of empty space), but in porous rocks it is lower. The real specific weight, compared with the apparent gives the level of compactness of the rock, i.e. the lesser or greater presence of empty space.
Porphyry – apparent volumetric mass, average value: 2555 kg/m3.

1.3.4. Compressive strength: UNI 9724/4

This determines the unit load, under simple compression expressed in M/mm2 (1Mpa = 10.2 kgf/cm2), necessary to produce breaking of the sample – either a cube with 7.1 cm sides or a cylinder with diameter between 4 and 8 cm and a height: diameter ration of 2.
The load is applied with constant rate of 0.4 Mpa/sec in a direction perpendicular to the planes of preferred splitting of the rock.
Knowing the characteristics like resistance to compression and resistance to deformation (bending), not to mention the modulus of normal elasticity, is clearly important for the necessary statistical evaluations of elements (tiles, blocks etc..) which undergo the effects of mechanical wear and tear.
This applies not only in the case of load-bearing elements which are after all rare, but in relation to the particular effects of flexing caused by pressure, form example due to the wind on cladding tiles.
Porphyry – resistance to mono axial compression: average value 221.5 Mpa.

1.3.5. Resistance to deformation (bending): UNI 9724/5

This test is carried out on samples 12 cm long, 3 cm wide and 2 cm high. The samples are placed on the rounded edges of two blades 100 mm apart and a gradually increasing load is applied by a third blade in the middle until breaking occurs. The breaking load of flexion (bending), R, is expressed in Mpa (or N/mm2 where 1 Mpa = 10.2 kgf/cm2) from the formula:

$$R = \frac{3 P l}{2 b h^2}$$

in which P = load of breaking of the sample, in Newtons; l = distance between the supporting blades, in mm; b = the width of the sample in mm; h = height of sample in mm. The test is usually carried out with load applied perpendicular to the natural splitting planes of the rock.

Porphyry – breaking strain under indirect traction through flexion, average value: 22.5 Mpa.

1.3.6. Coefficient of linear thermal expansion

This represents the variation in length of the test samples, expressed in mm/(m°C), caused by a change in temperature of 1°C. The dilatometer containing the sample is attached to a thermostat and brought first to a temperature of O°C and then to 50°C. The expansion is measured by the gauge which has a feeler in contact with the transmission bar (in silica). To calculate, it is assumed that the coefficient of linear thermal expansion of the silica is ALFA° = 0.5 x 10-6/°C. It is essential that all the rock parts used in building have the opportunity to expand whatever their coefficient of expansion by means of the addition of suitable expansion joints.

Porphyry – coefficient of linear thermal expansion, average value: 5.55 x 10-6/°C.

1.3.7. Coefficient of normal elasticity

This is usually obtained by testing samples with a cuboid shape, the base being 5 cm by 5 cm and the height 20 cm. Alternatively a cylindrical sample with diameter of at least 5 cm and height: diameter ration of about 3 may be used. The samples are subjected to compression along their longitudinal axis while measurements of deformation are taken by a couple of electrical extensimeters placed longitudinally in diametrically opposed points from the lateral surface of the sample. The load is applied with constant rate of 0.4 Mpa/sec, in a direction perpendicular to the preferred splitting plane of the rock.

The elasticity is therefore defined as the ratio between the variation of the axial force and the consequent unit longitudinal deformation and is expressed in Mpa (=N/mm2) or GPa.

With the results obtained it is possible to draw a force – deformation (stress – strain) graph from which is obtained the modulus of elasticity tangent Et (measured at a stress corresponding to 50% of the breaking strain) and the elasticity secant modulus Es (measured between the value zero of the stress and 50% of the breaking strain).

Porphyry – Elasticity tangent modulus Et: 66180 Mpa. Elasticity secant modulus Es: 59360 Mpa.

1.3.8. Impact test

This is measured as defined in article 3 of the law R.D. 2234 of 16.11.1939 determining the minimum fall height, expressed in cm, of a steel sphere with mass 1 kg which, hitting the centre of the samples which are 20 x 20 cm squares, 3 cm thick, resting on a bed of sand 10 cm thick, produces breaking. The rock may demonstrate strength or weakness to impact and thus resistance to sudden impact.

Information, such as the resistance to impact and Knoop micro hardness tests, facilitates the assessment of the behaviour of the rock used in paving and steps, i.e. in places particularly exposed to impact from objects and the passage of people and vehicles.

Porphyry: impact test, minimum fall height average value: 62 cm.

1.3.9. Knoop micro hardness: UNI 9724/6

The test is based on the determination of the measurement of a series of 20 imprints (or 40 for materials with uniform grain structure) produced by a diamond punch pressed with a specific load on the highly polished surface of a sample under examination.

The Knoop micro hardness HK is expressed in Mpa (1Mpa = 0.102 kgf/mm2) from the following formula:

$$HK = \frac{14.23 P}{l^2}$$

In which

P= the load on the punch, expressed in N; l = the length of the longest diagonal of the imprint left by the punch, expressed in mm.

The values of micro hardness, calculated for a series of examined points are plotted on a graph in increasing order (hardness graph) which has on the X – axis of the graph the points measured and on the Y – axis the corresponding values of micro hardness.

Porphyry – Knoop micro hardness, average value: 5416 Mpa.

1.3.10. Coefficient of absorption

To determine the coefficient of absorption the constant mass sample is first dried at 105° and the mass is measured to within an error margin of 0.01 g. It is then immersed in distilled water until it reaches a stable weight +/- 0.01g.

This is an indication of the maximum compactness, resistance and durability of the rock and is of particular importance for rock materials used in construction, especially for roofing, paving and cladding.

The coefficient of absorption is the measure of the maximum quantity of water absorbed by the rock material when it is immersed in de-ionised water at ambient temperature and pressure, expressed as a percentage of the dry mass of the sample.

The permeability of rock materials is the possibility of movement of fluids within the rock through the internal pore spaces. The permeability is related to the shape and size of the spaces rather than the actual porosity which expresses the amount of spaces themselves. Its low coefficient of absorption has led to porphyry being used where it is in direct and continuous contact whit water, on the bed and banks of rivers for example and exterior paving.

Porphyry – coefficient of absorption, average value: 6.53%.

1.3.11. Freeze/thaw behaviour

The breaking load is measured under simple compression according to article 8 of R.D. 16.11.1939 no. 2232 after a cycle of 20 immersions in water at 35°C alternated with periods in a refrigerator at –15°C.

The material is considered resistant if after the freeze/thaw test the results are not more than 25% lower than the average tests carried out on dry samples. Rocks are considered not resistant if they crumble under the effect of freezing, i.e. due to the increase in volume of the absorbed (pre) water and consequent pressures on the walls of the cavities with the progressive deterioration of the rock. The resistance to freezing and the coefficient of linear thermal expansion are therefore extremely important for the selection of rock materials for exteriors and related technical uses. Materials must be able to withstand the action associated with climatic conditions including considerable temperature variations and low temperatures.

Porphyry demonstrates a level of breaking under compression after the freeze/thaw cycle among the highest for rock materials. This characteristic, of particular importance in cold climates, ensures a high level of resistance even after freezing and thawing for all those places and structures which are subjected to forces, paving, external cladding, load bearing walls etc..

Porphyry – Mono axial compression after freeze/thaw, average value: 202.6 mPa.

1.3.12. Resistance to abrasion

This measurement is based on the loss of thickness, expressed in mm, demonstrated by 2 samples with 7.1 x 7.1 cm square base which must endure a certain number of laps of a rotating abrasive track against which they are pressed with a pressure of 0.03 N/mm2 (the Amster tribometer test).

According to article 11 of R.D. 2232 of 16.11.1939 and the norm CNR of 1953, the result is the relative coefficient of abrasion, i.e. the ratio between the thickness of a sample of S. Fedelino granite after abrasion and that of the sample under examination after undergoing the test described above carried out simultaneously. The relative coefficient of abrasion is therefore a number which is directly proportional to the resistance to wear of the material. In fact rocks which are more resistant than S. Fedelino granite give a result of more than 1, while those less resistant give a result of less than 1.

This characteristic is extremely important in interior and, in particular, exterior public places where stone used for paving is subjected to particular wear, and above all in road surfaces where there is wear due to sliding friction which, over the course of time, tends to alter the original surface of the material.

The different hardness of the minerals of which it is composed gives paving of porphyry the characteristic roughness which it maintains over time thanks to its vitreous structure. Porphyry, in fact, unlike other volcanic rocks like granite, tends not to disintegrate (lose individual crystals) but remains rough, and so

has optimum adherence even in the rain.
Porphyry – resistance to abrasion, relative value with reference to the S. Fedelino granite: coefficient 1.51.

1.3.13. Other properties

Other properties should be mentioned even though they are not measured precisely or classified on the basis of regulation physical – mechanical tests. They nevertheless help to define the characteristics which are often important for the end use.

Durability

Any rock material situated outside is subjected to a process of ageing due to chemical and physical agents produced by atmospheric factors (rain, sun temperature etc..) and aggravated by localized conditions of pollution (carbon monoxide and other chemicals present in the atmosphere, pollen etc..)

As nothing can be done to reduce ageing (neither varnish, nor treatments have proved effective) it is necessary to use rocks which have the highest level of durability like igneous rocks, and in particular porphyry.
This should be remembered as one of the most important qualities of this material, its high level of resistance to chemical attack which makes it particularly suitable as paving material in special circumstances (chemical, mechanical) or in the presence of lubricating oils, where the hardness and roughness of the surface are of particular importance.

Workability

This is the property of the rock which means that it can be transformed into the desired shape. It is closely related to the fabric and structure of the rock and also its hardness. The workability can be defined as behaviour to:

• Breaking, which usually depends on the fabric of the rock. A specific characteristic of porphyry, thanks to its "stratified" structure, is that it splits along natural, parallel planes. As it behaves like glass from a mechanical point of view, porphyry can easily be split along planes which are perpendicular to stratification;
• Sculpting or reaction to being shaped with sculpting tools;
• Sawing or reaction to being sawn; a widely used technique with porphyry both for finishing edges and for obtaining slabs or tiles with all their faces sawn;
• Polishing or the reaction to being treated to produce a polished or shiny surface. The porphyry used normally for interiors is highly polished, mirror finish.

APPARENT VOLUMETRIC MASS

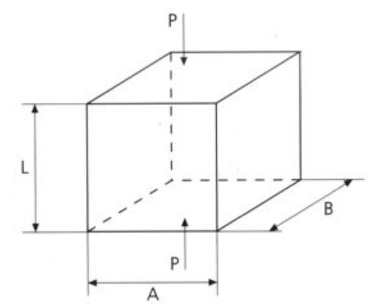
(From tests carried out on regular shaped samples according to the norm art. 5 of R.D. 2232 of 16.11.39)

SAMPLE (I): porphyry
Location: Mexico
Rock type: porphyric quartzite

Sample (or material)	Sample Number	Apparent volumetric mass	
		Single values (kg/m3)	Average value (kg/m3)
	1	2560	**2555**
	2	2550	

BREAKING TEST UNDER MONO-AXIAL COMPRESSION

(On cubic samples)



SAMPLE (I): porphyry
Location: Mexico
Rock type: porphyric quartzite

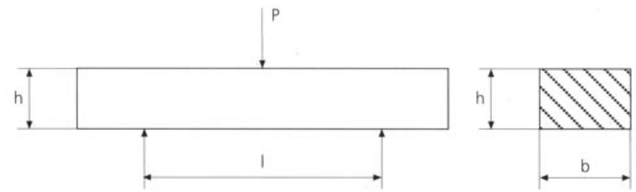
Orientation of possible planes of discontinuity or schistocity with respect to the direction of load DRY SAMPLES

Sample (or material)	Sample Number	Dimensions L (mm)	A (mm)	B (mm)	Breaking load P(kN)	Resistance to Mono-axial compression C_0(Mpa)*
	1	71.7	70.5	69.7	1091	222.0
	2	69.5	71.0	71.0	942	186.9
	3	67.0	72.0	71.0	1114	217.9
	4	69.5	69.5	70.0	1261	259.2
Average result of 4 samples Com=221.5 Mpa						

*1Mpa = 10.2 kgf/cm^2

BREAKING DUE TO INDIRECT BENDING TEST

SAMPLE (I). Porphyry
Location: Mexico
Rock type: porphyric quartzite



Sample (or material)	Sample Number	Length (mm)	Height H (mm)	Width B (mm)	Breaking load P(kN)	Resistance to bending σ(Mpa)*
	1	100	21.0	29.3	2.2	25.5
	2	100	21.8	31.2	1.9	19.2
	3	100	24.5	31.2	2.5	20.0
	4	100	20.0	30.0	1.7	21.2
	5	100	20.0	31.3	2.2	26.4
Average result of 5 samples σ_m = 22.5 Mpa						

*1Mpa = 10.2 kgf/cm2

COEFFICIENT OF LINEAR THERMAL EXPANSION

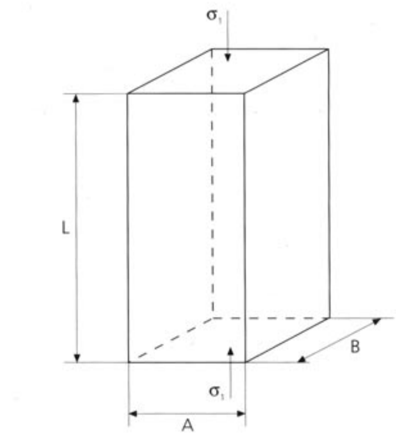
(Tests carried out on cylindrical samples)

Sample Or material	Sample Number	Dimensions of samples		Coefficient of linear thermal expansion	
Porphyry	1	Diameter (mm)	Height (mm)	Single values (10^{-6} /°C)	Average value (10^{-6}/°C)
	2	30.9	200.0	5.6	**5.55**
		30.9	200.0	5.5	

ELASTIC MODULUS TEST

SAMPLE (I): porphyry
Location: Mexico
Rock type: porphyric quartzite

Orientation of possible planes of discontinuity
or schistocity with respect to the direction of load.



L = 199.0 mm
A = 51.5 mm
B = 50.00 mm

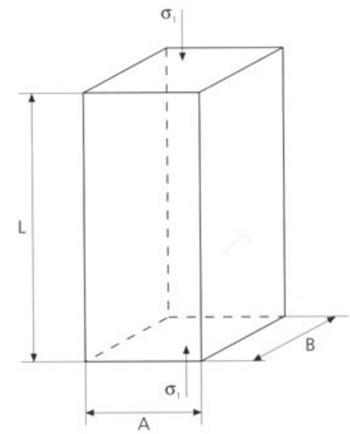
Applied Load	Axial Pressure	Longitudinal Deformation		Applied Load	Axial Pressure	Longitudinal Deformation
P(kN)	σ_1(MPa)*	$\varepsilon_1(\mu\varepsilon)$		P(kN)	σ_1(MPa)*	$\varepsilon_1(\mu\varepsilon)$
0	0	0		294.3	114.2	1993
29.4	11.4	238		323.7	125.7	2181
58.9	22.9	467		353.2	137.2	2368
88.3	34.3	683		382.6	148.6	2556
117.7	45.7	882		412.0	160.0	2745
147.1	57.1	1081		441.4	171.4	2939
176.6	68.6	1268		470.9	182.9	3148
206.0	80.0	1443		500.3	194.3	3346
235.4	91.4	1623		510.1	198.1	breaking
264.9	102.9	1807				
Breaking load under monoaxial compression: C_0 = 198.1 MPa						

*1 MPa = 10.2 kgf/cm2

ELASTIC MODULUS TEST

SAMPLE (I): porphyry
Location: Mexico
Rock type: porphyric quartzite

Orientation of possible planes of discontinuity
or schistocity with respect to the direction of load.

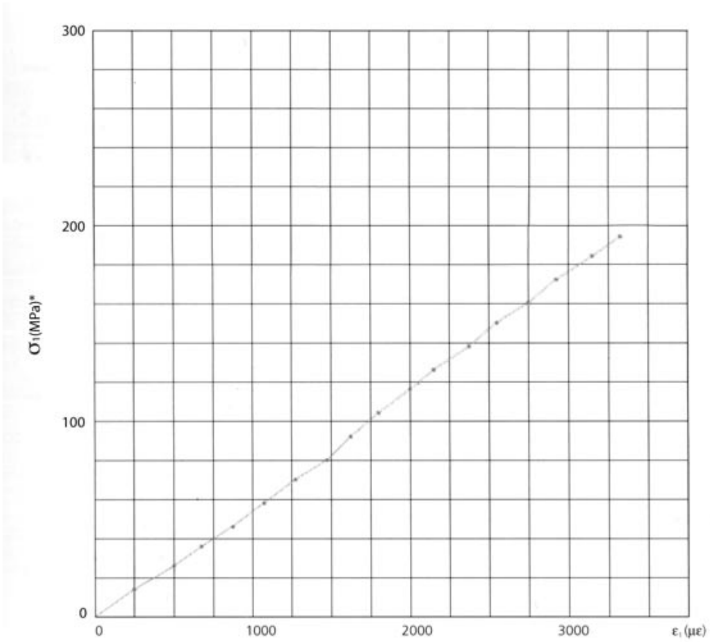


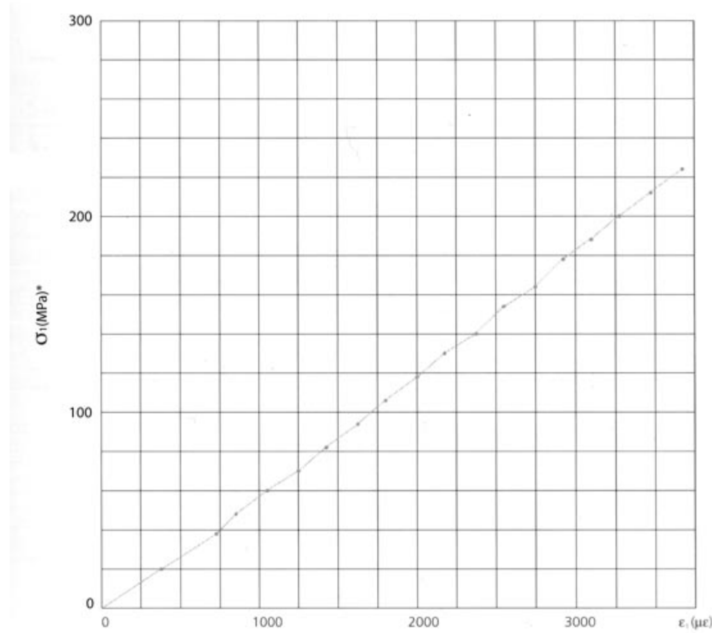
L = 201.00 mm
A = 50.5 mm
B = 49.5 mm

Applied Load	Axial Pressure	Longitudinal Deformation		Applied Load	Axial Pressure	Longitudinal Deformation
P(kN)	σ_1(MPa)*	$\varepsilon_1(\mu\varepsilon)$		P(kN)	σ_1(MPa)*	$\varepsilon_1(\mu\varepsilon)$
0	0	0		323.7	129.5	2180
49.0	19.6	365		353.2	141.3	2364
98.1	39.2	722		382.6	153.0	2549
117.7	47.1	856		412.0	164.8	2737
147.1	58.8	1056		441.4	176.6	2917
176.6	70.6	1242		470.9	188.4	3107
206.6	82.4	1432		500.3	200.1	3290
235.4	94.2	1620		529.7	211.9	3480
264.9	106.0	1810		559.2	223.7	3677
294.3	117.7	1994		578.8	231.5	breaking
Breaking load under monoaxial compression C_0=231.45 MPa						

*1Mpa = 10.2 kgf/cm^2

ELASTIC MODULUS TEST





Porphyry (1)

*1 MPa = 10.2 kgf/cm2

Elastic modulus tangent: Etg = 67150 MPa
Elastic modulus secant: Esec = 57420 MPa

Porphyry (2)

*1 MPa = 10.2 kgf/cm2

Elastic modulus tangent: Etg = 65210 MPa
Elastic modulus secant: Esec = 59360 MPa

Elastic modulus tangent average: Etg = 66180 MPa
Elastic modulus secant average: Esec = 58390 MPa

IMPACT TEST

(According to article 3 of R.D. 2234 of 16/11/39)

Material	Sample Numbers	Sample dimensions Length (mm)	width (mm)	thickness (mm)	Minimum fall height of a sphere with mass 1 kg which breaks the slab Single value (cm)	Average value (cm)
Porphyry	1	200	200	30	70	**62**
	2	200	200	30	60	
	3	200	200	30	50	
	4	200	200	30	70	

KNOOP MICRO HARDNESS TEST

From the formula $HK = 14.23 \cdot 10^6 \cdot \frac{P}{l^2}$ (MPa)*

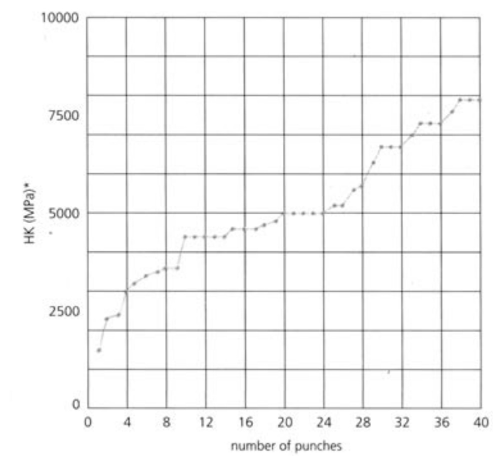
In which P = load on the punch in N

l = length of the longest diagonal of the imprint in µm;

Results based on 40 single measurements on points 1 mm apart in a line

SAMPLE (I): porphyry
Location: Mexico
Rock type: porphyric quartzite
Load on the punch: 1.96 N

Distribution of micro hardness



*1 MPa = 10.2 kgf/cm2

Sample (or material)	Average Value (MPa)*	KNOOP micro hardness Maximum value (MPa)*	Minimum value (MPa)*	Standard error (%)
Porphyry	**5416**	8894	1531	-

*1Mpa = 10.2 kgf/cm2

ABSORPTION COEFFICIENT

(Ration, expressed as a percentage, of the increase in mass which a sample undergoes when saturated with water and its dry mass according to art. 7 RD 2232 of 16.11.39)

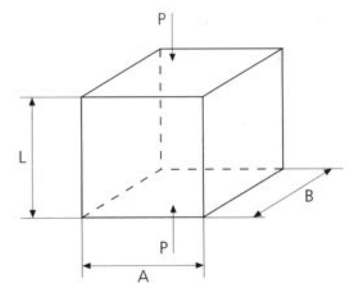
SAMPLE (I): porphyry
Location: Mexico
Rock type: porphyric quartzite

Orientation of possible planes of discontinuity or schistocity with respect to the direction of load THE SAMPLES ARE DRY

Sample (or material)	Sample Number	Initial Mass (g)	Saturated Mass (g)	Absorption coefficient	
				Single value %	Average value %
	1	234.26	236.15	8.07	
	2	253.46	254.71	4.93	**6.53**
	3	238.15	239.55	5.88	
	4	251.22	253.47	8.96	
	5	232.25	233.37	4.82	

BREAKING TEST UNDER MONO AXIAL COMPRESSION AFTER FREEZING

(On cubic samples)



SAMPLE (I): porphyry
Location: Mexico
Rock type: porphyric quartzite

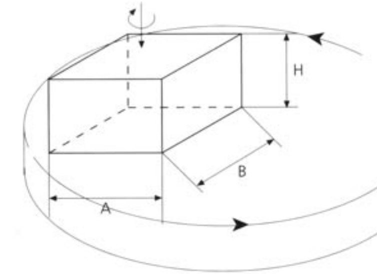
Orientation of possible planes of discontinuity or schistocity with respect to the direction of load THE SAMPLES ARE DRY

Sample (or material)	Sample Numbers	Dimensions			Breaking load P(kN)	Resistance to monoaxial compression C0 (MPa)*
		L (mm)	A (mm)	B (mm)		
	1	70.0	74.0	72.0	1177	220.9
	2	69.4	70.0	70.0	1226	250.2
	3	71.0	72.0	69.0	907	182.6
	4	69.3	72.6	71.0	809	156.9
Average result of 4 samples σ_1(MPa)*= 202.6 MPa						

*1 MPa = 10.2 kgf/cm2

WEAR DUE TO SLIDING FRICTION TEST

(Using the AMSLER instrument according to art. 5 of RD 2234 of 16.11.39)



SAMPLE (I): porphyry
Location: Mexico
Rock type: porphyric quartzite

Orientation of possible planes of discontinuity or
schistocity with respect to the direction of load unite load on sample: 0.03 MPa

Sample (or material)	Sample Number	Dimensions			Abrasion coefficient (height of worn layer after passing the disc for 1000m)	
	1	H (mm)	A (mm)	B (mm)	single values (mm)	Average value (mm)
Porphyry	2	18.6	71.5	71.0	2.06	**2.12**
	3	18.4	73.0	71.5	2.04	
S. Fedeline granite	1	17.6	71.5	71.0	2.26	
		16.3	71.3	70.6	3.22	
Relative coefficient of abrasion (Ratio between the thickness of worn of S. Fedelino granite and the sample) = 1.51						

TAB. 13 – Data from: "Manuale dei marmi, pietre, graniti" by E. Corbella and R. Zini, Vallardi, 1988

Trade Name	Petrological Definition	Trade classification	Mass of unit volume	absorption coefficient	breaking load under simple compression	breaking load under simple compression after freezing	elastic modulus tangent	elastic modulus secant	breaking load due to indirect bending	wear due to sliding friction relative to S. Fedelino granite	impact teste: minimum fall height	coefficient of linear thermal expansion
Rocks tested – samples 1988 (date of extraction from quarry)			Kg/m3	%	MPa	MPa	MPa	MPa	MPa	coef.	cm	10^{-6}/°C
Mexico Porphyry	Rhyolite with elastic structure	Porphyry	2,555	6.53	221.5	202.6	66,180	58,390	22.5	1.51	62	5.55
Bianco Carrara	Marble	Marble	2,705+-5	0.60	131	126	75,000	83,550	16.9	0.52	61	6.8
Rosso Aciago	Limestone	Marble	2,608+-2	1.60	156	156	75,400	75,400	14.2	0.85	44	7.3
Fiordipesco Carnico	Micritico Fossiled Limestone breccia	Marble	2,711+-10	0.88	128	110	82,150	80,200	13.0	0.68	55	5.3
Verde San Nicolaus	Oficalcite (serpentine breccia)	Marble	2,725+-15	1.65	162	139	72,450	66,075	17.9	0.90	55	3.7
Grigio perlato di Sardegna	leucogranite	Granite	7,615+-5	3.41	178	168	47,200	38,300	12.8	1.17	77	8.3
Diorite di Vico	diorite	Granite	2,805+-4	2.91	219	201	45,700	42,300	20	0.85	90	7.6
Serizzo Formaza	augen gneiss	Granite	2,660+-0	3.97	141	127	47,300	31,950	13	0.81	89	6.8
Serizzo Valmasino	tonalite	Granite	2,818+-1	2.23	148	141	44,850	34,000	22.2	0.91	95	7.5
Travertino romano di Tivoli	vacuous limestone	Travertine	2,409+-4	7.39	82	77	52,050	52,050	13.1	0.53	57	6.6
Pietra di Vicenza San Gottardo	fossiled vacuous limestone	Stone	2,204+-2	125.49	24	22	17,150	17,150	3.9	0.13	34	4.6
Pietra Serena di Firenzuola	feldspatic sandstone	Stone	2,600+-0	18.19	102+-5	87	17,750	16,550	11.9	0.49	89	13.1
Basaltina di Bagnoregio	basalt	Stone	2,262+-6	40.85	58+-3	57	38,100	38,100	13.5	0.46	34	9.7

Chapter 2

QUARRING

2.1. QUARRYING AND SORTING

The quarrying of porphyry is carried out in the open in excavation lots which are on large steps between 10 and 30 metres high.

At present the material is split from the quarry face, usually with the "mine piane" explosive technique. This consists of putting a series of explosives at the foot of the step, parallel and perpendicular to the quarry face, this cuts the foot of the slab and causes it to fall from the face above.

The diameter of the holes, their length and the distance apart depend on the height of the face, its conformation and the presence or absence of faults or fractures intersecting the two series of main stratification. The amount of explosive is determined empirically, taking into account all the tectonic elements present on the quarry face, but usually based on 50/80 grams of explosive per tonne of material to be brought down.

In order to maintain the quarry face and deep it free of danger such as large rocks or slabs, the explosives are used in isolation, and also large metal punchers on the end of mechanical shovels.

The porphyry thus quarried is first separated with mechanical shovels and the waste material, in this phase composed of "cappellaccio" (the top weathered part), earth and fault intrusions, is loaded on to lorries and sent off to various destinations (land fill, reclaimed land, crushers, banks of rivers, rubbish tips. The workable part is taken to be sorted more carefully.

The larger blocks are split with pneumatic hammers mounted on excavators or mechanical shovels and reduced to dimensions which can be dealt with by the quarry workers who can carry out the sorting. With the aid of mallets and wedges, and following the planes of the rock, slabs of variable sizes and thicknesses are obtained from the blocks.

The quarry workers then proceed with the sorting of the slabs on the basis of quality, thickness, size and shape. From the thinnest slabs, tiles or crazy paving will be obtained, from the medium thickness ones, cubes, while from the thicker slabs blocks, kerbs, steps etc.. Will be made. Obviously the larger the slab the grater its value as it produces a greater quantity when worked.

The slabs are then loaded into containers of various types ready for the next phase of working.

From this phase a series of products which can be defined as "finished" do result. The so-called "crazy paving"; tiles of irregular shape and size which can be used for paving or facing of "opus incertum". These tiles are loaded directly on to wooden palettes of about one metre square which can be covered in plastic and bound and are ready for the warehouse or sale.

The material sorted and selected is transported in mechanical containers to the next stage of working.

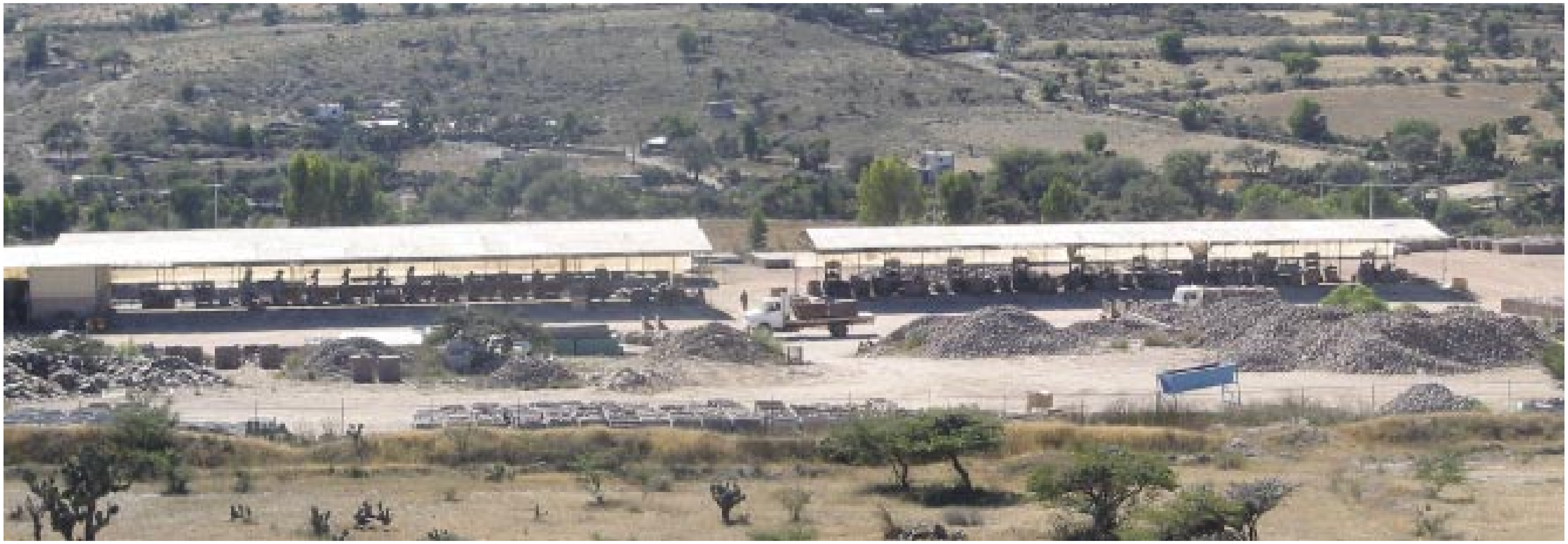
As we have seen, from the initial sorting in the quarry area, slabs with varying characteristics are obtained.

But what do they have in common?

• A surface which is more or less flat, slightly rough, certainly not slippery, defined as "quarry split surface" or "natural surface";
• Good quality physical and mechanical properties (no breaks or fractures);
• They are suitable for further working.

They are different however in:

• Thickness; varying generally from 1 cm to 20 cm (actually these are separated in sub-categories, difficult to explain here due to large differences which exist between one quarry and another);
• Size; which varies from 15 – 200 cm or more, measured on the longest diagonal;
• Colour; mixed, not uniform, unless from an extraction area which is fairly homogeneous with predominant shades of grey or red.



This raw material (which can already be marketed) can be roughly divided into:

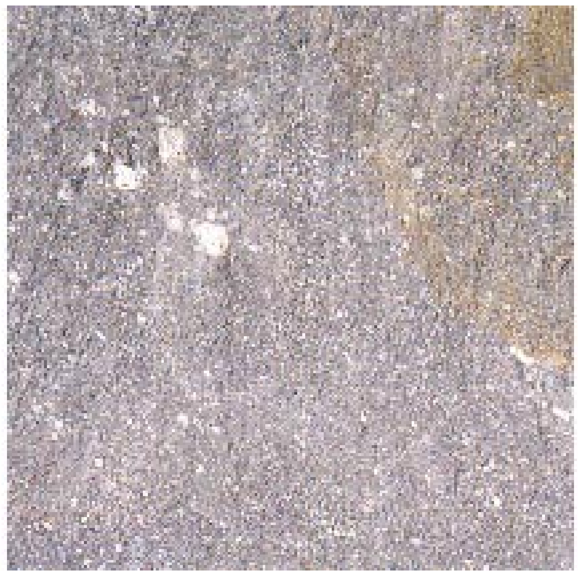
- Material for cubes (cubetti): for producing cubes;
- Material for blocks (binderi): for producing blocks, ashlar blocks and sawn face blocks;
- Standard slabs: put on the market as a finished product;
- Thin slabs: put on the market as a finished product;
- Large thin slabs: put on the market as a finished product;
- Large slabs: for producing tiles, or put on the market as a finished product;
- Slabs to be sawn: for producing risers, tread, and other pieces;
- Blocks to be sawn: for producing kerbstones, solid steps, slabs of various thickness, various other pieces.

2.3. EXAMPLES OF THE MATERIAL

GREY
Three photographs showing different shades of grey of the natural surface.
These are just some examples and do not illustrate the vast range of possible shades and colour variations

RED – PURPLE

Three photographs showing different shades of red – purple. These are just some examples and do not illustrate the vast range of possible shades and colour variations.



BUSH HAMMERED – SEMI-POLISHED – POLISHED
Three working of the surface:
Top left – bush hammered
Top right – semi-polished
Bottom – polished

Chapter 3

INTERIOR AND EXTERIOR PAVING AND FACING

3.1. CUBES

Cubes of porphyry are roughly cubic paving elements obtained by chemical splitting which have variable dimensions depending on the type. They are classified according to the thickness of the slab from which they are obtained.

In the normal production cycle, the "quarried material for cubes" is transported to covered deposits near the cubing machines.
These machines, in use since the beginning of the 1970's, consist of a metal structure which also supports the work top, one or two pistons with one or more wedge-shaped tools with tungten tips, a motor, electrical controls and a dust extractor.

The operator, or "cubettista", positions the slab on the work top (or on the fixed piston).
Using the controls, he controls the fall of the piston onto the slab and causes splitting due to compression. The operator repeats the operation until he obtains cubes which have a head size compatible with the thickness of the slab being worked. For example, if the slab is 9 cm thick the cubes will be 8-10 cm but if the thickness were 5 cm the cubes would measure 4-6 cm. If the cubes are not perfect, any imperfections are modified by hand using a special mallet with an acute angle edge in which a plate of extremely resistant tungsten has been inserted. The upper surface (and almost always also the lower) of the cube has the natural quarry surface, not too rough, which is a useful surface for paving, while the four sides have been split mechanically and are therefore rougher but not enough to affect the joints between the cubes from being less than 1 cm (at least for the 4-6 and 6-8 types).
The edges of the cube do not have to be exactly the same and the mechanically split faces may be irregular.

The cubes are then stored according to size in metal containers lined with soundproofing and stored outside in large sheds.

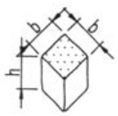
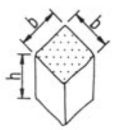
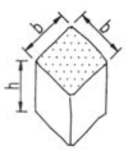
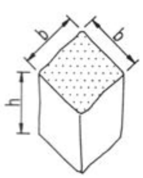
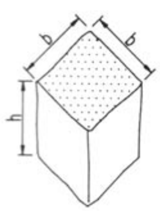
The cubes are divided into the following sizes:
a. **Type 4/6**: the height/thickness varies from 4-6 cm and the size of the top is between a minimum of 4 cm to a maximum of 7 cm. The weight per m2 of laid material is about 100 kg/m2.
b. **Type 6/8**: the height/thickness varies from 5.5-8 cm and the size of the top is between a minimum of 6 cm to a maximum of 9 cm. The weight per m2 of laid material is between 130 and 140 kg.
c. **Type 8/10**: the height/thickness varies from 7.5-11 cm and the size of the top is between a minimum of 8 cm to a maximum of 12 cm. The weight per m2 of laid material is between 180 and 200 kg.
d. **Type 10/12**: the height/thickness varies from 10-13 cm and the size of the top is between a minimum of 10 cm to a maximum of 14 cm. The weight per m2 of laid material is between 220 and 250 kg.
e. **Type 12/14**: the height/thickness varies from 12-15 cm and the size of the top is between a minimum of 12 cm to a maximum of 16 cm. The weight per m2 of laid material is between 250 and 300 kg.
f. **Type 14/18**: the height/thickness varies from 14-20 cm and the size of the top is between a minimum of 14 cm to a maximum of 20 cm. The weight per m2 of laid material is between 300 and 350 kg.

The measurements which define the type (or piece) are necessary essentially for two reasons:
- the placing in overlapping arcs needs to be done with cubes of the correct sizes: at the centre of the arc the cubes must be larger than the ones towards the edges;
- the tolerances make it possible to work with lower production costs.

So they are sold either by the lorry load, loose, or, on request, in crates (about 100 x 100 x 120 cm, weighing about 1500 kg) or in sacks.

On request, cubes of smaller sizes can be produced for marking straight lines or patterns.

CHART No. 1

CUBE	TYPE	SIDE b	HEIGHT h	WEIGHT	NO. OF PIECES
	4/6	variable from 4-7 cm	variable from 4-6 cm	approx. 100 kg/m2	approx. 290-300/m2
	6/8	variable from 6-9 cm	variable from 5,5-8 cm	130-135 kg/m2	approx. 155-160/m2
	8/10	variable from 8-12 cm	variable from 7,5-11 cm	180-190 kg/m2	approx. 95-100/m2
	10/12	variable from 10-14 cm	variable from 10-13 cm	235/250 kg/m2	approx. 63-67/m2
	12/14	variable from 12-16 cm	variable from 12-15 cm	250-300 kg/m2	approx. 44-47/m2
	14/18	variable from 14-20cm	variable from 14-20 cm	300-350 kg/m2	approx. 27-31/m2

3.2. SPLIT TILES

The split tiles are produced from slabs which are split into squares by means of compression (so they are fairly irregular). They are used for paving exterior areas, both public and private, and by selecting the appropriate size and thickness can be used in areas of heavy traffic. From the huge slab (or the "quarried material for tiles") the split tiles are obtained (a spacco).

The quarried slabs have a diagonal measurement which is almost never less than 40 cm. The slab is placed onto the work surface of the hydraulic shearing machine (similar to the cubing machine but bigger and with many more tools). It is compressed and thus split by two sets of wedge-shaped tools with double edges of tungsten carbide tips which work both on the upper and the lower surface.

The operator, or "piastrellista", cuts out the squares in such a way as to get the best in terms of size and quality. The tiles are therefore of variable length with the width going in multiples of 5 cm. With tolerances of more or less 1 cm with respect to the chosen measurement, and imperfections are modified by hand using a special mallet or a tool called a "sgiandin". The tiles should have parallel sides and right angles, allowing for a tolerance as mentioned before of approximately not more than 1 cm. The side faces are split perpendicular to the plane or slightly under-squared. The tiles are variable length, at least equal to the width but it is usually greater than the width. The tiles are divided into two main categories according to their thickness:

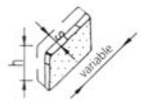
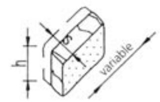
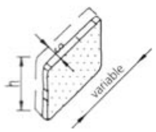
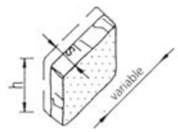
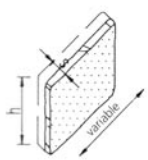
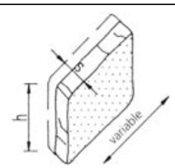
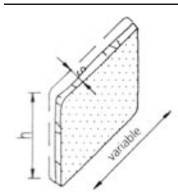
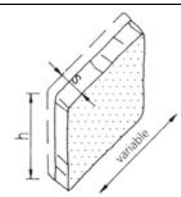
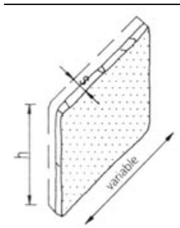
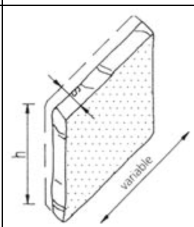
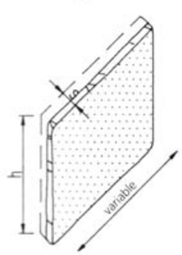
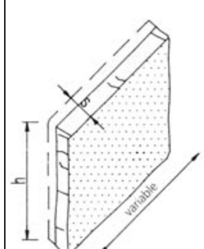
3.2.1. Standard

The thickness varies between 2 – 5 cm; by far the most common, they are packed in palettes of 15m2, weighing 90-100 kg/m2.

3.2.2. Thick

The thickness varies between 5 – 8 cm; they are quite common, they are packed in palettes of 12 m2, the weight varies from 150 to 170 kg/m2. If required, it is possible to produce tiles with larger or smaller thicknesses. The normal widths are 10, 15, 20, 25, 30, 35, 40 cm, but it is possible to produce tiles with different widths or fixed dimensions on request, depending on availability.

CHART No. 2

SPLIT TILES Standard	SPLIT TILES Thick	THICKNESS s Standard	THICKNESS s Thick	HEIGHT h	LENGTH	WEIGHT Standard	WEIGHT Thick
		2-5 cm	5-8 cm	10 cm	Variable	Approx. 100 kg/m2	Approx. 160 kg/m2
		2-5 cm	5-8 cm	15 cm	Variable	Approx. 100 kg/m2	Approx. 160 kg/m2
		2-5 cm	5-8 cm	20 cm	Variable	Approx. 100 kg/m2	Approx. 160 kg/m2
		2-5 cm	5-8 cm	25 cm	Variable	Approx. 105 kg/m2	Approx. 160 kg/m2
		2-5 cm	5-8 cm	30 cm	Variable	Approx. 110 kg/m2	Approx. 160 kg/m2
		2-5 cm	5-8 cm	35 cm	Variable	Approx. 110 kg/m2	Approx. 160 kg/m2

3.3. SMALL BLOCKS (binderi)

The form of these elements is basically rectangular. The working of the blocks takes place on machines similar to those for tiles, but they are mores powerful, which compress the "quarried material for small blocks" and cause controlled splitting forming long blocks or "filagne". These are then finished by machine or by hand with specially shaped mallets.
Blocks are used around the edge of a paved area often to outline the are but they are also used as paving elements in their own right. The upper face is natural surface, nicely squared with parallel sides. The sides are split perpendicular to the plane or slightly under-squared. The standard production of blocks is divided into two categories: "standard" bricks and "large" blocks, which are themselves divided into various types.
The various types are divided according to their length and height which determines their ultimate use. The smaller types are used as elements both for paving and for outlining of other paved areas. The larger types are used to produce borders of a more rustic type.

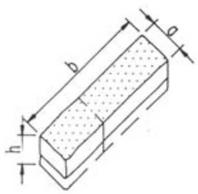
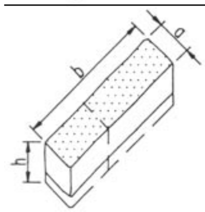
3.3.1. Standard

Their dimensions are:
a. **Type 10 x 5-8**: width 10 cm, length variable but generally between 15 and 40 cm, height/thickness variable between 5 and 8 cm, weight about 18 kg/m.
b. **Type 10 x 8-11**: width 10 cm, length variable but generally between 15 and 40 cm, height/thickness variable between 8 and 11 cm, weight about 22 kg/m.
c. **Type 12 x 10-15**: width 12 cm, length variable but generally between 20 and 40 cm, height/thickness variable between 10 and 15 cm, weight about 35 kg/m.

3.3.2. Large

Their dimensions are:
a. **Type 12.15-20**: width 12 cm, length variable but generally between 20 and 40 cm, height/thickness variable between 15 and 20 cm, weight about 60 kg/m.
b. **Type 14x15-20**: width 14 cm, length variable but generally between 20 and 40 cm, height/thickness variable between 15 and 20 cm, weight about 70kg/m.

CHART No. 3

BLOCKS	TYPE	SIDE a	SIDE b	HEIGHT h	WEIGHT
	STANDARD 10 x 5/8	10 cm	Variable 15 – 40 cm	Variable 5 – 8 cm	Approx. 18 kg/m
	STANDARD 10 x 8/11	10 cm	variable 15 – 40 cm	variable 8 – 11 cm	Approx. 22 kg/m

3.4. IRREGULAR SHAPED TILES
(CRAZY PAVING – PALADIN – MOSAICS)

These tiles, as we have already seen, are obtained directly at the end of the sorting operation of the quarried material.
The tiles, improperly called Paladin, mosaic, crazy paving, opus incertum, etc.., are used for the formation of exterior paving (pavements, courtyards, paths, gardens, etc..) and facing (road walls, buildings, terraces, etc..).

They consist of slabs of porphyry of irregular shape divided into various types according to their thickness and size.

The upper surface (the trodden surface) will be a natural quarry surface which is not too rough and has a regular surface, but the split edges are irregular.

3.4.1. Standard Type
This is by far the most produced and used, and it is suitable for paving of any surface, even for light traffic. It is not recommended for roads which have heavy traffic.
The diagonal must measure a minimum of 20 cm (average 30 cm).

The thickness varies from 2 – 5 cm. The weight of laid tiles, allowing for spacing of not more than 2.5 cm, is approximately 85 kg/m2.
They are nearly always packed on palettes of about 1m3, weighing 1.5 – 1-7 tones, fastened with heat shrink plastic, or sometimes loose.

3.4.2. Thin Type
These are suitable for facing and paving of patios, etc.. But are not recommended for surfaces which are used by traffic.
The diagonal must measure a minimum of about 20 cm (average 30 cm).

The thickness varies from 1–3.5 cum. The weight of laid tiles is approximately 60 kg per m2, allowing for a joint of not more than 2.5 cm. They are packed on palettes of 1 m3, weighing 1.5 t approx., and fast ended with heat shrink plastic.

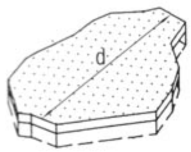
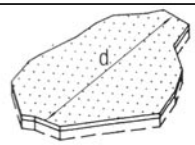
3.4.3. Large type
These are used for any type of paving, including surfaces where traffic passes (though in this case the laying must be carried out extremely carefully). They may also be laid in gardens, directly on earth (though sand is better), with large spaces between which are filled with soil where grass can grow.

The diagonal of the pieces measure on average about 50 cm. The thickness can vary from 3 to 7 cm. The weight of laid pieces is about 100 kg/m2, allowing for spacing of not more than 3.5 cm. They are packed on palettes of about 1.2 m3, weighing 1.5 – 1.8 t each, and fastened with heat shrink plastic or other binding.

3.4.4. Thin large type
These are rarely produced and therefore not always easy to find. They are used for paving, but not for heavy traffic, and for facing.

The diagonal measures on average about 45 cm. The thickness varies from 2 to 4 cm. The weight of laid tiles is about 75 kg/m2, allowing for a joint of not more than 3 cm. They are packed on palettes of about 1.2 m3 weighing about 1.5 t, fastened with heat-shrink plastic.

CHART No. 4

IRREGULAR SHAPED TILES	TYPE	DIAGONAL	LAID M2/100 KG aprox.	THICKNESS	WEIGHT
	STANDARD	D: minimum 20 cm D: average 20 cm	1.15	2 – 5 cm	With joints 2.5 cm Approx. 90 kg/m2
	THIN	D: minimum 20 cm D: average 20 cm	1.67	1 – 3 cm	With joints 2.5 cm Approx. 60 kg/m2

Chapter 4

PRODUCTS FOR WALLS AND ENVIRONMENTAL PROJECTS

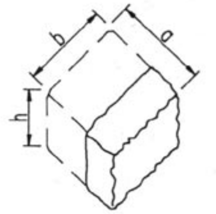
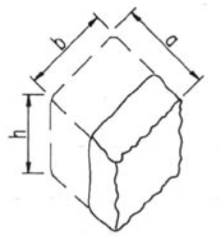
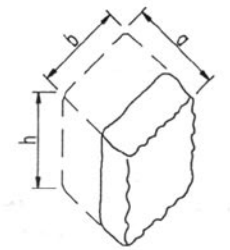
4.1. PRODUCTS FOR THE BUILDING OR CLADDING OF WALLS

4.1.1. BLOCKS FOR WALLS
These are obtained in the selection phase (quarry material for "binderi" blocks) and used for load-bearing and retaining walls, and also facing.
The blocks have a natural surface, irregular sizes and rough edges. The thickness varies from 10-20 cm, although they may easily be supplied on request with a smaller or larger thickness. They are almost always supplied loose, but sometimes on palettes.

4.1.2. ASHLAR ("BUGNATA") VISIBLE FACE
These are for the formation or facing of walls. The visible face is more or less square or ashlar ("bugnata"). The sides are rectangular with natural surface. The depth or "entrance" (the dimension of the block measured from the exterior towards the interior of the wall) varies between 10 – 25 cm. Almost always the length is variable. Three types are defined according to the thickness (height):

- 10/15 type: Thickness/height between 10-15 cm weight about 300 kg/m3.
- 15/20 type: Thickness/height between 15-20 cm weight about 350 kg/m3.
- 15/25 type: Thickness/height between 15-25 cm weight about 400 kg/m3.

CHART No. 5

ASHLAR VISIBLE FACE	TYPE	SIDE a	SIDE b	HEIGHT h	WEIGHT
	10/15	10 –25 cm	Variable	10 – 15 cm	Approx. 300 kg/m2
	12/20	10 - 25 cm	Variable	12 – 20 cm	Approx. 350 kg/m2
	15/25	10 – 25 cm	Variable	15 – 25 cm	Approx. 400 kg/m2

4.1.3. SPLIT VISIBLE FACE

These are used for the facing (only in special cases for building) of supporting or retaining walls or for the border or part of the facing combined with other building products.

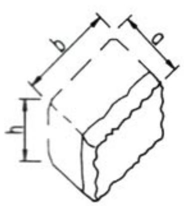
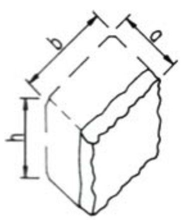
The visible face is split and the 2 lateral heads perpendicular to the supporting sides have natural surface. The two heads are also split with respect to the visible face with an angle equal to or less than 90 degrees.

The depth (entrance) varies from 4 – 13 cm. The length is variable. There are 2 main types based on the size of their thickness/height:

- **8/14 type**: thickness/height 8 – 14 cm
  weight/area ratio 230 kg/m2
  Typical weight of block 2 – 15 kg
- **15/20 type**: thickness/height 15 – 20 cm
  weight/area ratio 280 kg/m2
  Typical weight of block 3 – 25 kg

On request special pieces are produced for corners, pillars, fixed measurements or within limits, pieces with constant height/ thickness etc.. Usually supplied loose, sometimes in crates weighing 1500 kg.

CHART No. 6

SPLIT VISIBLE FACE	TYPE	SIDE a	SIDE b	HEIGHT h	WEIGHT
	8/14	4 –13cm	Variable	8– 14 cm	Approx. 230 kg/m2
	15/20	4- 13cm	Variable	15– 20 cm	Approx. 180 kg/m2

4.2. PRODUCTS FOR LAND DEFENCES AND ENVIRONMENTAL PROJECTS

Given the qualities of resistance and compactness of porphyry, after years of experience many different uses have been developed, especially by the public authorities (water companies, mountain communities, electricity companies etc..) in particular large sized products for construction and protection of the river banks, the formation of small water falls to interrupt the current flow, the construction of the beds and channels of rivers and streams, and for the protection of places of particular wear, and hydraulic projects.

The products most requested are "briglie" (large blocks) and "masselli", as well as the other previously mentioned blocks with ashlar and split visible faces.

4.2.1. LARGE BLOCKS ("BRIGLIE")

They are produced when ordered and are used to reinforce projects in reinforced concrete which are built to make stream water go over steps of various heights. They can be used to face only the submersed part, or for the whole project, including the banks. The upper side is natural quarry surface; the sides once split or worked are now generally ground for the whole thickness, apart from the visible face which is split and sometimes roughly standardised.

The thickness (height) varies from 20 – 25 cm, 30 – 35 cm, 35 – 40 cm or more. The length is usually variable and the depth (entrance) varies from 80 – 110 cm. Different working and particular dimensions such as fixed thickness or width, holes for anchoring, etc.. can be supplied on request.

4.2.2. BLOCKS ("MASSELLI")

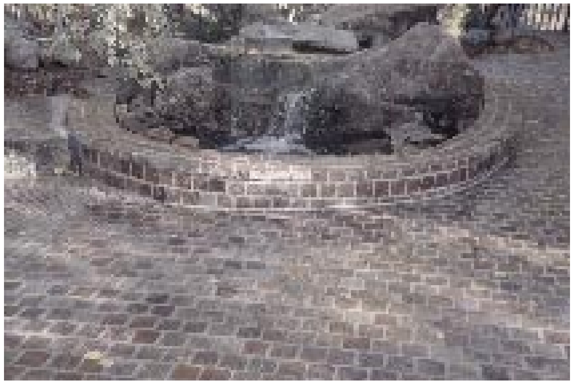
They are used to face the beds or banks of rivers or other hydraulic projects and serve to reinforce upstream (and downstream) the work of the "briglie".

The upper side is natural quarry surface, the sides are split perpendicular with respect to the plane or under-squared. The length and width may vary, or be fixed length. The thickness is between 12 – 18 cm, or 18 – 30 cm.

4.2.3. SAND AND GRAVEL

From the crushing of the porphyry, sand and gravel may be obtained which can be used for special concrete and mortar where exceptional resistance and hardness are required. The sand must be absolutely free of soil or organic matter and well-washed. The grains should be between 0 – 4 mm.

The gravel should have grains of:
• 5 - 8 mm grain size
• 8 – 15 mm grain size
• 15 – 30 mm grain size



Chapter 5

PRODUCTS FOR INTERIOR OR EXTERIOR PROJECTS

STEPS

Over the last few years, alongside the traditional products, a large range of products for urban building projects have been developed, in particular for the renovation of interior and exterior areas. In the working of porphyry the use of the sawing and cutting machines is becoming more and more popular. This has led to the arrival on the market of innovative products (or at least worked with new techniques) which has encourages the use of porphyry and the appreciation of its qualities and versatility.

Now it is possible for the designer to use the same material not only for paving the exterior areas, the formation and dressing steps, and facing of walls, but also to produce an interesting aesthetic continuity for interior surfaces with the use of polished or semi-polished flooring, stairs, sills, etc..

Here we will only describe the most common products while pointing out to the designer that there is potential to produce special pieces with sophisticated working on request according to the design.

5.1. TREADS

The tread is the horizontal plane of a step.

5.1.1. Natural surface treads

These are obtained from the larger slabs, defined as "slabs to be sawn", which have the natural surface from being split in the quarry (from stratified blocks, split along natural planes) and selected with thickness of 3 to 7 cm.

The slabs are ground to the dimensions required. The thickness are rarely uniform and, therefore, for obvious reasons of form and function the market demands, that the visible sides are uniform, the sawn pieces are measured and produced at the required thickness (usually 3,4,5 cm) for a standard depth of 5 cm (more on request).

The visible parts are uniform for the whole slab for a 5 cm strip, the rest may vary ±2 cm with respect to the required thickness.

The side and edges may be worked with different finishes;

• **ground**: the visible sides have disk sawn surface, both the upper and lower edges are slightly chamfered, both for reasons of safety and appearance;

• **split or ashlar ("bugnato")**: using the mallet and chisel, the sawn part is removed and the ashlar part is seen. It has a lovely effect with a simple rustic finish.

• **flame textured or thermally split**: with the use of a hand-held 'gun' from which comes a concentrated incandescent stream at high temperature, the chisel, due to thermal splitting, alters the ground face producing a surface which is similar to the natural surface. This finish is used more and more due to its appearance and its suitability in any environment.

• **bull-nosed ("toro")**: with suitable tools the edge is rounded completely or quarter round (the latter is known as "1/2 toro" or "owls beak"). The surface may be left just sawn, or flame treated, or bush hammered, or even smoothed or polished. Although the result is highly effective and valued, due to the hardness of the porphyry it is fairly expensive;

• **chiselled "alla cristiana"**: on the sawn edge numerous superficial incisions are cut with a chisel and mallet.

5.1.2. Worked surface treads

These undergo the same working as granite. From compact blocks of even large sizes using machines slabs are obtained of the required thickness. The surface of the slab thus obtained will then be treated in the desired manner -flamed, ground, polished, bush hammered etc.. The slabs are then cut to the dimensions required.

a. Flame treated treads

Porphyry reacts well to thermal splitting, at the right temperature and concentration. The slabs come out of the cutting machines and go to an automatic (or semi-automatic) flaming machine which causes thermal splitting and this produces a surface which both in touch and colour resembles the natural surface but without the irregularities. The thickness is fairly constant for the whole piece and the sides can be of any of the finishes.

b. Semi-polished treads

This semi-polished finish is typical, and unique for stone working. It is obtained by starting with the natural surface and rubbing down, smoothing and/or polishing the slab only partly (about 70%). Only the slightly higher parts of the surface are altered while the lower parts remain natural surface giving the whole surface a unique and stunning irregular effect of polished and rough surfaces.

The rest of the tread may be finished with any of the other workings. It is recommended that the visible sides be polished or at least bush hammered, while the other sides should be ground.

c. Smoothed and polished treads

To obtain a smooth or polished surface the machines used for granite may be used. The machines have grinding wheels of varying abrasive level which smooth the surface. The level of smoothness depends on the fineness of the abrasive material. It is divided thus:

coarse -
obtained with abrasive plate no. 1 (60 grain)
medium -
obtained with abrasive plate no.2 (120 grain)
fine -
obtained with abrasive plate no. 3 (220 grain)
satin finish -
obtained with abrasive plate no. 4 (400 grain)
polished -
obtained with a disk of felt and the application of polish (tin oxide) or special plates and lead leaf.

The final treatment is a physical/chemical treatment which produces a mirror finish on the surface of the polished slab. The polishing of the porphyry, due to its fine, compact

structures, tends to last much longer than almost any other stone.
The working of smoothed or polished pieces is much more precise and similar to granite.

d.Sand-textured treads
This is the most recent finish to be added to the various working techniques. The sawn surface of the slab is sand-textured with a jet of sand at high pressure.

5.2. RISERS
The riser is the vertical part of a step. Porphyry risers may be divided thus:

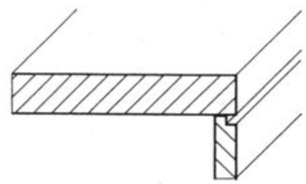
5.2.1. Natural Surface Risers
Obtained from "sawn surface" slabs of slim thickness variable from 1-3 cm, with no serious variations. The sides are sawn, the width fixed for each flight of steps and the length variable or fixed (not usually more than 70cm). The heads, if visible, can be uniform and worked in the same way as the head of the tread. Greater thicknesses (3-4 cm) for risers are rarely used, in this case space must be made for the increased space required for the riser itself (5-6 cm) and the mortar.

5.2.2. Worked surface risers
a. Semi polished
As before but the surface is semi-polished (about 70% polished, 30% natural).
b. Flamed surface
Obtained from blocks. They are obtained by the sawing, with block cutting machines, of blocks of small sizes. The surface is then flamed and the sides cut to size. The thickness is whatever requested (usually 2 cm).
c. Polished
As before, but with polished surface
d. Sand texture
The process is the same as for the flamed risers but the surface is san-textured instead.

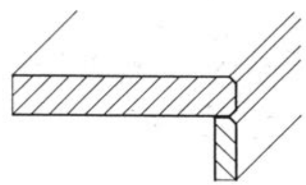
DIAGRAM No. 1

STANDARD TYPES OF RISERS AND TREADS

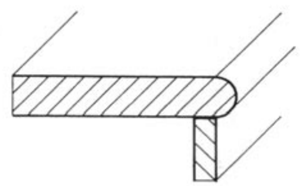
TREAD WITH SQUARED
VISIBLE EDGE
AND RISER IN LINE
WITH GROOVE



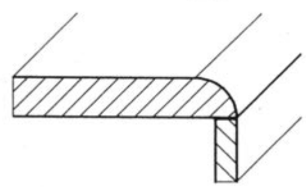
TREAD WITH SQUARED
VISIBLE EDGE AND
CHAMFERED EDGES RISER
IN LINE WITH CHAMFERING



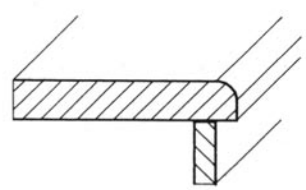
TREAD WITH BULL-NOSED
EDGE RISER INDENTED
SQUARED



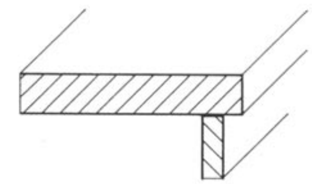
TREAD WITH
QUARTER ROUND
EDGE RISER IN LINE
SQUARED



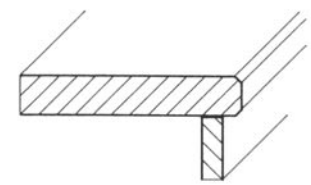
TREAD WITH SHAPED
EDGE RISER INDENTED
SQUARED



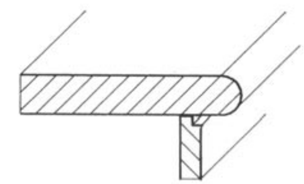
TREAD WITH SQUARED
VISIBLE EDGE RISER
INDENTED SQUARED



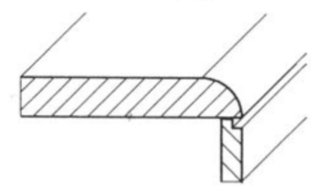
TREAD WITH SQUARED
VISIBLE EDGE AND
CHAMFERED EDGES
HEAD INDENTED
SQUARED



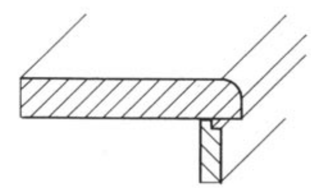
TREAD WITH BULL-NOSED
EDGE RISER HEAD
INDENTED SQUARED
WITH GROOVE



TREAD WITH
QUARTER ROUND
RISER IN LINE,
WHIT GROOVE



TREAD WITH SHAPED
EDGE RISER INDENTED
WITH GROOVE



5.3. SOLID STEPS

Steps made of solid single blocks of porphyry create a stunning effect.

The more expensive laying costs and cost of the product discourage designers and the use of this product. But a close analysis shows that, if one considers the appearance and their almost unlimited durability the solid steps are a competitive option. For exteriors, the natural and flamed surfaces represent a tread surface which is one of the most non-slip and safe.

The working of the sides is particularly important, as it determines the whole appearance of the flight of steps.

So it is necessary to choose the most suitable finish carefully for the architectural setting and the other materials present. The thickness varies from 6-20 cm. There is no difficulty in supplying, on request, steps which fan or are curved or other special shapes. The horizontal part (the tread) of solid steps may be:

a. natural surface: the natural surface must be regular with 0.5 cm tolerances: the visible sides standardised at least 5 cm, the others sawn. The parts not standardised may not be more than 3 cm more than the standardised side.

b. flamed: flamed steps are usually obtained from grinding compact blocks with diamond disks. They will therefore have the uniform thickness required.

c. sand textured: the ground surface is sand textured. The visible sides may be:

• **split**: this results from an ashlar finish using mallets and heavy hewing tools. The side has a continuous bulge up to 3 cm and a decidedly rustic effect.

• **Coarse point**s: from the split surface, bye hand with mallets and large chisels of steel the bulges are altered and "points" are highlighted every 2/3 cm.

• **Fine point**s: after finishing the above process more, but finer chiselling continues.

• **Bush hammer ("bocciardata")**: this effect may be produced by hand using the special tool, after having finished the above processes. However, nowadays it is carried out by machines which work on the disk ground surface. The edges, which can't be treated by machine are left sawn, or worked with a chisel or polished. The edges should never be left "sharp".

• **Ground**: the surface of the side is left after disk grinding, the edges are chamfered, at least enough to take off the sharpness.

• **Flamed**: the ground surface is flame-textured. The edges must be chamfered to at least 5mm, but it is even better if they are rounded and flamed. The surface of the side looks similar to the natural surface and the whole step has a continuity between its horizontal and vertical sides which is particularly pleasant.

• **Sand textured**: the side is sand textured in a uniform way, the edges are chamfered.

5.4. COPING STONES

These are elements which border, cover and protect building parts such as walls, terraces, balconies etc.. They are divided into 2 categories: coping stones with natural surface and thickness and coping stones with worked surface and thickness.

5.4.1. Coping stones with natural surface and thickness

a. split: they undergo the same processes as split tiles but have a chosen surface and thickness (never above a tolerance of 0.5 cm with respect to the reference thickness). The width is on request (usually 25, 30, 35 cm) and the length is variable but not less than 40 cm. So they are rather simple elements for exterior use (gardens, yards etc..) suitable for outdoor projects.

b. Ground: they are processed in the same way as treads, but measured and worked also the other long edge or also a head. If all the sides have been worked it is called “cappello” (hat). The thicknesses available are from 3 to 20 cm or more (generally 5 cm); the width on request and also the length (preferably and length).

5.4.2. Coping stones with worked surface

They have flame textured, smoothed, polished, bush hammered (minimum thickness 3 cm) semi-polished, sand textured, acid treated etc.. surfaces and one or more sides in view worked as required. If all the sides are worked it is called “cappello”.

5.5. LEDGES, BORDERS AND SILLS

Elements similar to treads can be used. If natural surface or semi-polished surfaces are used it is necessary to take account of increased space required for the internal part of the element (+2 cm with respect to the measured thickness.)

5.6. TILES

5.6.1 Natural surface with ground sides

The “slabs for sawing” also provide semi-worked slabs which are used to produce tiles with natural surface. The slabs placed individually on the machine are cut to size by a rotating diamond studded disk in contact with the stone. The hewn slabs must be cut in such a way as to maximise use (or to minimise waste). With this aim, modern machines have lasers which indicate where to cut. The programming of work in the workshop will not follow a chronological order but will adapt to the economical situation of the raw material. It is therefore very important, given the variations of size and thickness of the slabs, to gave complete orders with all the precise measurements and finishes. Great difficulty arises with the alteration of quantity or production of special pieces when work has nearly finished. Tiles cut from porphyry are divided according to their thickness, which is never uniform, even though sorted within tolerances: from 2-5 cm (for surfaces with not much traffic), from 3-7 cm (for surfaces with light traffic) from 5-8 cm or more (for surfaces with heavy traffic).
On request they may have different thicknesses. The tiles will have parallel sides and right angles. The sides are perpendicular to the trodden surface. The widths with normal finishes can be chosen from 20-40 cm. The length should be variable to cut down waste and consequently cost, but similar or greater than the chosen length.
However, fixed length tiles can be supplied without any difficulty up to a tile of 30 x 60 cm. Larger sized tiles, although possible, are more difficult to supply.

Multiple-bladed grinding machine with laser measurement control.

The weight of the 2/5 type, the most common, varies from 90-100 kg/m2. The weight of a single element or other types can be calculated from the specific weight. They are packed vertically or horizontally on palettes.

5.6.2. Semi-polished tiles

They are the same as the natural surface tiles except that the upper surface is semi-polished.

5.6.3. Flame textured tiles

They are obtained from slabs cut by machines and processed with thermal splitting (flaming). The sides are ground, the thickness is almost always 2 cm. The width is normally 15-20 cm and the length may vary or be fixed. The weight is about 50 kg/m2.

5.6.4. Tiles with sawn surface

They have the surface which results from the sawing machines or disks. Once in place they are almost always smoothed and polished. If this is the case it is very important that the order is complete so as to avoid differences in colour. If large quantities are being used it may be necessary to subdivide the pieces according to the surface to be paved so as to uniformly distribute over the whole area any colour differences which occur due to the use of different blocks. With the slabs of one block you can pave one or more areas but slabs for different areas must never be mixed, as it is impossible to distinguish the colour until they have been polished. It should be noted that with porphyry it is very rarely, and then only for specific areas and colours, possible to have uniform colour like granite.

5.6.5. Sand-textured tiles

These are sawn surface tiles whose surface has been treated with a high pressure jet of quartz sand and water which alters the less resistant superficial components.
After this treatment the surface is slightly rough but uniform. The width of normal working is 10-5 cm. The length can be variable or fixed.

5.6.6. Polished tiles

The slabs with machine cut surface are smoothed and polished and cut to size (variable of fixed). The thickness available is 2 cm. The width if from 15-20 cm and the length variable or fixed. The weight is about 50 kg/m2 at 2 cm thick.

5.7. SKIRTING AND WAINSCOTING PANELS

The place where the vertical surface (wall) meets the horizontal (floor, stairs etc..) needs a linear element to finish it off with thin section which can cancel inevitable defects in the joint and harmonise with other structural materials and finishes: skirting. Up to 10 cm in height it serves as protection from cleaning appliances. Above that it is a decorative element. The width varies but is usually 6-30 cm. The length can vary or be a fixed measurement. The side edges can be finished as required.

5.7.1. Natural surface

These are obtained from thin slabs with natural surface. The sides are ground, the thickness is from 1-3 cm. They should be laid in mortar.

5.7.2. Flame textured surface

From slabs cut by machines and flamed, thickness preferably 2 cm, but also 1.5 or 1 cm.

5.7.3. Sand textured surface

From the sawn surface slab which is then sand-textured.

5.7.4. Semi-polished

Semi-polished surface, ground sides, thickness 2 cm, also 1.5 and 1 cm.

5.7.5. Smoothed surface

From disk cut slabs or polished slabs, smoothed or polished surface, 2 cm thick, also 1.5 or 1 cm.

PART TWO

DESIGN AND LAYING

Chapter 6

EXTERIOR PAVING

6.1. TECHNOLOGICAL ASPECTS

6.1.1. FOUNDATIONS

In this chapter we will briefly deal with problems which may arise from the ground which will support the paving project. These problems are often underestimated but in fact may be the cause of subsidence or irregularities which can negatively affect the outcome of the project.

Obviously for large-scale projects advice must be sought from a geologist before starting any architectural work, so here we will mention some points which may be useful for designers but which do not in any way replace the need for a study of the terrain where the paving shall be laid.

Any terrain consists of a natural agglomerate of mineral and organic particles of different forms, sizes and structures. The solid for the foundation should be identified and classified according to its grain size as it can affect the mechanical behaviour of the ground itself. Here is the system of classification of soil based on grain size as used in Germany.

MATERIAL	**Grain size**
Stones	larger than 60 mm
Gravel	between 2-60 mm
Sand	between 0.06-2 mm
Silt	between 0.002-0.06 mm
Clay	less than 0.002 mm

Another classification consists of the distinction between cohesive and uncohesive ground. The terms uncohesive or loose are applied to soils made up of masses of granules without a binding substance (without water). Cohesive soils are those which exhibit resistance to traction due to the capillary tension of the water. It is important to know the average values of the angle of internal attrition which depends on the grain size and type, and increases with the size of the grains; the reaction of the ground to compression; the elasticity, which is the return to normal once a load has been removed; freeze-thaw behaviour- the tendency to increase in volume due to freezing of pore water - a characteristic which can lead to serious problems of stability on the paving above, especially in very cold climates. In this book we will not dwell on the loads and structures the foundation ground can withstand apart from these brief notes but please refer to the bibliography for further information about soil mechanics. We will only summarise ground/soil as good, mediocre and poor, based on their intrinsic ability to bear the foundations, bedding mortat and the paving in porphyry. In general terms rocky, or compact gravel or sand and dry clay are considered mediocre, and sandy, marshy or areas with organic content are considered poor. Clayey soils tend to expand on being made wet and contract on drying.

6.1.2 THE FOUNDATION

The foundation is made of an incompressible layer (with minimal give when load is applied) between the foundation ground and the bedding mortar of the paving. It is very important that the foundation is formed in the most appropriate way for the consistency and characteristics of the ground.

Another fundamental element is that it is laid at a suitable height and inclination for the paved surface. If the foundation layer is too high it can affect the correct choice of thickness for the paving elements and thus alter the resistance coefficient of the paving (e.g. cubes which are too thin).

If the height of the foundation layer were too low the layer of the bedding mortar would have to be increased and this would affect the resistance to load and the durability over time of the paved surface.

If the foundation layer is not laid with the necessary attention paid to the inclination this may lead to a non-uniform distribution of the bedding mortar and as a result a different reaction to loads which would lead to the formation of dips and depressions in the paving.

The ideal foundation for porphyry paving, then, is one which cannot be compressed, is as the correct height and with the same inclination as the finished paving will have, so as to allow the run of water (>1.5%).

The most common systems at present are the use of roadbed and concrete.

Roadbed is made of a layer of stones, larger ones in contact with the ground gradually getting smaller until there is no space between them near the layer of bedding mortar above.

At present the use of "stabilised soil" is common. This is a dry aggregate of various stones, gravel and clay with cement, lime and/or bitumen. The materials and percentages of composition of this mixture vary considerably depending on the availability of the various raw materials in the area of use. The roadbed must be compacted well by the repeated use of road rollers or similar.

Often used, due to its ease of laying, is a base in concrete. On top of the foundation ground a 10-15 cm layer of concrete is laid. It is a mixture of sand, fine gravel, water and cement in the ratio of 200 kg per m3. It is advisable to inmerse an electro-saldered metal grid in the mixture (5 mm diameter, 20 x 20 cm knit). The layer of concrete, especially for large areas, will need expansion joints to be included and these must be repeated in the paving above.

6.1.3. BEDDING LAYER

The bedding layer, placed on the foundation layer, is the bed for the laying of the paving elements. It may be made of:

a. SAND: this is the most traditional and most tested with regards to the laying of "cubes". Above the foundation, already at the correct height and consistency (even better on a layer of bedrock), a layer of sand is spread with a depth of 6-9 cm depending on the size of cubes to be used. Due to the laying, wetting and compacting of the cubes, the bed of sand will be compressed and will reduce its height by about 2 cm. Tables 7 and 8 show the best thickness for each type of cube. It is essential that the sand layer is never higher than the figures quoted so as not to compromise the stability of the paving over time.
Often the foundation, or part of it, is not at the correct level and, for reasons of time and deadlines, the level of sand increased. This is one of the most frequent causes of subsidence or sagging of paving in cubes, as the resistance to wear and load is compromised.
The sand should have fairly large grain size (0-4), it should be clean and free of soil particles. Fine sand or sand containing lime should be avoided as it does not supply the necessary mechanical resistance to the paving elements. The presence of earth in the sand may cause subsidence in certain points in the paving as the earth disaggregates in water creating holes in the bedding. It is not advisable to use sand from the sea, which contains a lot of salt which dissolves in the water used when compacting,

or rain water, and would result in the same above mentioned problems. It could also create ugly marks on the paving above. The bedding sand should be free of any foreign material which could inadvertently come into contact with it (pieces of brick, wood, stones, etc.) which could alter its properties.

The advantages of sand as the bedding are essentially the following:

• greater overall elasticity which allows the paving to uniformly absorb the load of traffic (without forming micro-fractures), possible settling and extreme changes in temperature;

• possibility of using the elements of paving again if excavation is necessary or other work which involves removing the paved surface;

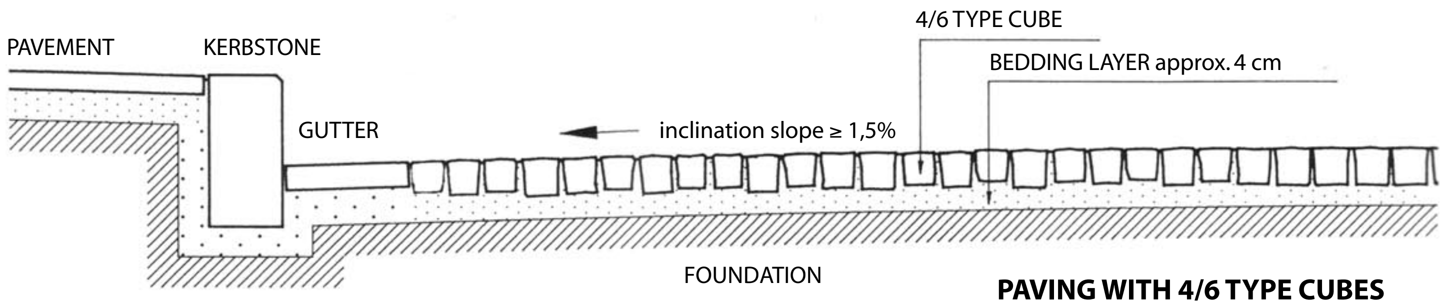
• total permeability of the surface, with evident advantages for dealing with rain etc., erosion and the refilling of the underground water bearing strata.

b. SAND AND CEMENT: cement is added to good quality sand in the ratio of 2 litres/m3. The mixing process, which is carried out dry to allow the laying of the cubes should be done carefully so as to produce a uniform, well-amalgamated mixture in every part of the bedding, otherwise points of differential resistance and permeability could result in depressions. It is advised, when possible, to mix the components by machines as this ensures improved mixing and blending, and, especially for large areas, a financial saving. The measurements and quantities are the same as those described above for just sand.

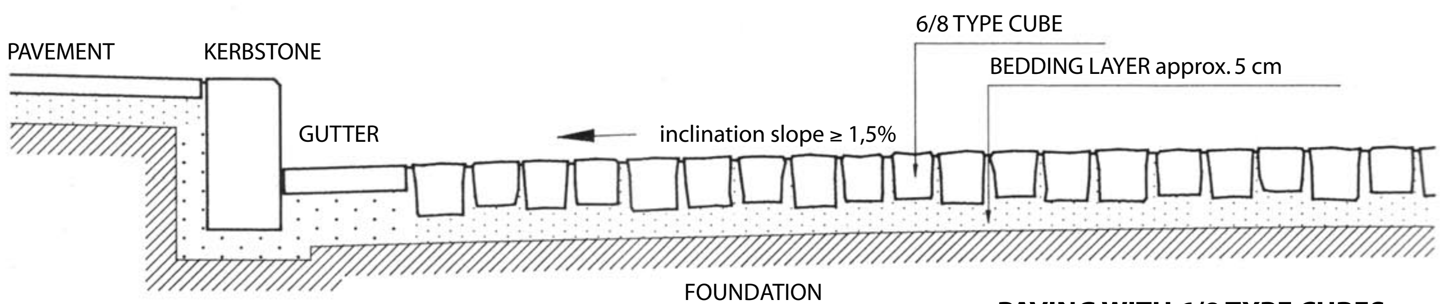
c. CEMENT MORTAR: many paving elements of porphyry (slabs, tiles, "binderi" blocks, etc.) are bedded on an at least 4-5 cm layer of cemented mortar. This is a bedding material made up of common mortar of sand and cement, with the doses 250 kg of R325 cement per cubic metre of sand. It is advisable, in the case of the foundation not being completely reliable, to add a 20 x 20 cm knit electro-saldered grid. The bed of mortar, at the moment of laying the individual elements, should be dusted superficially with cement in the ratio of a minimum 6 kg/m2.

DIAGRAM No. 2

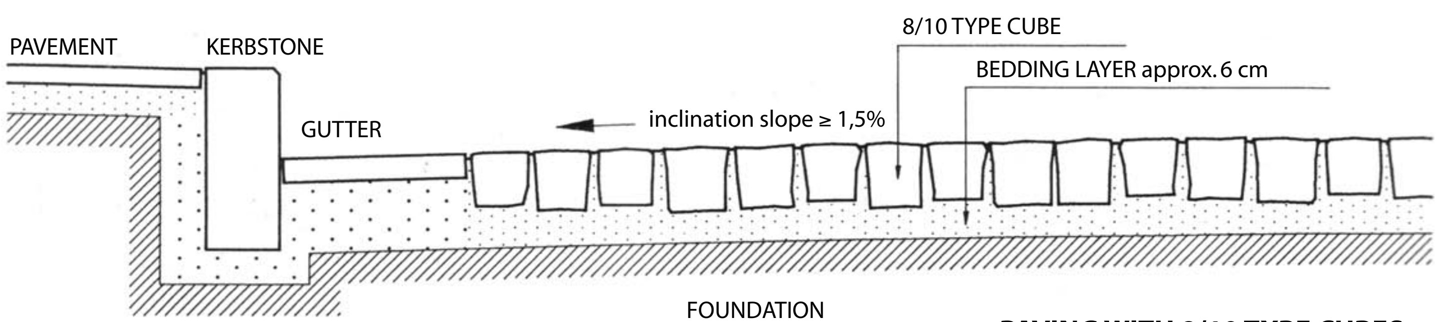
CROSS-SECTIONS OF PAVING WITH CUBES



PAVING WITH 4/6 TYPE CUBES



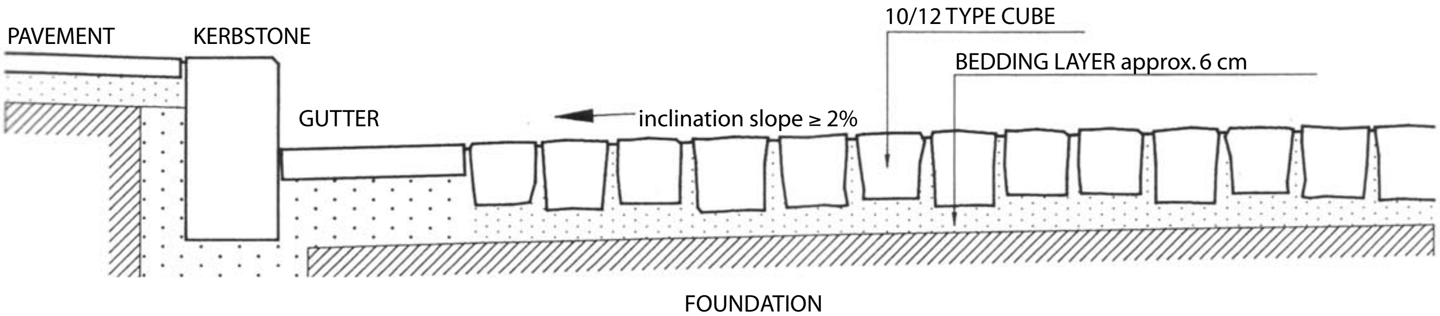
PAVING WITH 6/8 TYPE CUBES



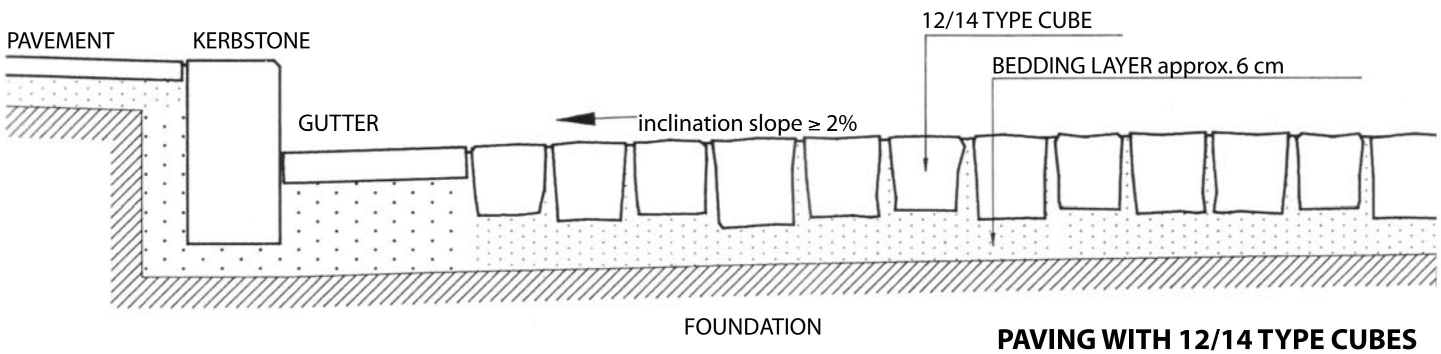
PAVING WITH 8/10 TYPE CUBES

DIAGRAM No. 3

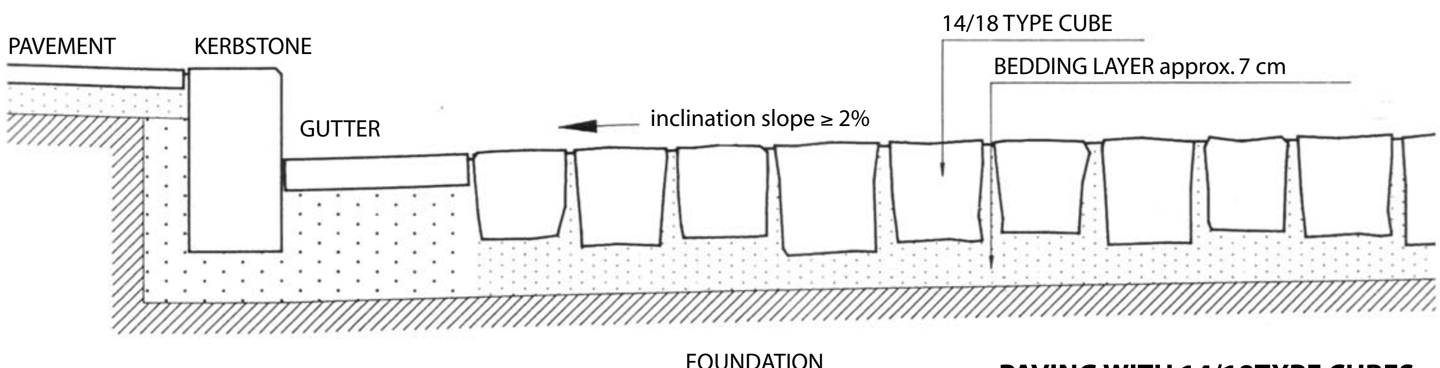
CROSS-SECTIONS OF PAVING WITH CUBES



PAVING WITH 10/12 TYPE CUBES



PAVING WITH 12/14 TYPE CUBES



PAVING WITH 14/18TYPE CUBES

6.2. HYDROLOGICAL ASPECTS

Any paved surface is shaped and sloped in order to allow the run off rain water, snow, hail etc. It should be remembered that the behaviour of the water varies depending on the area of the project, its position and, more generally, the geological, soil and morphological characteristics, the vegetation cover and the whole condition of the hydrological basin. A basin is an area where the surface water converge on a precise geographical place. Its characteristics vary due to the type of surface, terrain, vegetation, slope, size, orientation and exposure. Any project on the land leads to the alteration of the behaviour of the localised and distant flows of the surface and underground waters. The under-evaluation of this principle has contributed to the hydrological problems in our area including the alteration of the water table and an increase in subsidence. The need to conserve and plan water reserves and water quality is now the focus of attention from the public and also from the local authorities. Because of this much more attention is paid to the study of draining and run off water with new architectural projects.

The complex equilibrium of a basin should be maintained and excessive run off, erosion and subsidence due to excess water on the surface should be avoided.

Here we will mention briefly the problems related to surface draining i.e. water collection systems, management and control of surface waters.

The objective i.e. draining of the surface, involves the collection of the rain water etc. and sending it into channels or covered drains, water courses or surface bodies of water, or letting it percolate into the ground. The first action may occur with surface run off and channels on the surface or underground. The second involves the formation of wells or draining channels or reservoirs and the dispersion of the water. Run off occurs due to the effect of gravity on the whole of an impermeable paved area which must have suitable slope to avoid the formation of puddles and to make the water flow towards suitable drains. The minimum slope necessary for this in the case of porphyry is at least 1.5%. The collection and directing of the surface water are carried out by means of channels, ditches and glutters of various sizes. These pieces can be produced and/or faced with cubes, "binderi" blocks or tiles of porphyry in the appropriate size, especially if, due to the sleep slope, the water reaches a high speed. Remember that porphyry is one of the rock materials which is most resistance to sliding friction.

In urban areas the rain water etc. is usually collected through drain holes situated at convergent points of the paving and they lead to, with inspection wells with siphons, an underground network of pipes, which carry the water by gravity towards certain outlets. The outlets are grills, manholes, drain holes, etc. in walls and kerbs. Grills allow a continuity of surface, instant run off of a large volume of water and the possibility to collect and interrupt completely the linear flow from ramps, steps or steep slopes. They are usually made of metal but can be obtained to order in porphyry in different shapes, thickness and outlets (slots, holes etc.). Drain holes have the advantage of getting in the way the least and being least noticeable in the architectural setting but they are difficult to maintain and clean.

Manhole covers are one of the most common features. Their shape may vary: square, rectangular, round etc. as may the grill. In urban centres, gardens or other such places, it is better to use shapes and materials (stone or cast iron) which conform to the traditions of the place.

Manhole covers are produce in porphyry according to the required design and thickness which must take into account the volume of water to drain and also the load it will have to bear. The most common types are square with three or more rectangular cuts, or in the central part they are lower in the shape of a spherical vault, or holes of suitable diameter where the water falls.

All these collecting structures must be positioned, for obvious reasons of function, but also of appearance, perpendicular to the slope and flow of rain water.

DIAGRAM No. 4

RAIN WATER DRAIN WITH HONEYCOMB MANHOLE COVER

PLAN

SECTION

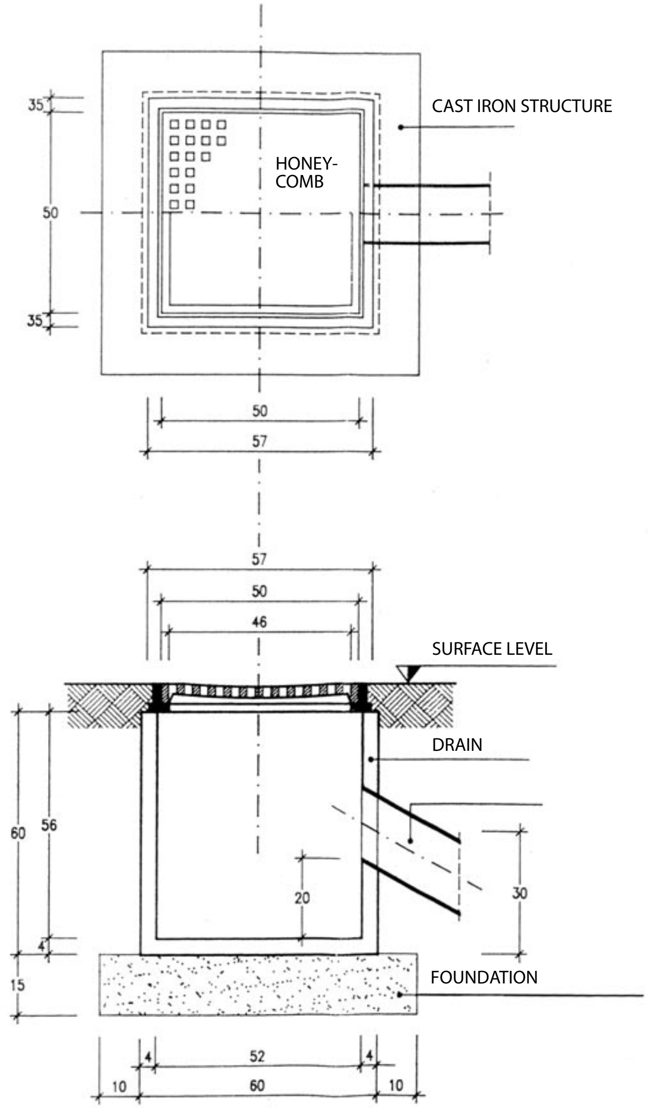
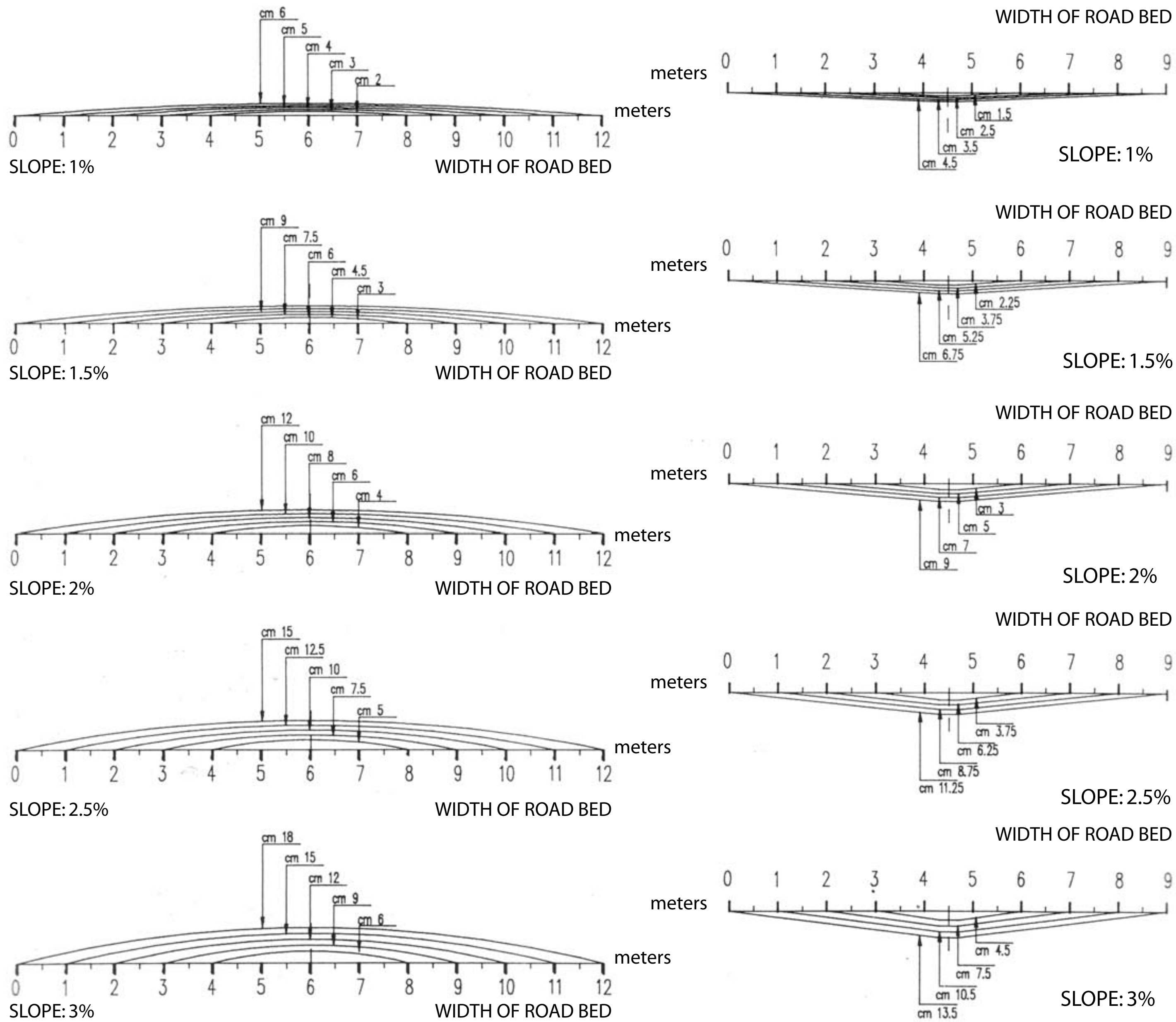


DIAGRAM No. 5


cm 6
cm 5
cm 4
cm 3
cm 2
meters
0 1 2 3 4 5 6 7 8 9 10 11 12
SLOPE: 1%
WIDTH OF ROAD BED
WIDTH OF ROAD BED
meters
0 1 2 3 4 5 6 7 8 9
cm 1.5
cm 2.5
cm 3.5
cm 4.5
SLOPE: 1%
cm 9
cm 7.5
cm 6
cm 4.5
cm 3
meters
0 1 2 3 4 5 6 7 8 9 10 11 12
SLOPE: 1.5%
WIDTH OF ROAD BED
WIDTH OF ROAD BED
meters
0 1 2 3 4 5 6 7 8 9
cm 2.25
cm 3.75
cm 5.25
cm 6.75
SLOPE: 1.5%
cm 12
cm 10
cm 8
cm 6
cm 4
meters
0 1 2 3 4 5 6 7 8 9 10 11 12
SLOPE: 2%
WIDTH OF ROAD BED
WIDTH OF ROAD BED
meters
0 1 2 3 4 5 6 7 8 9
cm 3
cm 5
cm 7
cm 9
SLOPE: 2%
cm 15
cm 12.5
cm 10
cm 7.5
cm 5
meters
0 1 2 3 4 5 6 7 8 9 10 11 12
SLOPE: 2.5%
WIDTH OF ROAD BED
WIDTH OF ROAD BED
meters
0 1 2 3 4 5 6 7 8 9
cm 3.75
cm 6.25
cm 8.75
cm 11.25
SLOPE: 2.5%
cm 18
cm 15
cm 12
cm 9
cm 6
meters
0 1 2 3 4 5 6 7 8 9 10 11 12
SLOPE: 3%
WIDTH OF ROAD BED
WIDTH OF ROAD BED
meters
0 1 2 3 4 5 6 7 8 9
cm 4.5
cm 7.5
cm 10.5
cm 13.5
SLOPE: 3%

Chapter 7

PAVING WITH CUBES

7.1. DESIGN ASPECTS

Among all the paving for exterior areas, with cubes of porphyry is traditionally the most common because of their high aesthetic and technical content and, above all, because they have a great adaptability to different situations and vast possibilities for design. Apart from all other tasks involved with design, a designer who chooses to use porphyry cubes must also decide on the geometric pattern, laying technique, number and size, and colour or colours.

COLOUR

The chromatic aspect is very important for the results when using porphyry. Bearing in mind what has been said about the color of porphyry, that the colour almost always varies from greys to reds, it should be remembered that the individual elements don't give the idea of the entire paving; i.e. the colour of a single element is not necessarily representative. The final colour will be a combination of all the pieces.

The smaller the pieces, the greater will be the "dilution" of the chromatic contribution of each element. Reddish ("strong") colours tend to weigh more heavily on the perceptive balance: a paving produced with the same number of grey and red cubes is seen by human eyes as a "red" paving. This perceptive phenomenon, that designers know well and is normal, is due to the bias of the stronger chromatic aspect (red) over the more neutral one (grey). The colour of paving with mixed cubes subjected to traffic, in proportion to the flow of vehicles, will inevitably tend to become darker because of dust left by car tyres, the pollution and a lot of other factors that occur on a road. The steps designers take to allow for this aspect are often in vain. However, in order to obtain suitable pieces for the project designers can ask for the necessary samples, or rather, above all for large areas, go to quarries and workshops to see all the existing possibilities.

PIECES

The choice of the pieces essentially depends on static and aesthetic factors. The final use of the paved area determines the type of cube to be used, even though mixtures are possible and using different pieces provides formal and structural diversity.

The 4/6 type is the most suitable for areas without traffic such as pavements, pedestrian areas, courtyards, gardens, and so on. The surface will be very smooth, with narrow (never more than 1 cm) gaps that make the design more apparent at short distances.

The 6/8 cubes are suitable for every kind of use, both pedestrian and medium-high traffic intensity areas. Because of its versatility and large production it is the most commonly used type.

The 8/10 cube is used to pave large areas and roads with heavy traffic.

Bigger pieces (10/12 – 12/14 –14/20) are not used much, although they are the most suitable for creating a surface that recalls the past paving materials with which many of our cities are paved. Abroad, above all in Germany and in Switzerland, even today they are widely used (often with blocks ("binderi")) to pave squares, or town centres, because they are resistant and durable, thus compensating for the higher cost of installation. Larger pieces will have wider gaps (up to 2 cm) and all the paved area will seem rustic, not well-finished, but very interesting when used in traditional environments (such as very old town centres, castles, etc.)

When choosing pieces, just as in choosing colours and geometry, it is important to maintain the traditional appearance.

DESIGN

The possibilities offered to designers using cubes regarding design and composition are infinite. The photographs and the tables in this book record only in part the results of projects conceived, tested and installed over the course of many years. Many other projects from throughout our country and all over the world could have been present here, and many others will certainly be designed, fruit of the imagination of designers both for restoration projects and new designs.

7.2. LAYING CUBES

We will limit ourselves here to dealing with the most wide-spread and most tested procedures of laying cubes. In order of importance they are: laying in "overlapping arcs", in "parallel lines", in the shape of "fans" or "peacock tails", and in "concentric circles".

7.2.1. LAYING OVERLAPPING ARCS

It is without doubt the most wide-spread pattern that easily suits every kind of area. This is the reason why it is also called "normal" lying. Following the design, the poser divides the area to be paved into strips (called "rande") whose width varies in relation to the type of cubes and the dimensions of the area itself. The strips are marked by ropes, which determine the outline, the slope and the height of the finished paving.

Along the rope of the perimeter, the poser places a straight line of cubes, as homogeneous in size as possible, called the "guide" because it is a sort of reference and border. Sometimes, for formal and functional reasons, the "guide" can be formed by more than one line (2, 3 or even more), and also has the function of a gutter. On the side of a regular area, such as a constant-width road, there will be this guide line, two middle arcs and then complete arcs, if possible and even number, above all if the roads are cambered. In this way there will be a whole arc in the middle of the road.

Then the poser starts laying using some triangular or trapezoidal elements ("wedge-shaped") both at the beginning and at the end of the pattern. After having set the curved shape of the arc, the poser places smaller cubes in the interior of the arcs (in the middle of the strip) and bigger cubes in keystone positions (that is on the side of the strip). The laying must be done so that cubes touch each other in their lower parts, minimising in this way the gaps between one cube and another. Too large or irregular gaps can compromise the aesthetic result and the mechanical resistance of the paving, as well as damage heeled shoes and form an unsafe surface. Cubes must be placed staggered compared to those of the

preceding strip, so that they have greater resistance to forces and potential removal or loss of elements. Also the "toothing" (final cubes placed at the edges of a strip) must be staggered, if possible not in a repetitive way.

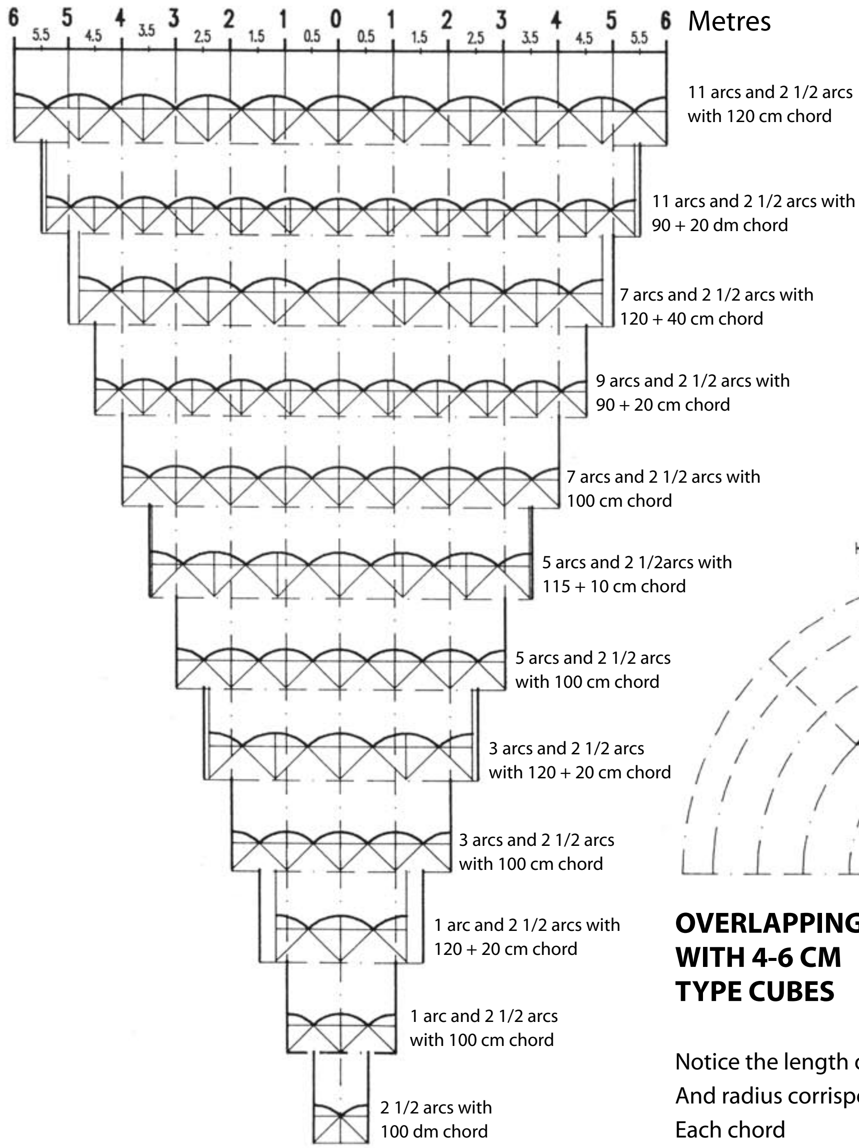
The experienced poser juxtaposes in the arc (in fieri) every cube that his sensitive hands pick up and places in its right position and adjusts it with the "facing-hammer" (an elongated, shaped hammer with a flat side used to move small quantities of sand). In a sloping area the arc will have the convex part turned up, due to mechanical resistance, and the laying operations will start from a lower point.


The Hope Collection
Contemporary Glass Art

DIAGRAM No. 6

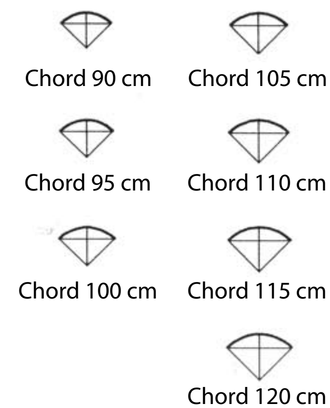
DIAGRAM SHOWING THE RELATIONSHIP BETWEEN OVERLAPPING ARCS AND THE WIDTH OF THE ROAD

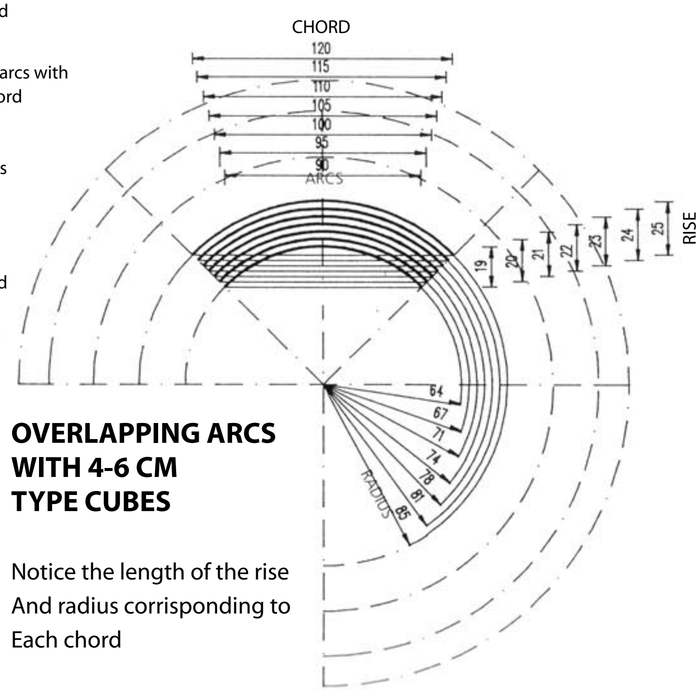
WITH OF THE ROAD



4/6 TYPE CUBE

TYPES OF OVERLAPPING ARCS





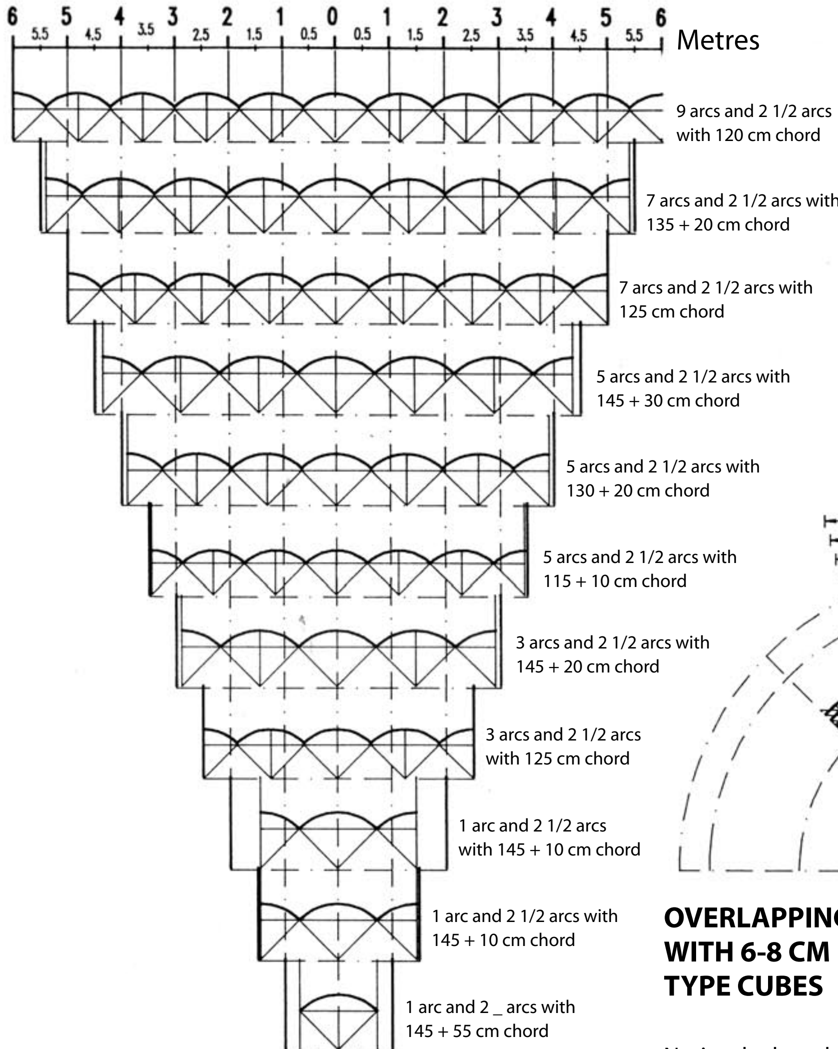
OVERLAPPING ARCS WITH 4-6 CM TYPE CUBES

Notice the length of the rise
And radius corrisponding to
Each chord

DIAGRAM No. 7

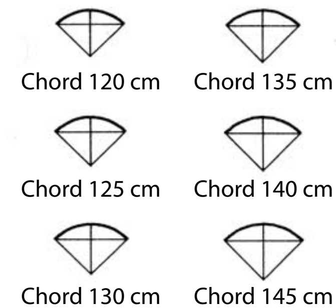
DIAGRAM SHOWING THE RELATIONSHIP BETWEEN OVERLAPPING ARCS AND THE WIDTH OF THE ROAD

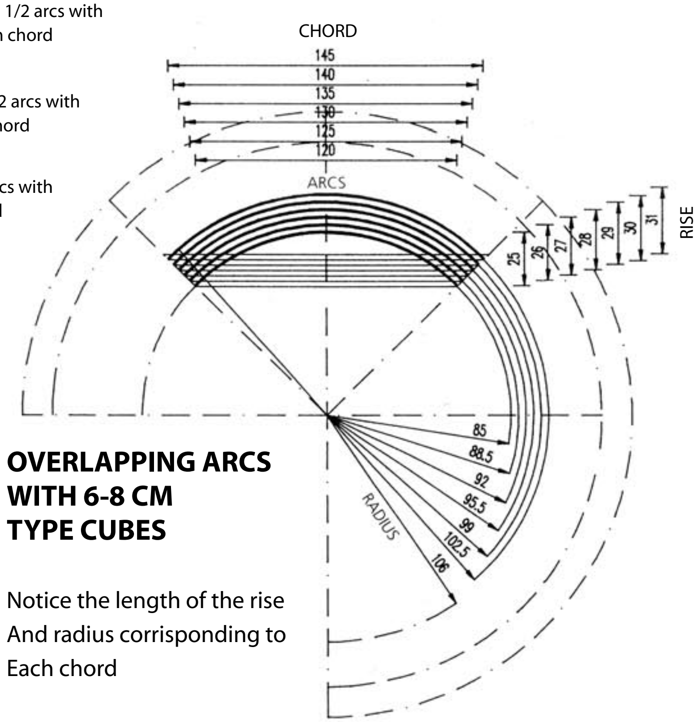
WITH OF THE ROAD



6/8 TYPE CUBE

TYPES OF OVERLAPPING ARCS





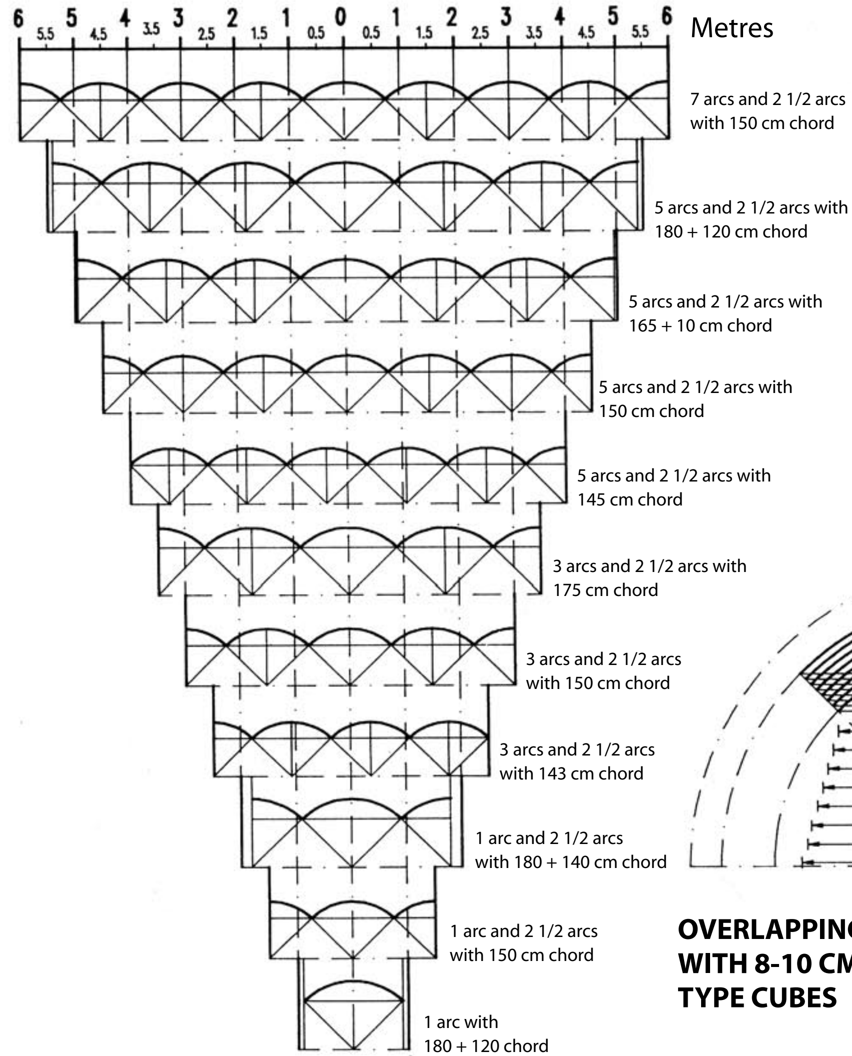
OVERLAPPING ARCS WITH 6-8 CM TYPE CUBES

Notice the length of the rise
And radius corrisponding to
Each chord

DIAGRAM No. 8

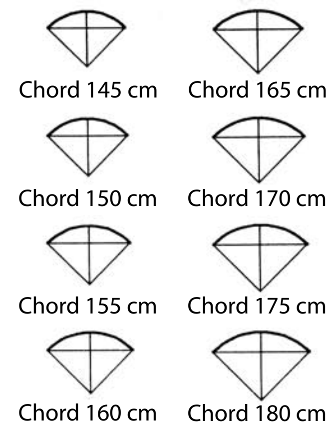
DIAGRAM SHOWING THE RELATIONSHIP BETWEEN OVERLAPPING ARCS AND THE WIDTH OF THE ROAD

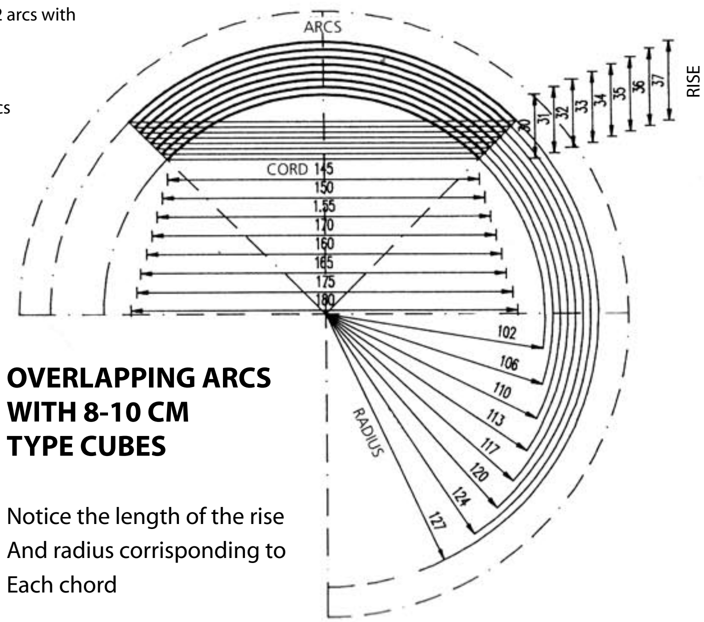
WITH OF THE ROAD



8/10 TYPE CUBE

TYPES OF OVERLAPPING ARCS





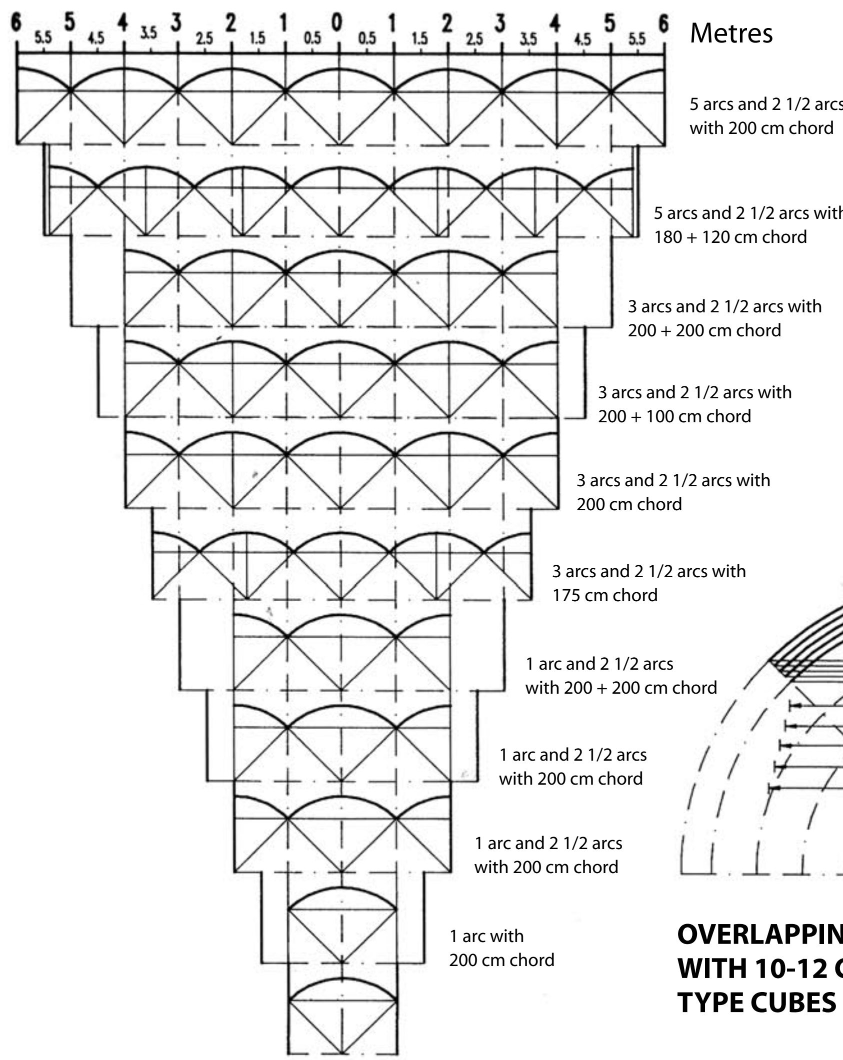
OVERLAPPING ARCS WITH 8-10 CM TYPE CUBES

Notice the length of the rise
And radius corrisponding to
Each chord

DIAGRAM No. 9

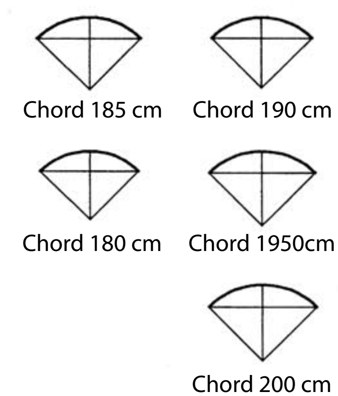
DIAGRAM SHOWING THE RELATIONSHIP BETWEEN OVERLAPPING ARCS AND THE WIDTH OF THE ROAD

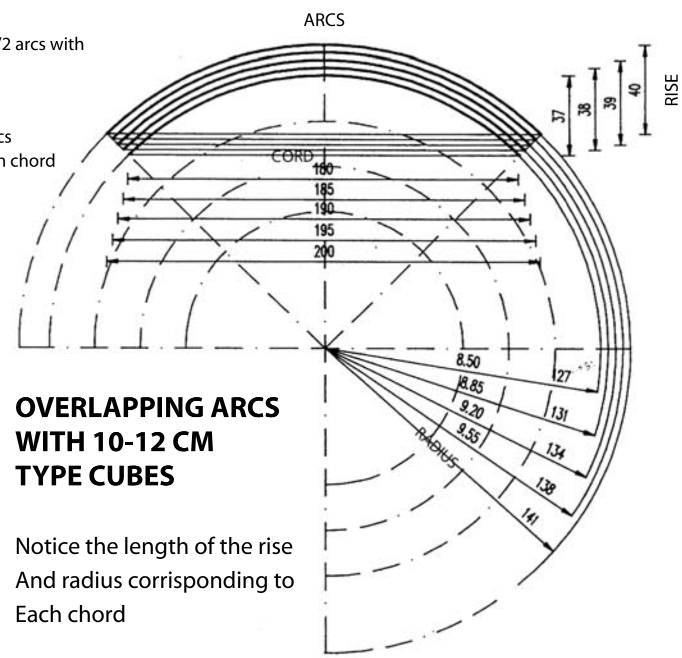
WITH OF THE ROAD



10/12 TYPE CUBE

TYPES OF OVERLAPPING ARCS



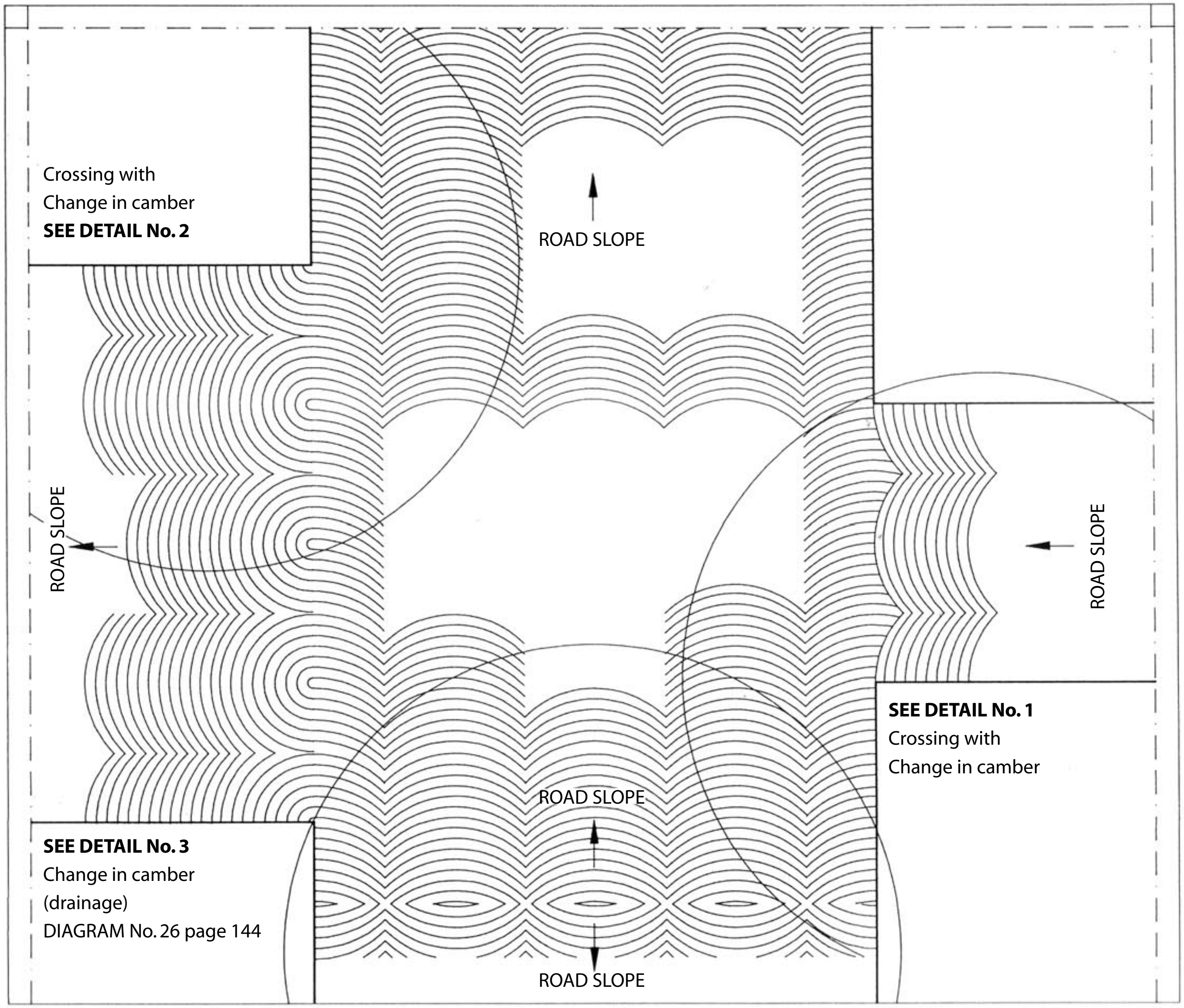


OVERLAPPING ARCS WITH 10-12 CM TYPE CUBES

Notice the length of the rise
And radius corrisponding to
Each chord

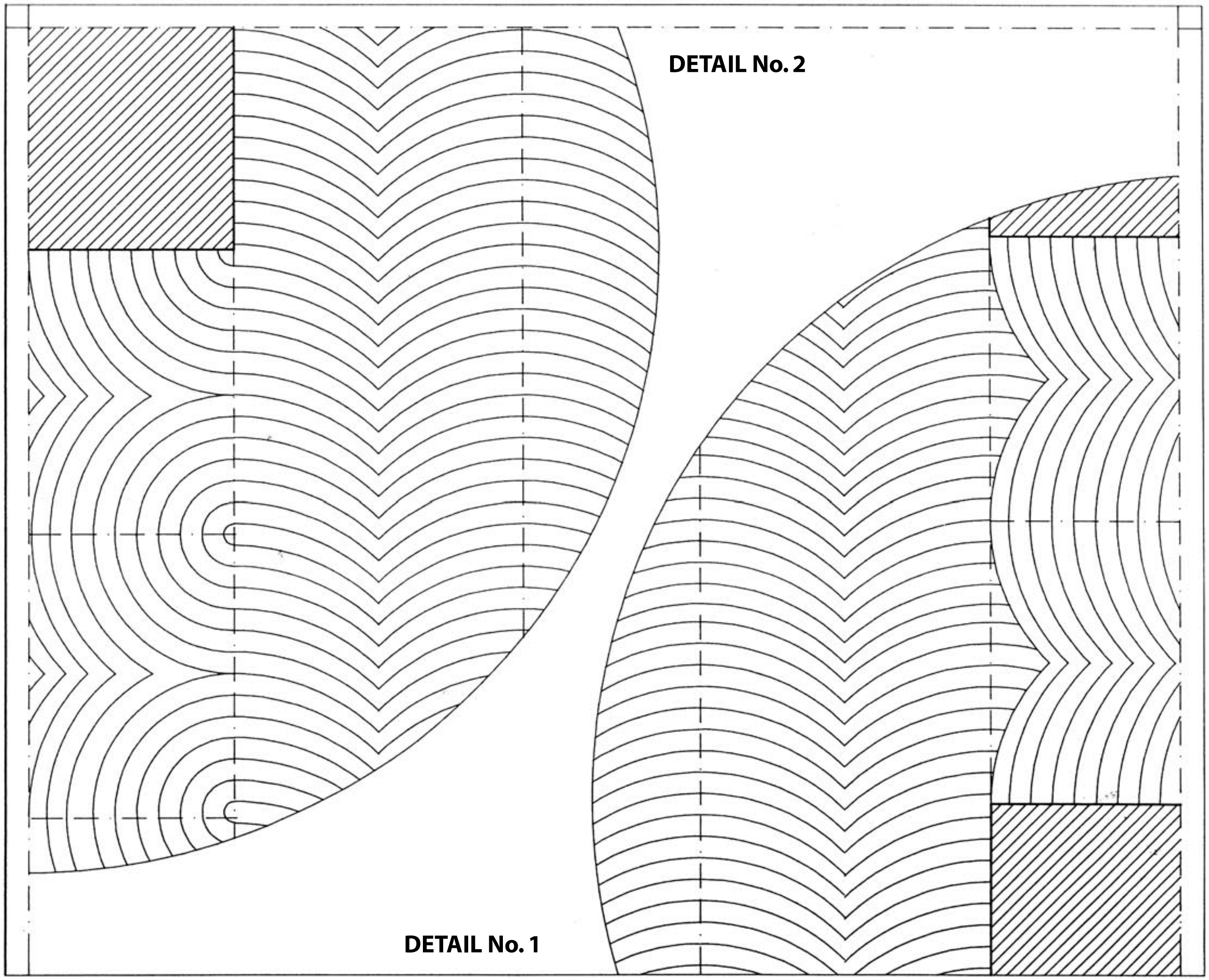
Diagram showing the crossing of roads paved with cubes and overlapping arcs

DIAGRAM No. 10



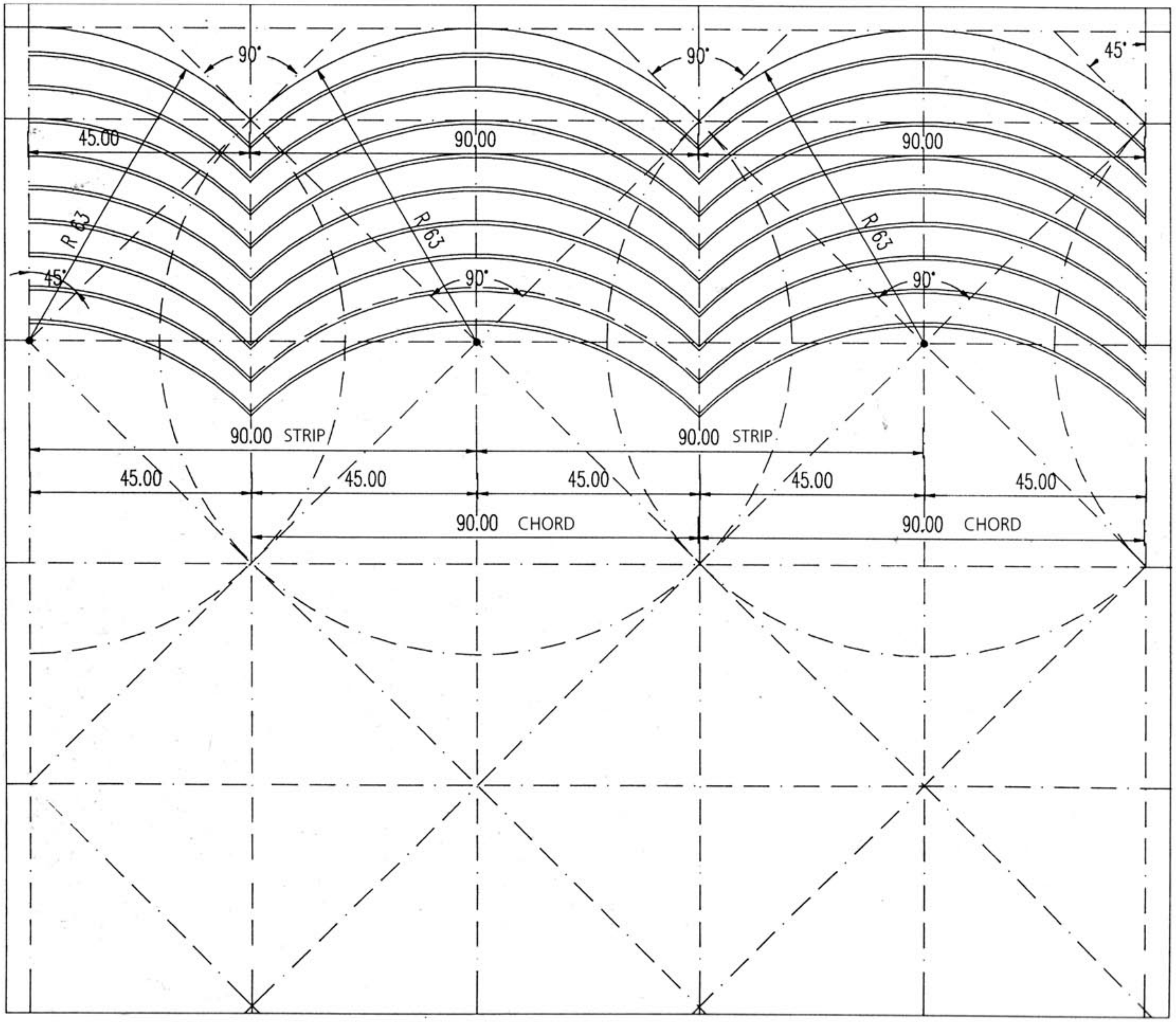
DETAILS

DIAGRAM No. 11



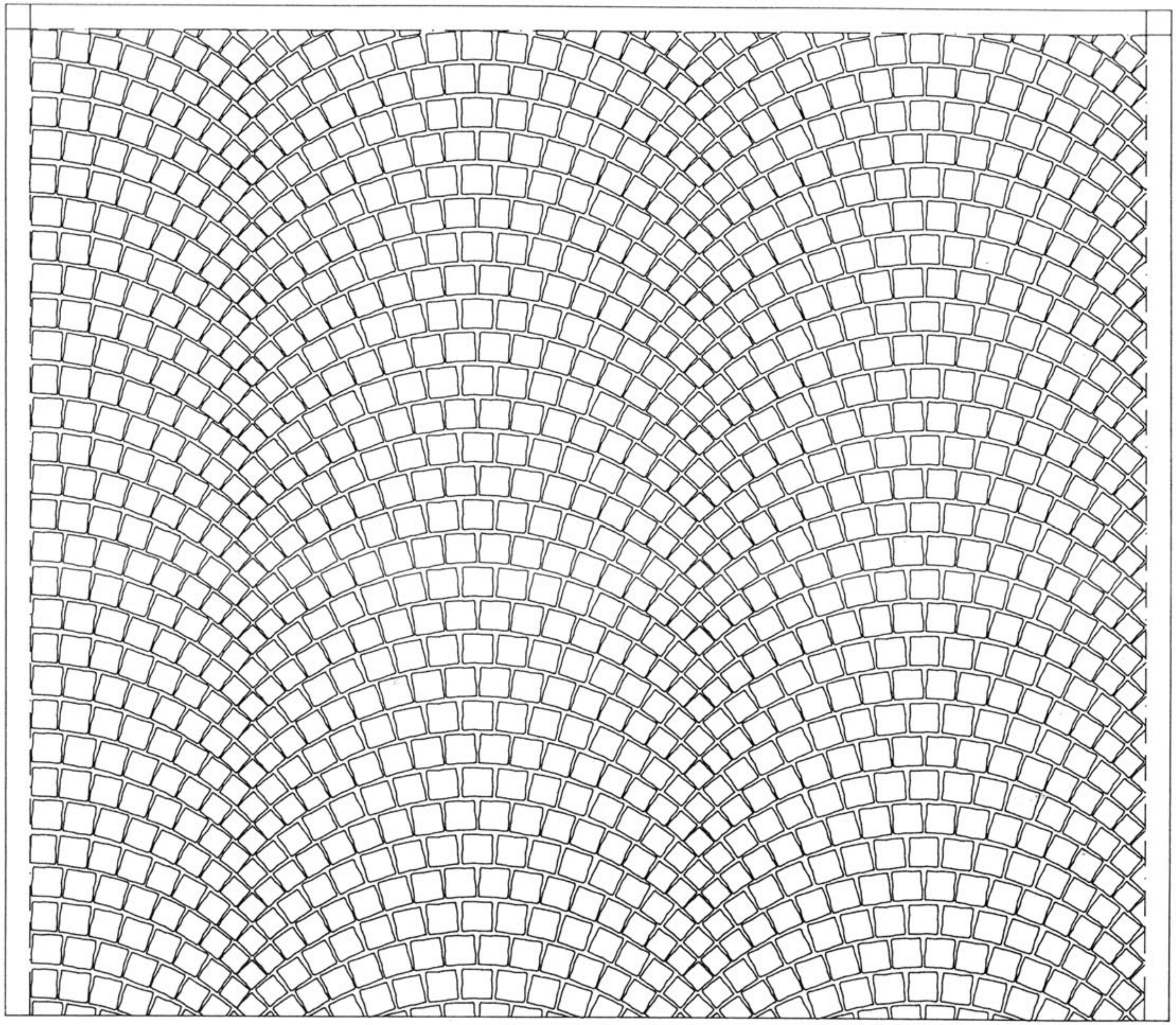
Geometric plan for the laying of overlapping arcs with 4/6 cubes –90-120 cm chord

DIAGRAM No. 12



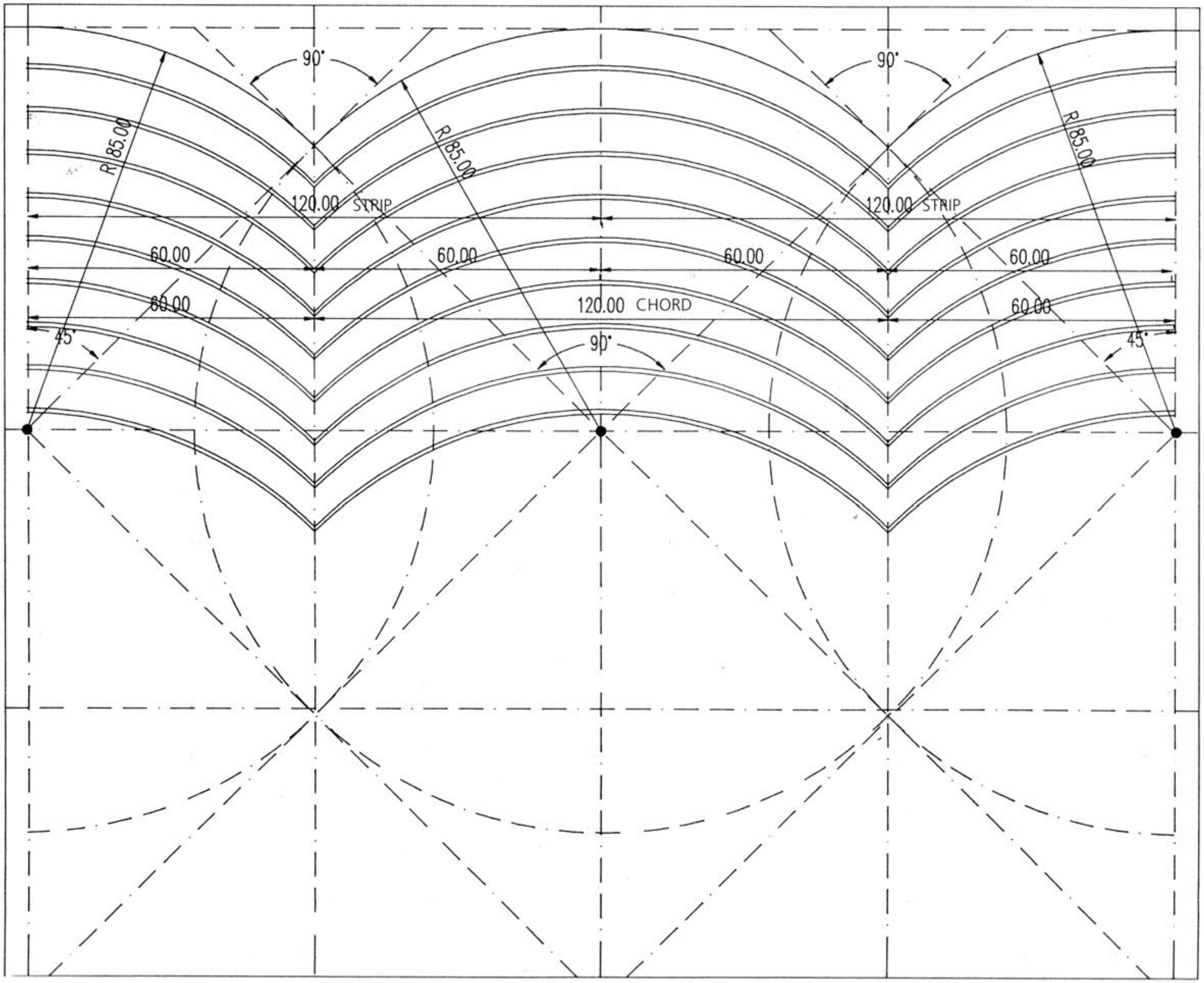
Drawing of overlapping arcs with 4/6 cubes –90-120 chord

DIAGRAM No. 13



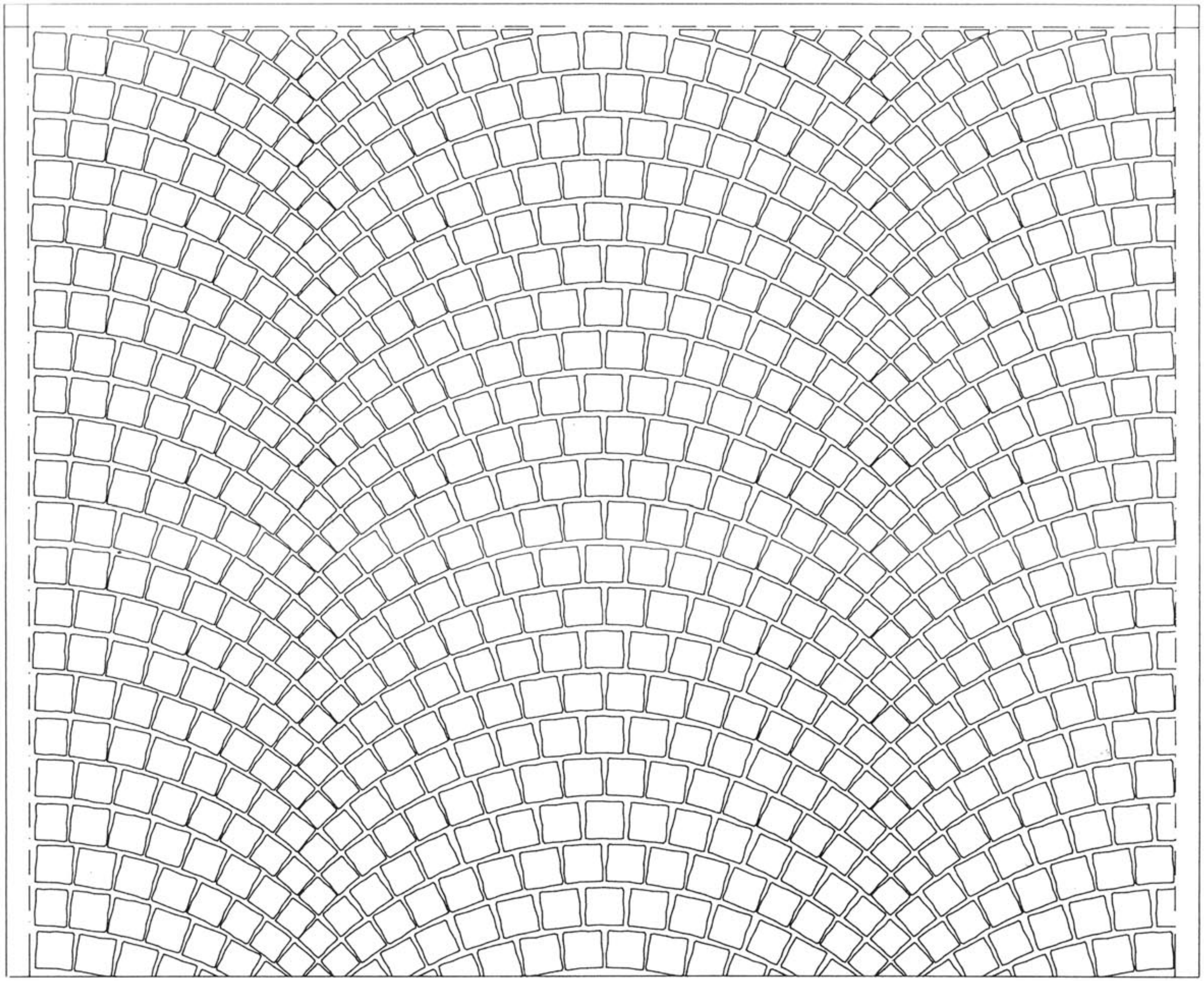
Geometric plan for the laying of overlapping arcs with 6/8 cubes –120-150 cm chord

DIAGRAM No. 14



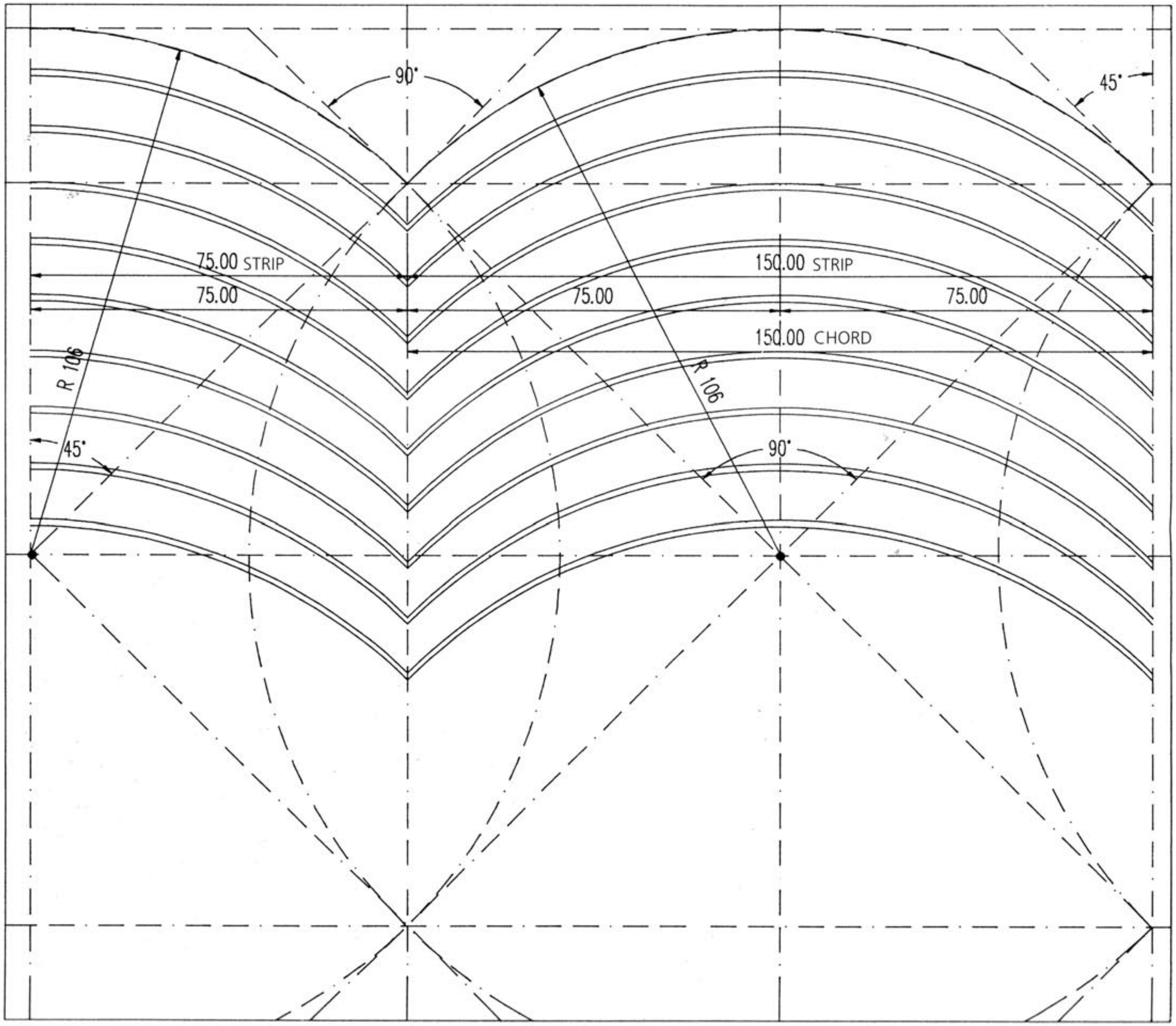
Drawing of overlapping arcs with 6/8 cubes –120-150 cm chord

DIAGRAM No. 15



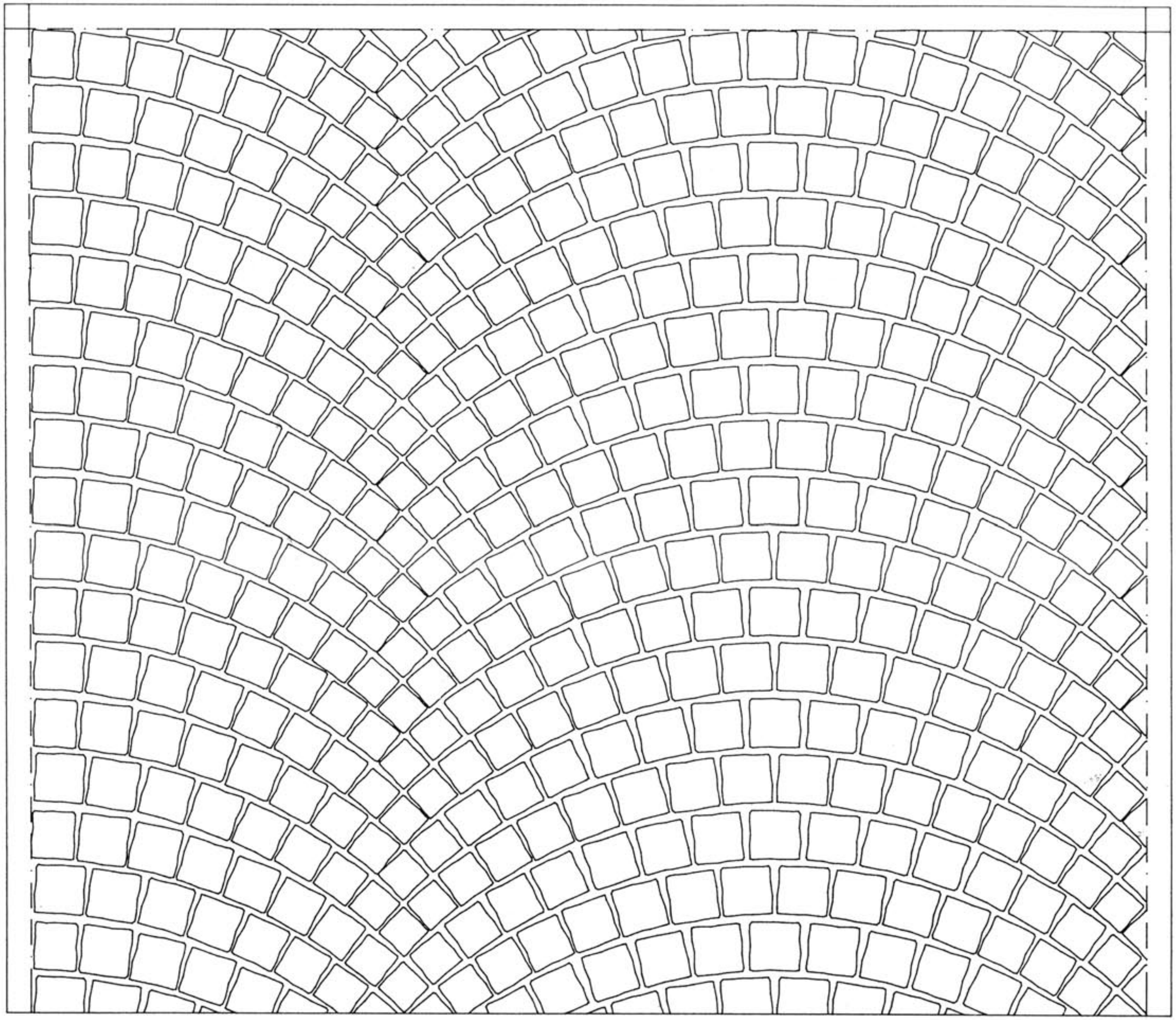
Geometric plan for the laying of overlapping arcs with 8/10 cubes – 150-180 cm chord

DIAGRAM No. 16



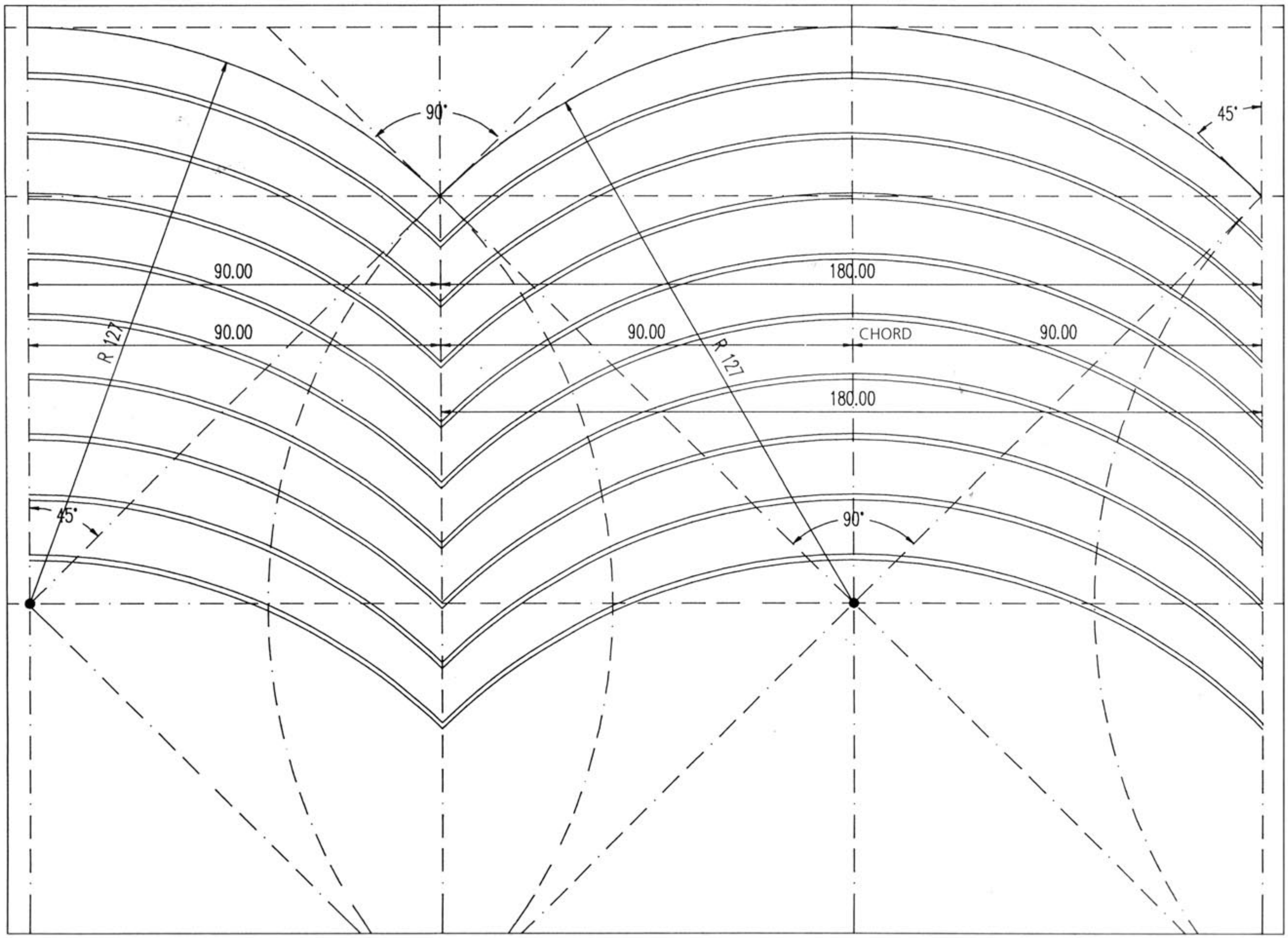
Drawing of overlapping arcs with 8/10 cubes –150-180 cm chord

DIAGRAM No. 17



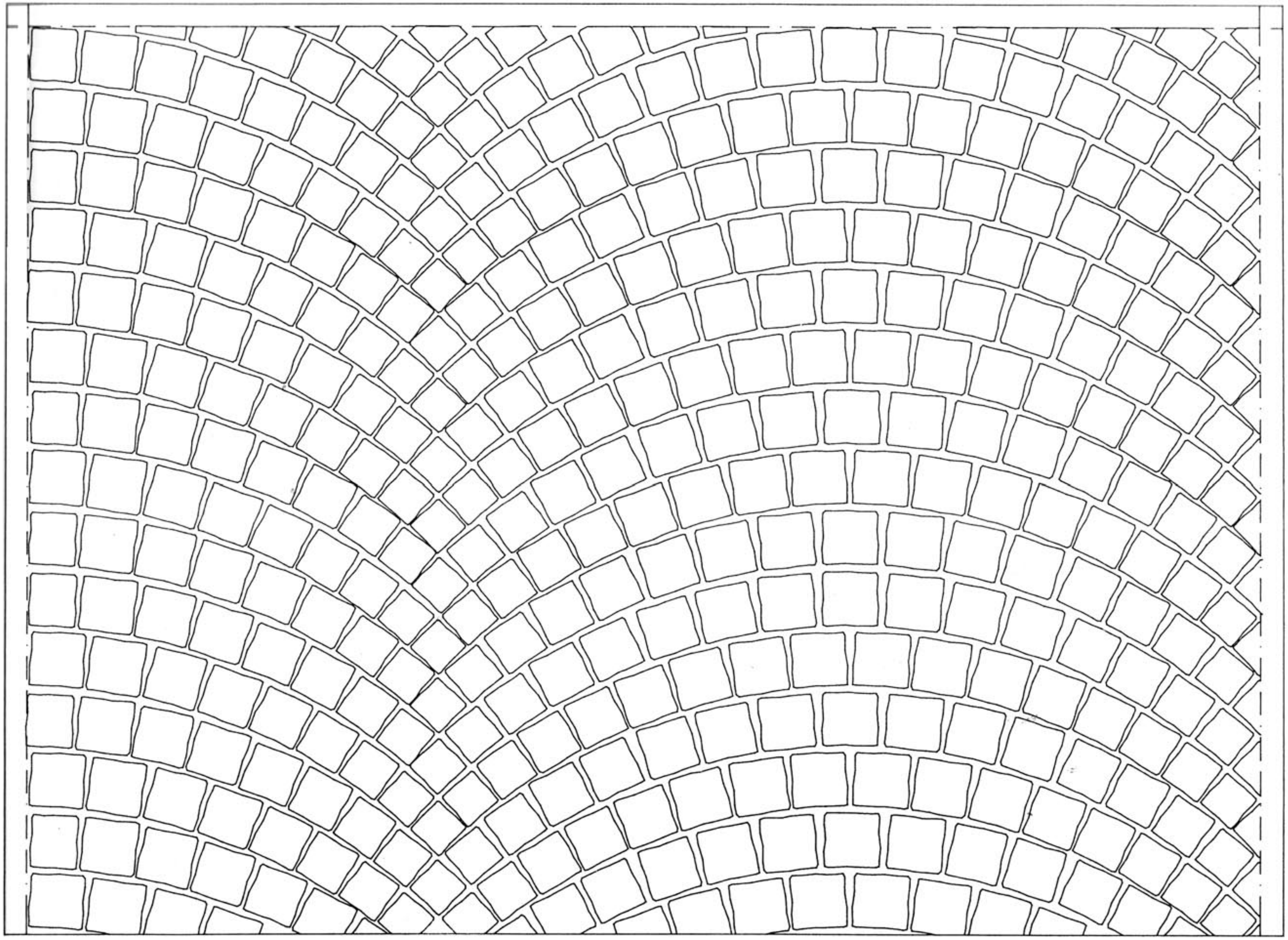
Geometric plan for the laying of overlapping arcs with 10/12 cubes – 180 cm chord

DIAGRAM No. 18



Drawing of overlapping arcs with 10/12 cubes – 180 cm chord

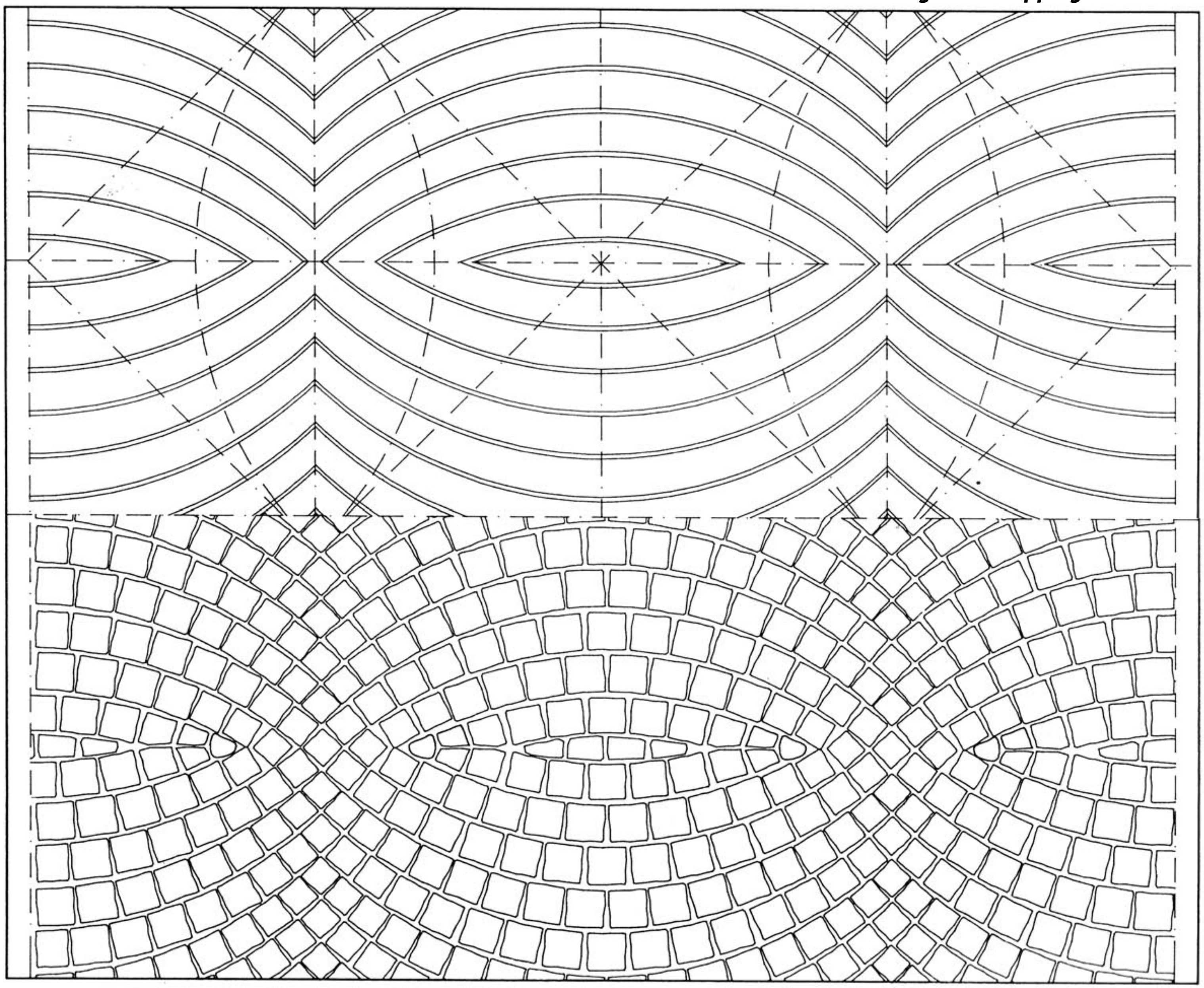
DIAGRAM No. 19



Geometric plan for the laying of overlapping arcs with 8/10 cubes –120-150 cm chord drainage between two roads (almond)

DIAGRAM No. 20

Drawing of overlapping arcs with 8/10 cubes

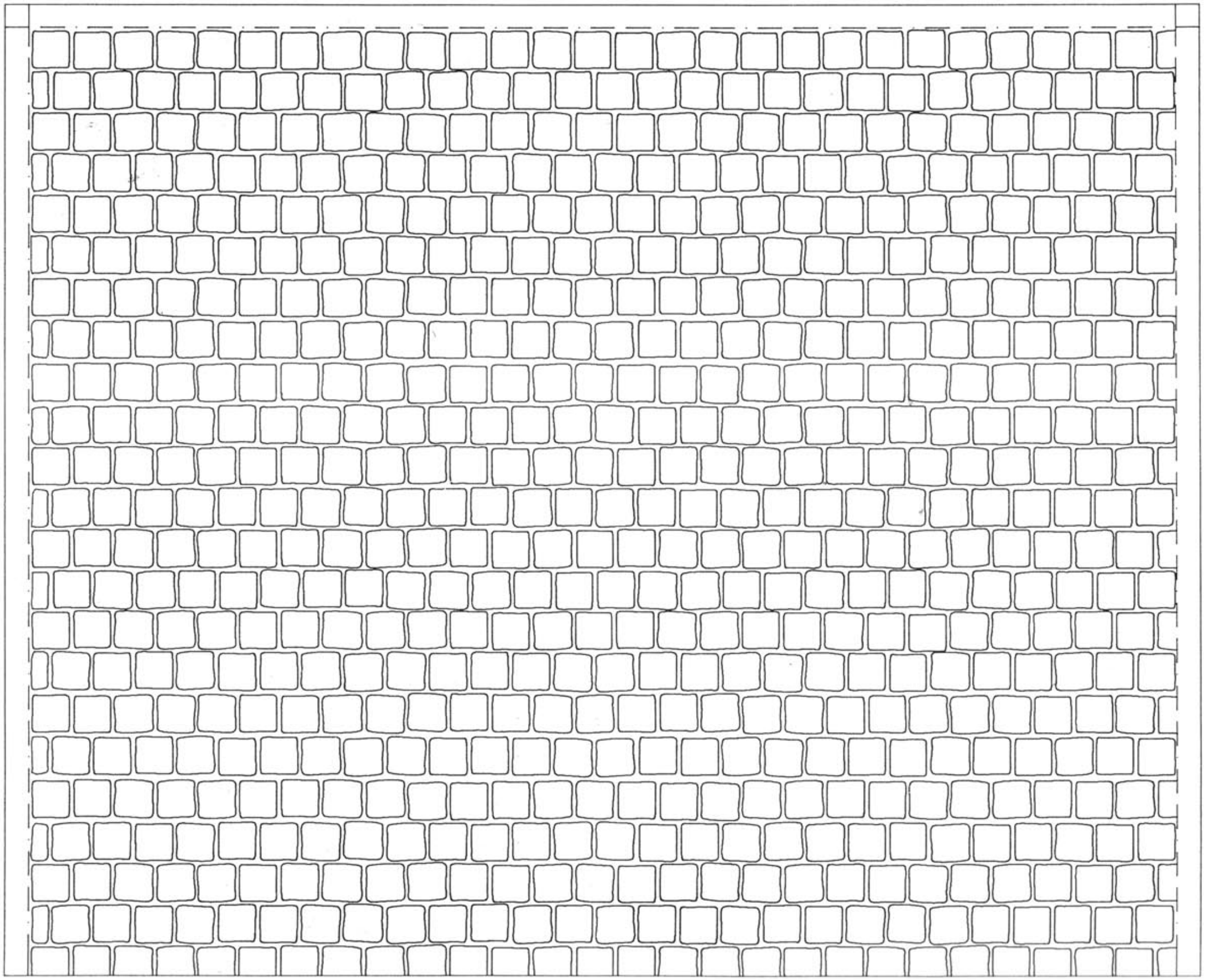


7.2.2. LAYING "PARALLEL LINES"

Laying "parallel lines", widely used in the past, is becoming more and more popular recently.
To obtain well-made paving of this sort it is better not to design lines which are too long during the design phase, because non-uniform cubes can make it very difficult for the poser to maintain perfect lines, and the aesthetic effect is lost. It is therefore recommended to design a line of about 10 meters at most. For the same reasons it is better to avoid right-angled lines.
The lines of cubes can vary a lot, they can be right-angled, parallel or with different angles depending on the axis or the position of the buildings, herring-bone, etc.
It is also possible to create different geometric patterns such as squares, rectangles, trapeziums and other regular figures.
For this kind of laying, above all when the level of finishing has to be raised, it is better to use specifically produced cubes whose dimensional tolerances are within limits. However if standard cubes are used, it is important to be sure that the shape and the quality of the cubes are excellent.

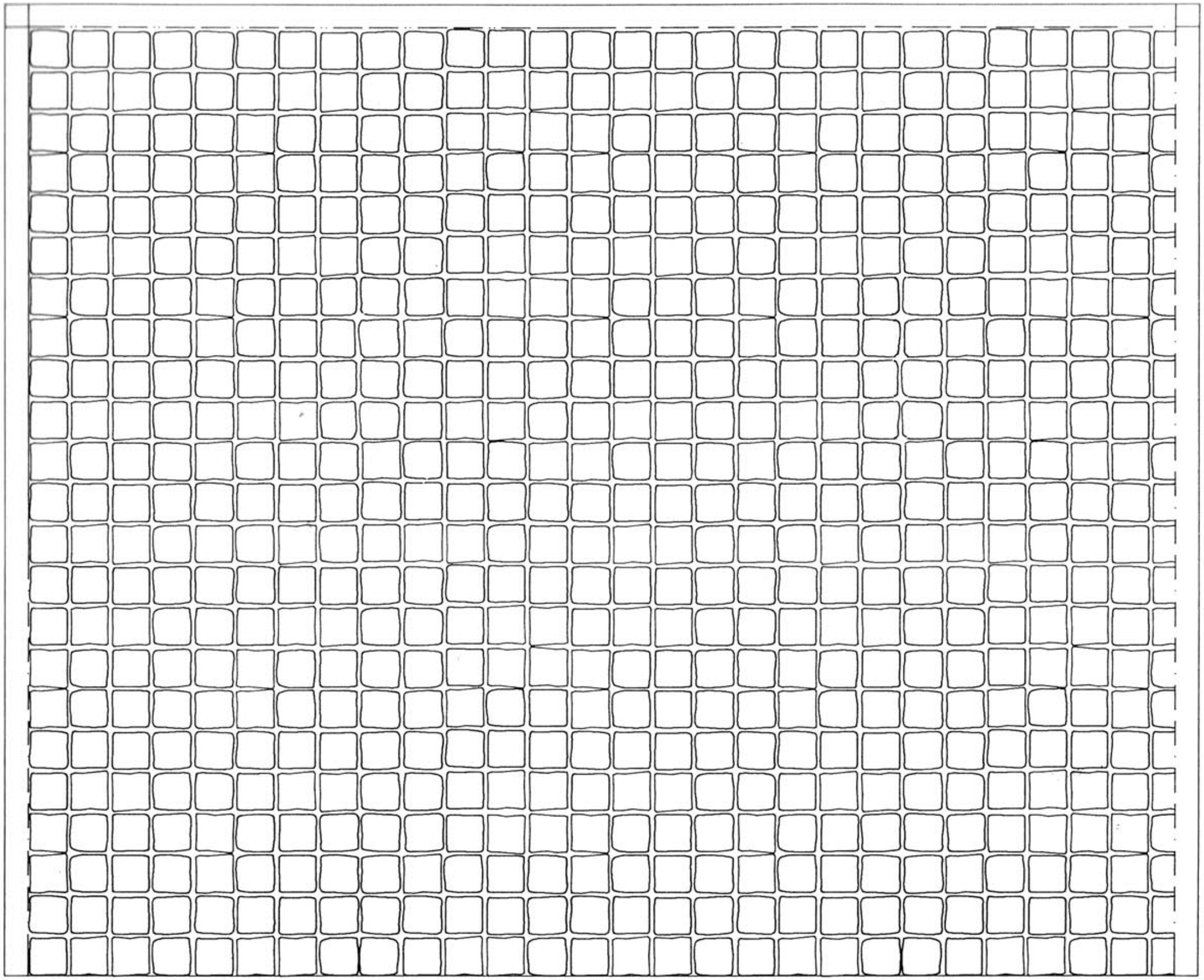
Drawing of parallel rows

DIAGRAM No. 21



Drawing of perpendicular rows

DIAGRAM No. 22



7.2.3. LAYING "FANS" OR "PEACOCK TAILS"

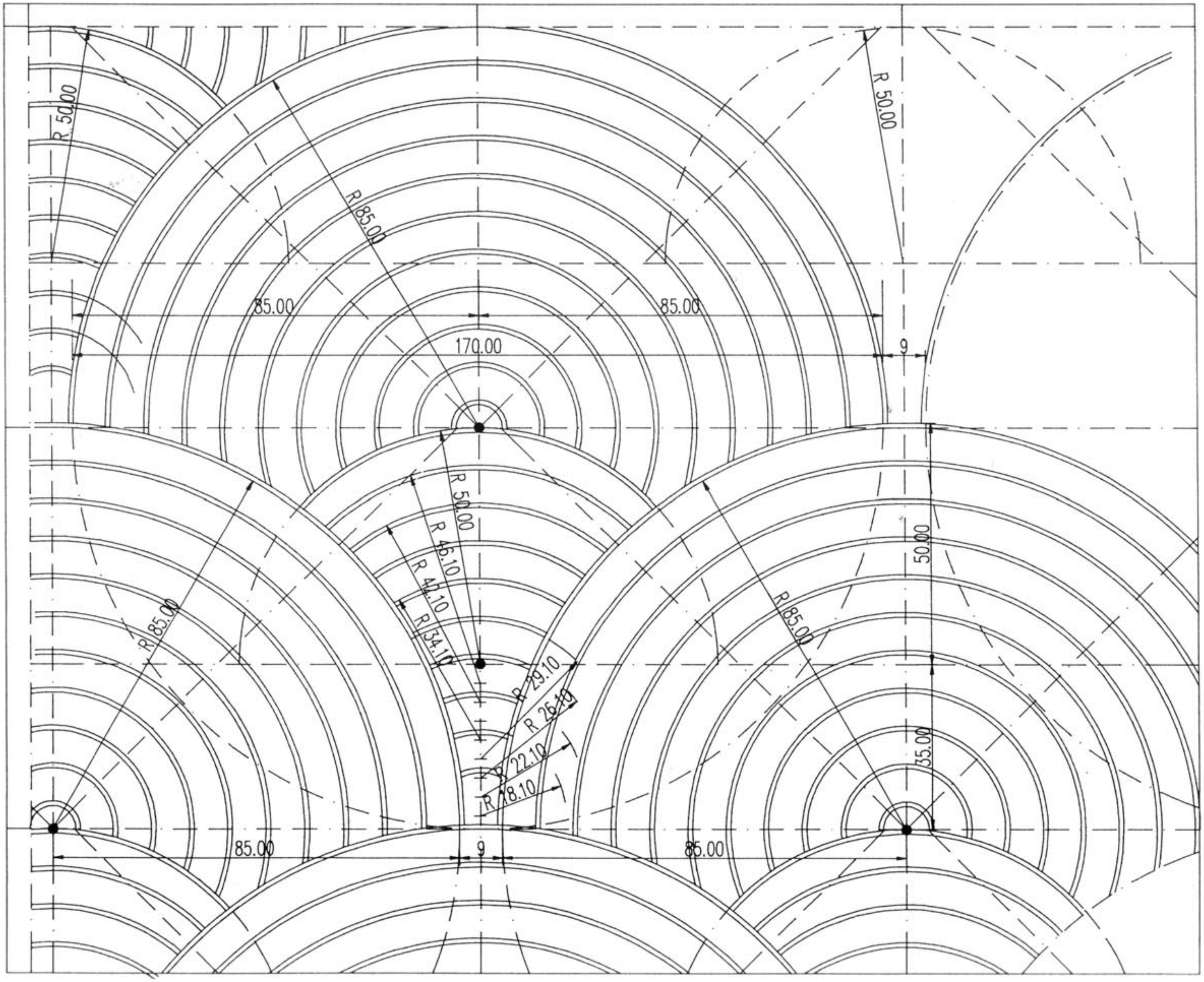
It is very common design, but because of its stunning effect it has to be used in particular contexts.

First of all, it is advisable to use small cubes (4/6 or 6/8), that are better suited to designs. The characteristic shape of a fan is obtained by preparing an outline (dime) in the shape of a semicircles of suitable diameter, depending on the size of cubes and the dimensions of the area to be paved.

The laying starts with a set of semicircles, that is obtained by following the outside thread of the outline with a line of cubes, generally made of marble, but also of porphyry of different colours, or polished, or of granite. Between one semicircle and another a space is left in order to put one or more cubes in it, an important phase in the final form of the laying. After having completed the outline of the figure, the figure must be filled and completed. Next comes the phases of compacting and the sealing of joints, that have to be particularly well-done in order to not alter the design.

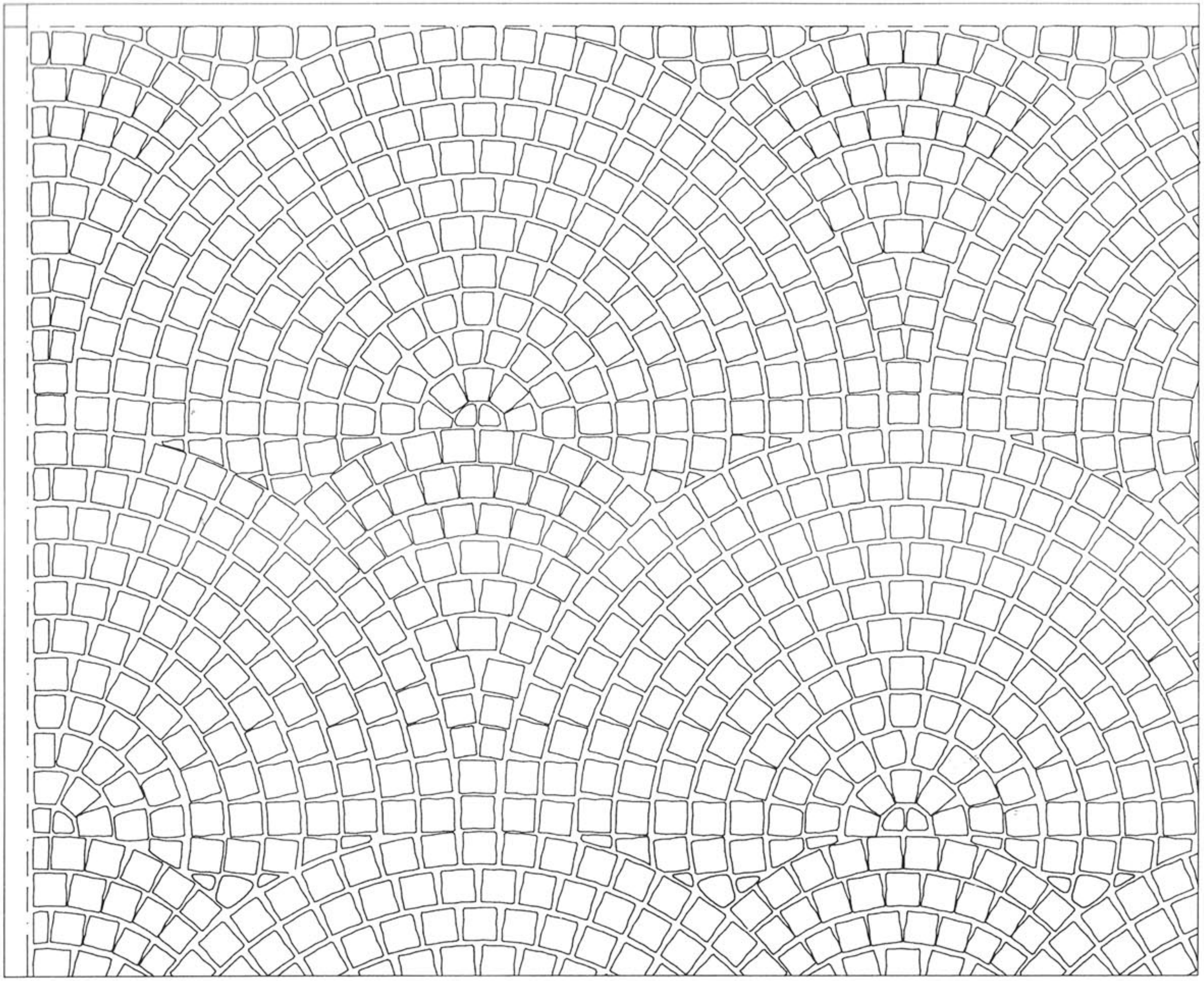
Geometric plan for the laying of double fans

DIAGRAM No. 23



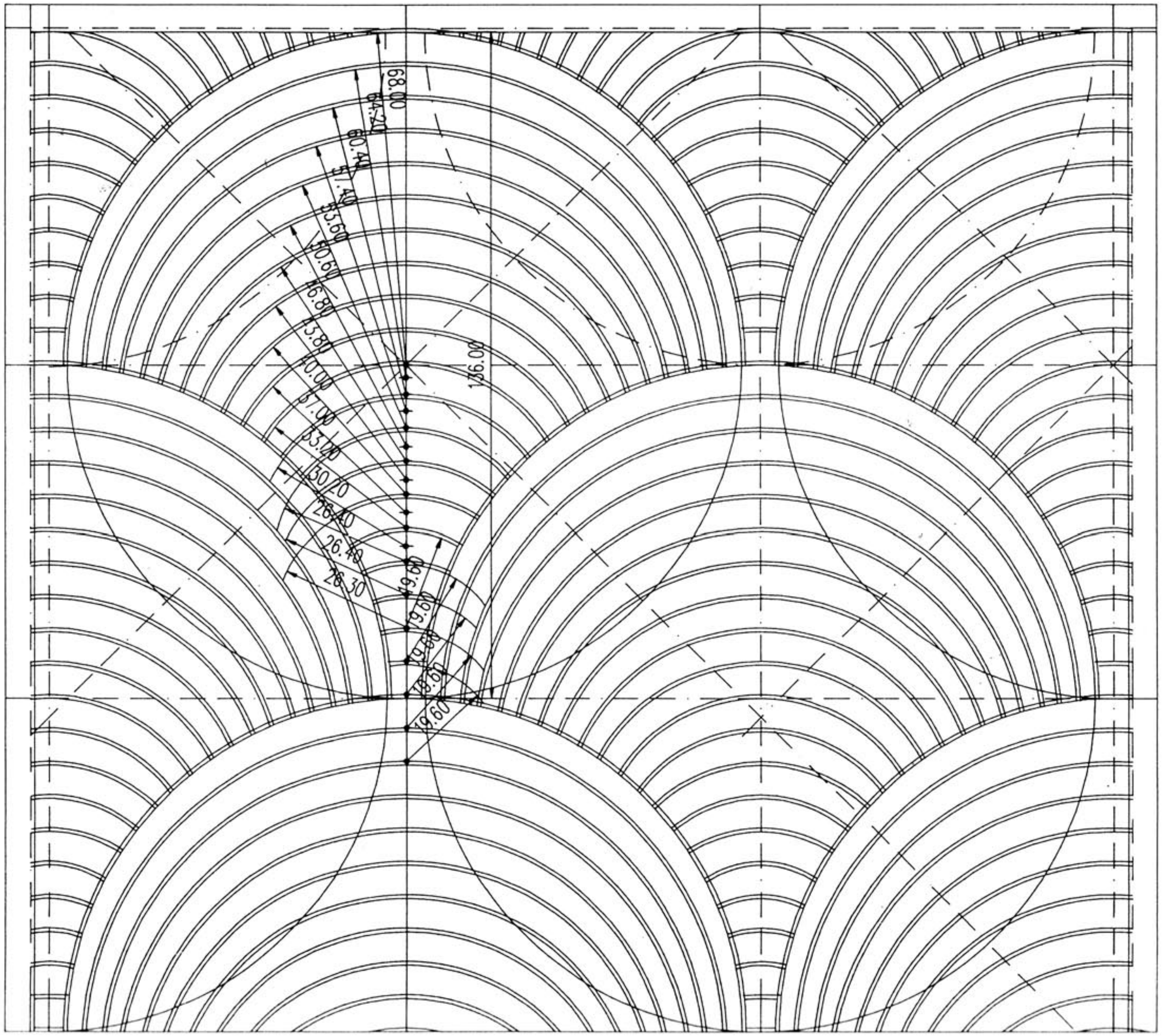
Drawing of double fans

DIAGRAM No. 24



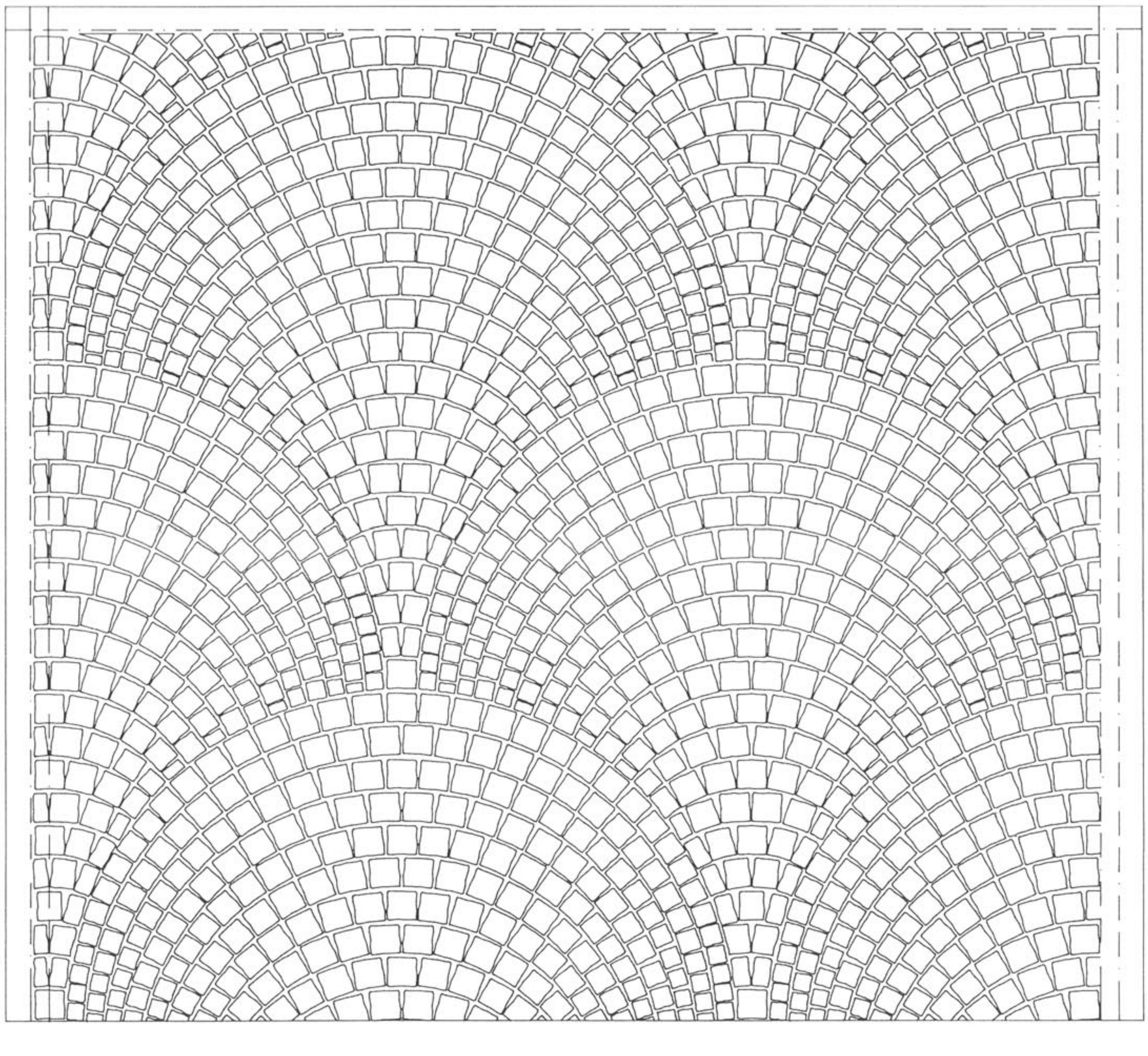
Geometric plan for the laying of multi-centred fans

DIAGRAM No. 25



Drawing of multi-centred fans

DIAGRAM No. 26



7.2.4. LAYING "CONCENTRIC CIRCLES"

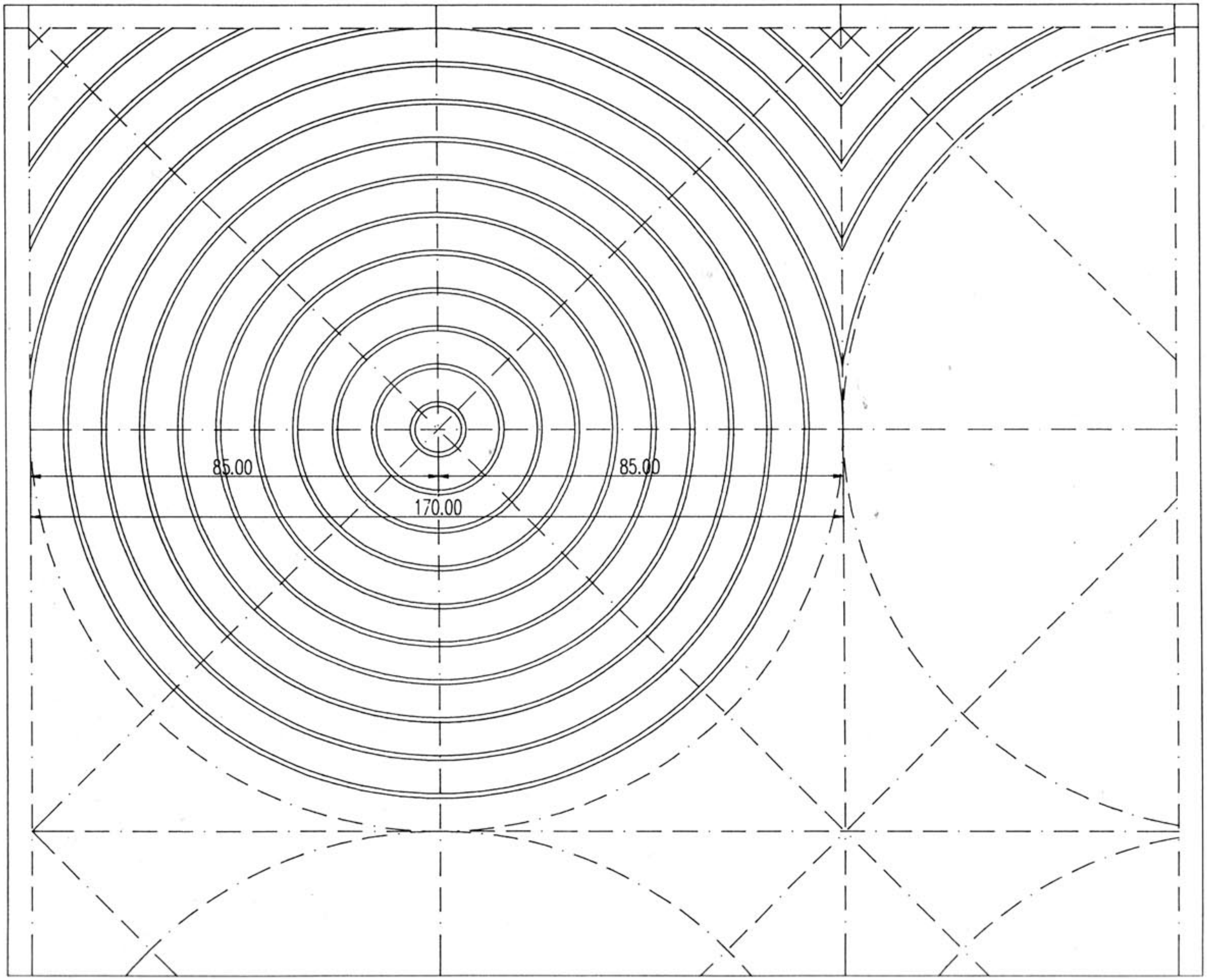
Another type of very common design is "concentric circles" (although the cost of the laying itself is expensive).

This pattern is obtained by laying cubes around a line of circumferences placed against each other and with the same centre. The dimensions of the circles must not be more than 8 m in diameter. Above this measurement it becomes very difficult to control the regular development of the lines of cubes that form the circumferences.

It is also advisable to put in the middle of the circle a round paving-stone as big as the dimension of three lines, the centre included. This has to be made to order in order to avoid cutting the cubes into wedge shapes, an aesthetic and economic drawback. Usually, in order to make the design visible, the outer circle of cubes is laid with cubes of different material (marble, granite, etc.) or of polished porphyry cubes. This work must be carefully done to obtain regular circles, i.e. circles that have the same radius for the whole circle, as it may be compromised during laying or compacting operations.

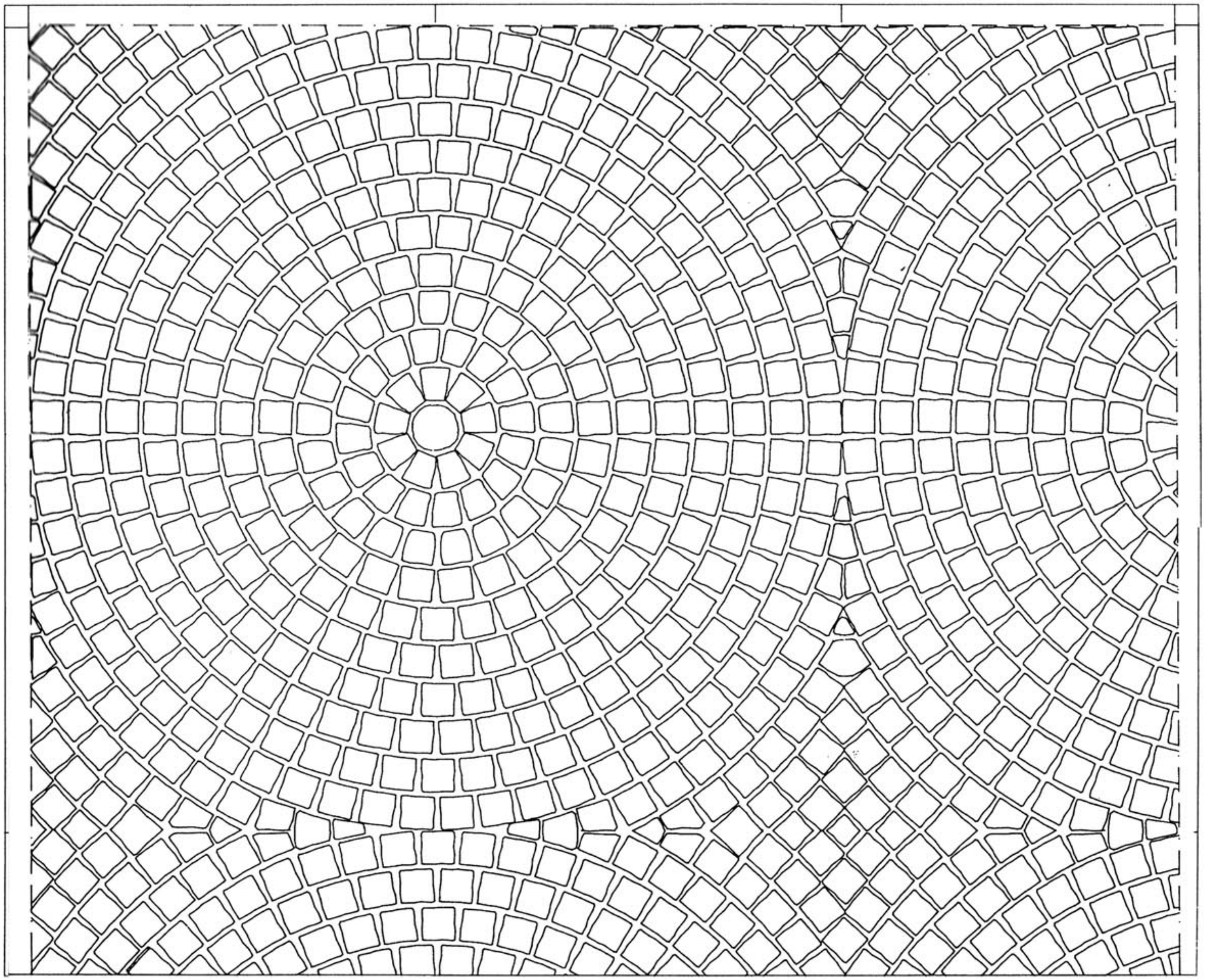
Geometric plan for the laying of concentric circles

DIAGRAM No. 27



Drawing of concentric circles

DIAGRAM No. 28



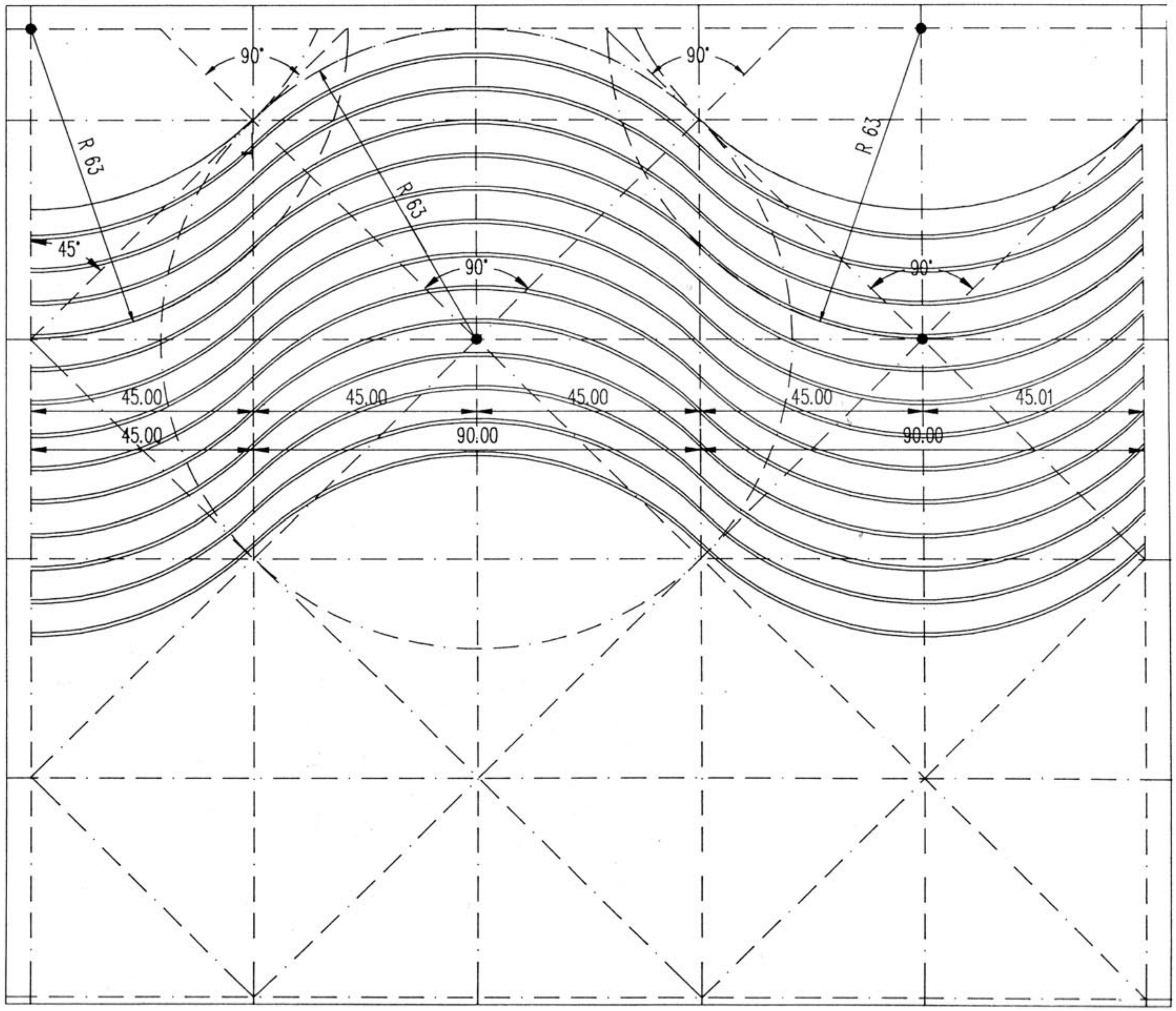
7.2.5. LAYING PATTERNS

Beside those already described, the most common designs, other possibilities and laying combinations are also used.

Here are some diagrams and photographs that should not limit the fertile imagination of designers or the flexibility of the material.

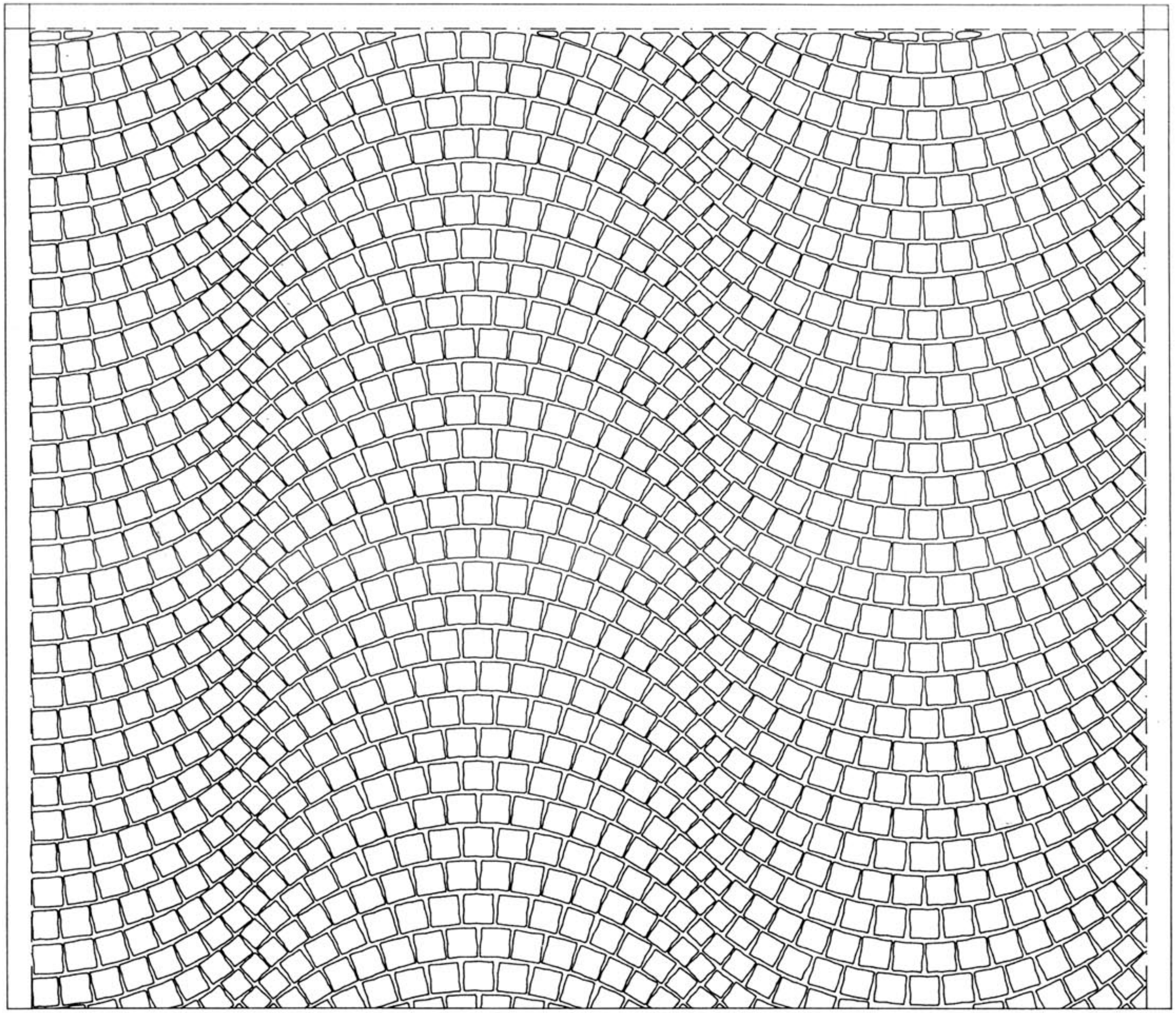
Geometric plan for the laying of alternating overlapping arcs

DIAGRAM No. 29



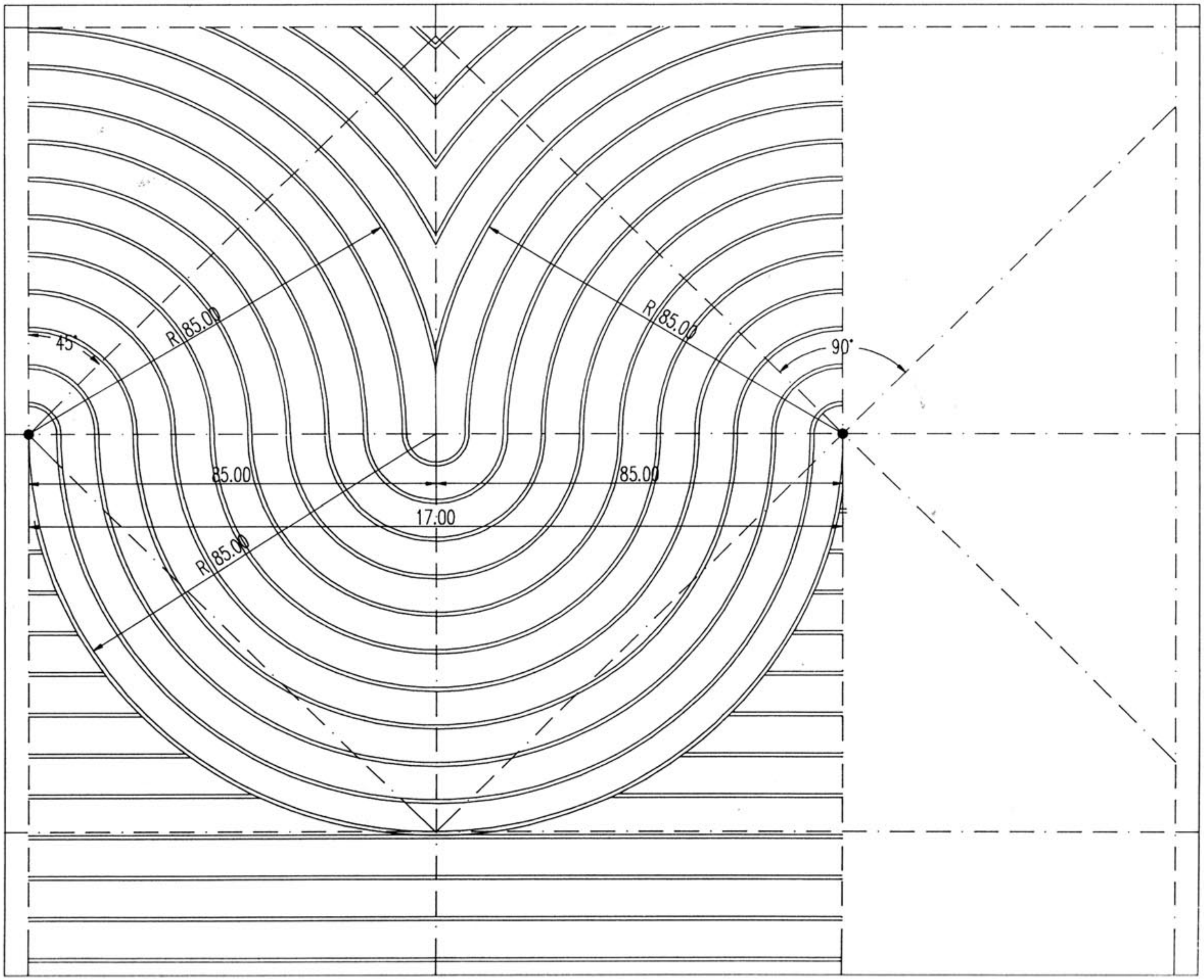
Drawing of alternating overlapping arcs

DIAGRAM No. 30



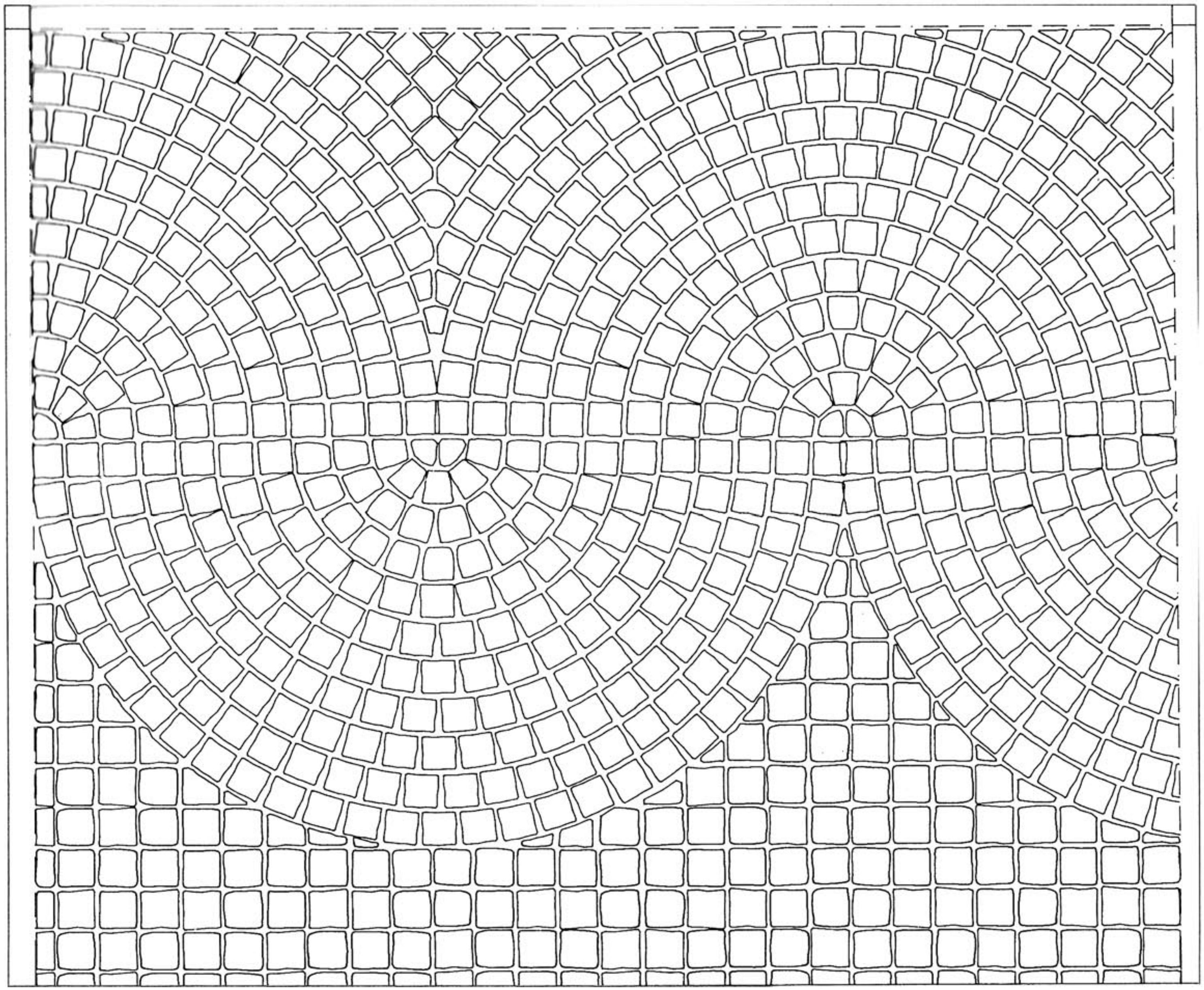
Geometric plan for the laying of alternating semi-circles

DIAGRAM No. 31



Drawing of alternating semi-circles

DIAGRAM No. 32



7.3. COMPACTING

After having completed the laying of the cubes and thoroughly cleaning the surface, the operations continue with the so called compacting.
That is the compaction of the paving elements in the bedding layer until the correct position is obtained.

First of all every space between a cube and another is filled with sand or sand mixed with cement using large flat trowels. The compaction is obtained by using vibrating plates of different dimensions and weight depending on the size of cubes. It is better not to use rollers that compact the cubes in an unsuitable way.

The vibrating plate must be vertical and a controlled water flow must precede it in order to make the bedding layer softer and facilitate the uniform compacting of the cubes.

The paving must be worked once in one direction and twice in a right-angled direction to the first one by turns. Where it is not possible to work with machines a tool, called a "tramper" is used i.e. a tool made of iron that weighs about 20-25 kg. It is operated by hand, setting the cubes and compacting them until the surface is uniformly flat. In the past all the compacting operations were done bye hand just using the tamper, it was extremely hard work.

During the compacting it is possible to find some defects in the laying: it is better to rectify them immediately.

7.4. SEALING

The word "sealing" here means the operations done to perfectly fill in the interstices formed between one element and another after the laying is completed. The sealing keeps elements firm and together with the others, so pieces are not lost or removed and the paving is safe. In the past, hot or cold bituminous sealing was used, techniques now completely fallen into disuse due to poor stability and poor aesthetic results and high costs.

At present the most common techniques used for sealing the cubes use:

• Sand: during the operations of compacting all the spaces between one cube and another are filled with sand with grain size the same as the sand used in laying. Once compacted, all the paving is sprinkled with sand and it is left until the sand has penetrated into every hollow (about 15 days). If the layer of sealing is removed (due to water, wind, etc.) it is necessary to sprinkle the sand again on the bare parts. The sand sealing allows complete recovery of cubes, if forced to remove them due to excavation or other works, and also a greater elasticity and flexibility of the system. Sealing only with sand needs careful maintenance, as weeds grow in the corners which are little used.

• **Cement "boiacca"**: is obtained by mixing equal quantities of very fine sand, water and cement. The compound obtained is a very thick liquid, called "boiacca" and is spread all over the paving and left to penetrate into the gaps aided by rubber brushes. After laying, the setting of the "boiacca" varies from one to two hours depending on the season and the atmospheric conditions (never when it rains). Then comes the cleaning with controlled water flow and big, flat rubber blades. Immediately after, the paving must be sprinkled with wet sawdust with special brushes, and then treated again with dry sawdust until the surface is perfectly clean. The cleaning of the surface must be completed in every part, because if the cement is not removed it becomes very difficult, almost impossible, to obtain an aesthetically good result. Incomplete cleaning is one of the most common, damaging and difficult defects to rectify.

• Sand and cement "a battere": this is a combination of the two techniques above described. A mixture of fine sand and cement in equal quantities is sprinkled over the paving and then it is brushed in order to fill in all the gaps between cubes. Then comes the compacting of the cubes, during which the mixture of sand and cement is reduced in quantity with the setting of the cubes and the wetting, and sets near the base of the cubes. The gaps are then filled up with sand.

However, the problem of sealing is not completely solved and technicians are testing other methods such as polymer mixture, asphalt-dust, and other products. But it too premature to mention these things as they haven't yet been tested for a sufficient period of time.

Chapter 8

PAVING WITH TILES AND IRREGULAR SHAPED TILES

8.1 LAYING OF TILES

Tiles, together with cubes and irregular shaped tiles, are traditionally one of the most used porphyry products. Paving with these materials can be found in numerous countries of all the five continents.

The non-slip surface, the resistance to strains and load peculiar to porphyry, the beautiful appearance due to the particular chromatic effects, the simple laying and also the good ratio of cost and quality have helped to spread the success of the products, which have paved millions of square meters of surfaces, always with great results in every kind of setting (historic centres, modern towns, etc.) and under every climatic conditions, from the hottest temperatures to the coldest.

The laying of tiles, simpler than the laying of cubes, is done almost exclusively on a bedding layer formed of cement mortar. There is no difference between the laying

of the tiles with "split sides" and ones with "sawn sides", because both can have variable thickness between the two natural quarry faces. The difference between these two types of laying is the width of the joints which affects the aesthetic result. The foundation layer must follow as closely as possible the final slope of the paving, its surface must be free of dust and other impurities that can cause poor adhesion of the foundation to the bedding mortar. It is also advisable to wet the surface of the foundation thoroughly (but avoiding puddles) before laying the bedding mortar.

The mortar is formed of a mixture of:

• builders sand with grain size from 0 to 4 mm, with no earth, clayey substances or colouring oxides;

• clean water, with no organic substances, salts, minerals or oxides in such percentages that dangerous and ugly efflorescence can happen;

• Portland 325 cement, 250 kg per cubic metre of sand;

• hydrated lime in quantity of about 20% of the weight of cement (the lime is necessary to facilitate the mixing, to control and reduce the quantity of surplus water and to lighten the colour of the mortar).

The thickness of the mortar must be at least 2 cm and not more than 6 cm, these measurements plus the thickness of the paving-stones are used determine the height to which the layer of the foundation must be laid. For example, if tiles of variable thickness, from 2 to 5 cm, are used the foundation must be laid 9 cm lower than the height of the finished paving.

Using special ropes the poser determines the inclination (never less than 1%) and the alignments that are repeated, course after course, and must be respected with great care. Then it is necessary to distribute the half-dry mortar in a quantity sufficient to lay a limited number of pieces.

Next, the part of mortar to be laid must be wet with clean water without causing puddles or dripping. It is advisable to spread a light layer of cement dust on the mortar immediately before laying, in order to obtain good adhesion. The same result is also obtained by sprinkling the interior surface of the paving-stones with liquid cement before laying. It is better, however, before the laying phases, to wet the paving-stones thoroughly with clear water, not only to clean the paving-stones from dust and impurities that limit adhesion to the mortar, but also to reduce the absorption of liquids from the mortar, which could make it powdery and effect setting. Also, the washing of the paving-stones dramatically reduces the absorption of possible staining substances that are in the mortar, and reduces the possibility of ugly deposits.

Tiles are then set on the bedding layer and, depending on the configuration and the dimension of the pieces, the mortar is removed or added with a trowel.

The they are softly pressed with a rubber hammer, in such a way that all the lower surface of the paving-stones rests on the mortar, without forming spaces that inhibit setting and affect the resistance of the paving-stones.

The joints between one tile and another must be at least one centimetre for the paving-stones with split sides (and 3 mm for the sawn paving-stones) in order to allow the sealing to function as a welding element. A joint which is too narrow, or no gap, in the long run can compromise the resistance of the sealing thus exposing the edges of the paving-stones to

mechanical and atmospheric agents.
The damage caused by water during very cold seasons can be easily imagined and parts of paving can come away.

The joint itself becomes a decorative factor that can contribute to the general design of the paving.

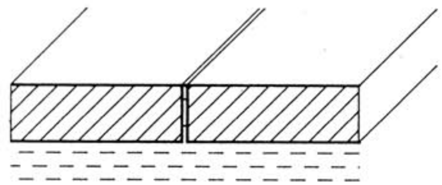
The sealing is done by filling the interstices between every paving-stones with cement "boiacca" obtained by mixing equal quantities of fine sand, cement and water. In practise, two good techniques are used.

• The first consists of squeezing the "boiacca" into the gaps until they brim over, using suitable containers. After some time, when the "boiacca" inside the gaps has begun to set, the excess "boiacca" is removed with a trowel and the surface of the paving-stones is thoroughly cleaned with resistant sponges.
• The second technique is almost the same of the one already described for the sealing of cubes i.e. the surface is completely sprinkled with "boiacca" with big rubber spatulas, taking care that all the gaps are, and remain, full during the necessary resting time, that is until the "boiacca" has achieved the right consistency. With a controlled jet of water and a big rubber spatulas and two operations with sawdust the surface should become completely clean. After completing these operations the surface of the paving-stones must be completely clean, because if spots or cement remain, they can affect the aesthetic result of the entire paving and they cannot be removed easily, or rather, they cannot be removed at all.
• In the last few years machines have begun to be used to do the operations of sealing. These machines are already used for paving of pottery tiles, brick tiles, and so on. This very simple and very light machine consists essentially of small electric motor that runs a spongy rubber belt on rollers. The belt, on contact with the "bioacca", absorbs the "bioacca" completely and releases it into a container of water through which it is cleaned. It is necessary to keep the surface free from anything that prevents perfect drying of the paving; to keep people away, and even more important not let vehicles pass over the paving for at least two days; to protect the finished paving from possible environmental damage (unexpected downpour, vandals, etc.).
In garden tiles are sometimes laid dry on a thick bed of sand. In this case, it is necessary to use tiles of suitable thickness (5/8 cm) and of sufficient size (30-40 cm in width).

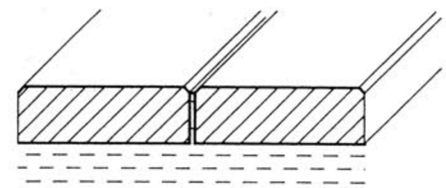
DIAGRAM No. 33

STANDARD TYPES OF JOINTS

INDOOR PAVING WITH TILES

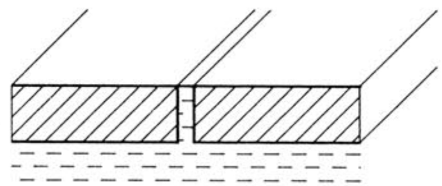


JOINT IN CONTACT
SAWN SIDES WITH 90° EDGES

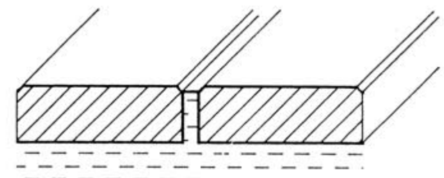


JOINT IN CONTACT
SAWN SIDES WITH CHAMFERED EDGES

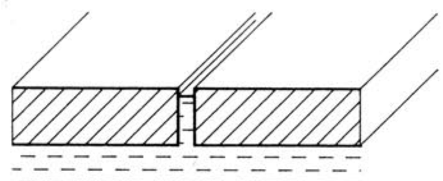
EXTERIOR PAVING WITH TILES



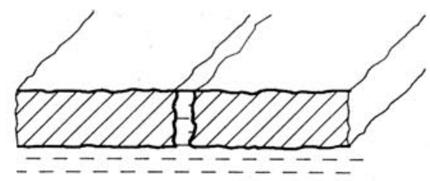
VISIBLE JOINT LEVEL WITH SURFACE
SAWN SIDES WITH 90° EDGES



VISIBLE JOINT INDENTED
SAWN SIDES WITH CHAMFERED EDGES

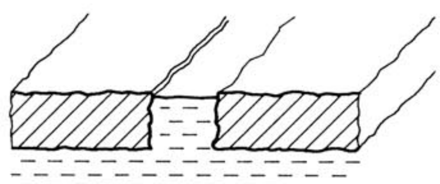


VISIBLE JOINT INDENTED
SAWN SIDES WITH 90° EDGES



VISIBLE JOINT LEVEL WITH SURFACE
SPLIT SIDES

EXTERIOR PAVING WITH SLABS

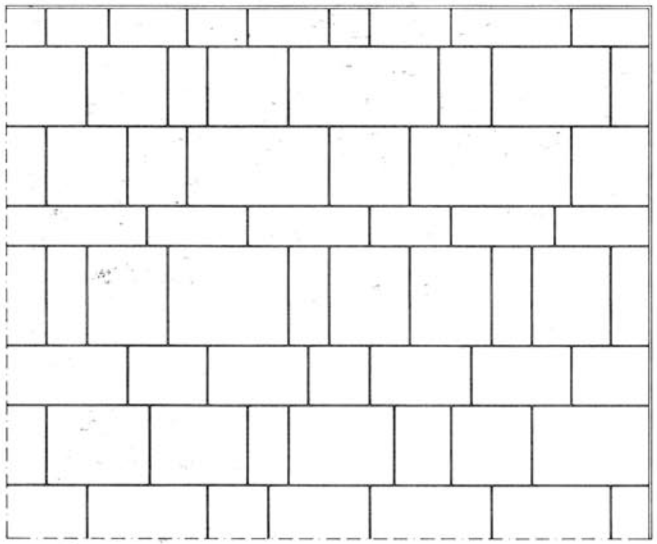


WIDE INDENTED JOINT
SPLIT SIDES

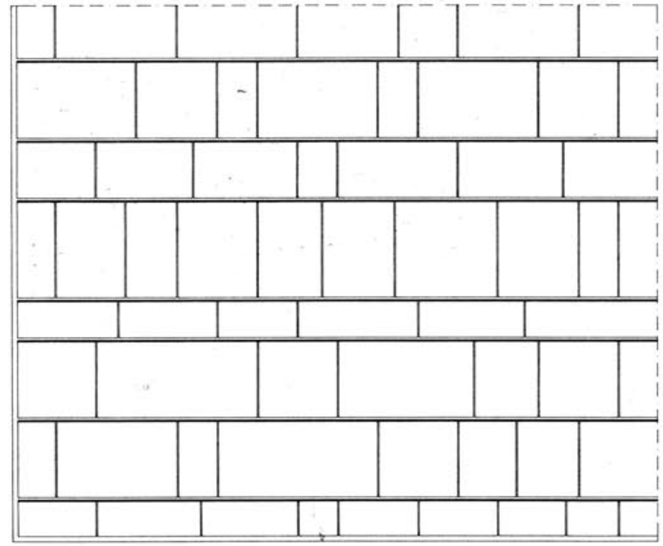
WIDE JOINT OF EARTH (GRASSED)
SPLIT SIDES

DIAGRAM No. 34

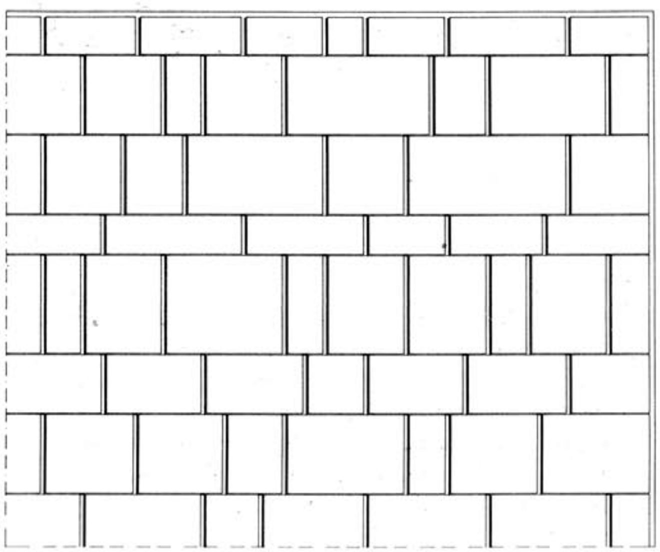
GEOMETRIC PLAN FOR LAYING SHOWING THE JOINTS



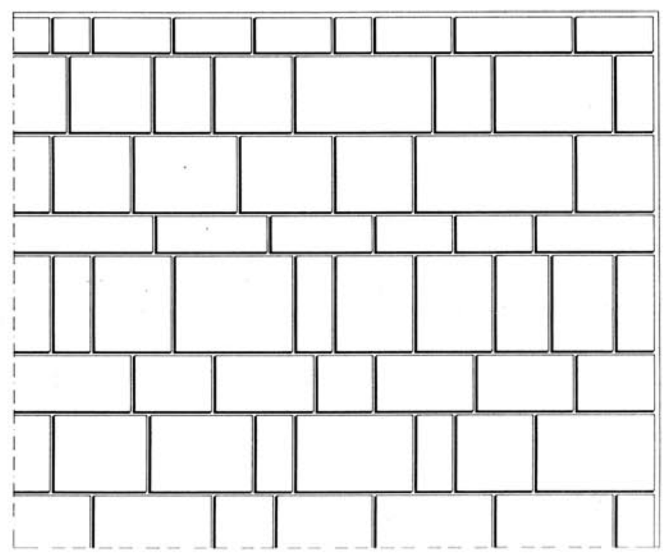
CLOSED LONGITUDINAL JOINTS
CLOSED TRANSVERSE JOINTS



OPEN LONGITUDINAL JOINTS
CLOSED TRANSVERSE JOINTS



CLOSED LONGITUDINAL JOINTS
OPEN TRANSVERSE JOINTS



OPEN LONGITUDINAL JOINTS
OPEN TRANSVERSE JOINTS

Chapter 9

EXTERIOR PAVING AND ACCESSORIES

9.1. LAYING OF COARSE TILES ("SMOLLERI")

In the 20s, 30s coarse tiles or "smolleri" began to be used to pave sloping surfaces in many mountain villages in Trentino, and also in Lombardy and in Veneto. They are little slabs of porphyry, in the past they were very thin, now of variable thickness between 3 and 8 cm, variable length and up to 12 cm in depth, worked with split visible face and head and "planted" sideways or head first, usually in parallel lines. In the 60s the cement of Bergamo was paved mostly with "smolleri" of fixed dimensions and laid with herring-bone design, and still today it is unchanged both in its function of paving surface and in its aesthetic value.

However, paving or surfacing of "smolleri" remains a rather rustic product. It is necessary to evaluate its use with attention, so that these products can find their natural place in the architectural contest.

The "smolleri" for paving are generally laid in builders sand with grain size from 0 to 4 mm; sometimes the sand is dry mixed with cement in quantity of 200 kg per cubic metre.

The dimensions of paving made of "smolleri", plus its bedding layer is about 18-20 cm from the height of the foundation to the finished height.

Having decided the laying planes, the inclination (at least 4%) and determined fixed points of reference, the bedding sand is laid to the most appropriate height. The poser starts the real laying, with a rapid selection of elements by sight, in order that their thickness is such that, brought close together near the "head", they can be laid in regular and potentially parallel lines.

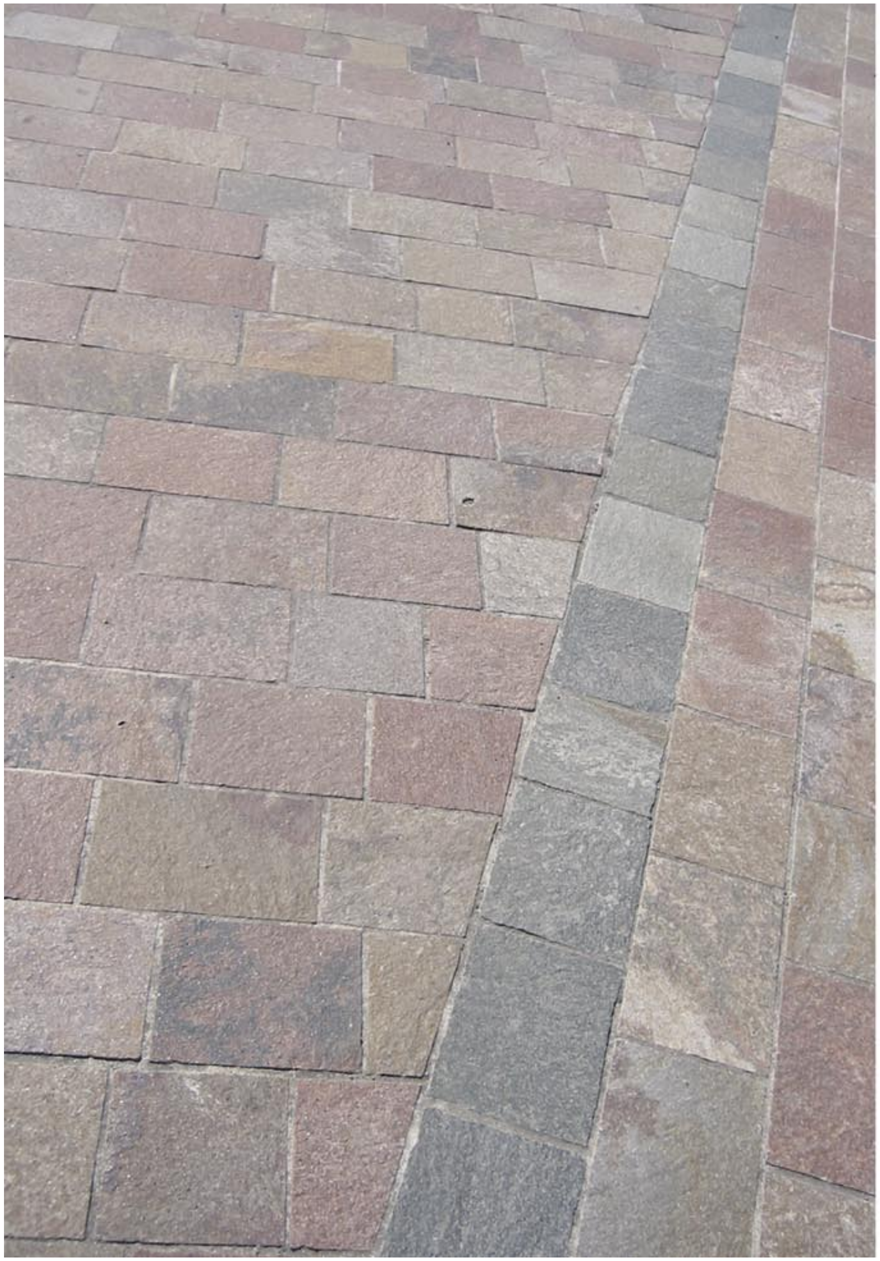
The elements are inserted into their bedding layer with a hammer. Once the laying is finished, the surface is sprinkled with sand until all the possible spaces are filled. The paving is wet thoroughly and then it is compacted and levelled with a machine or by hand. Finally, the surface is sprinkled again with sand for as long as is necessary to fill all the interstices completely.

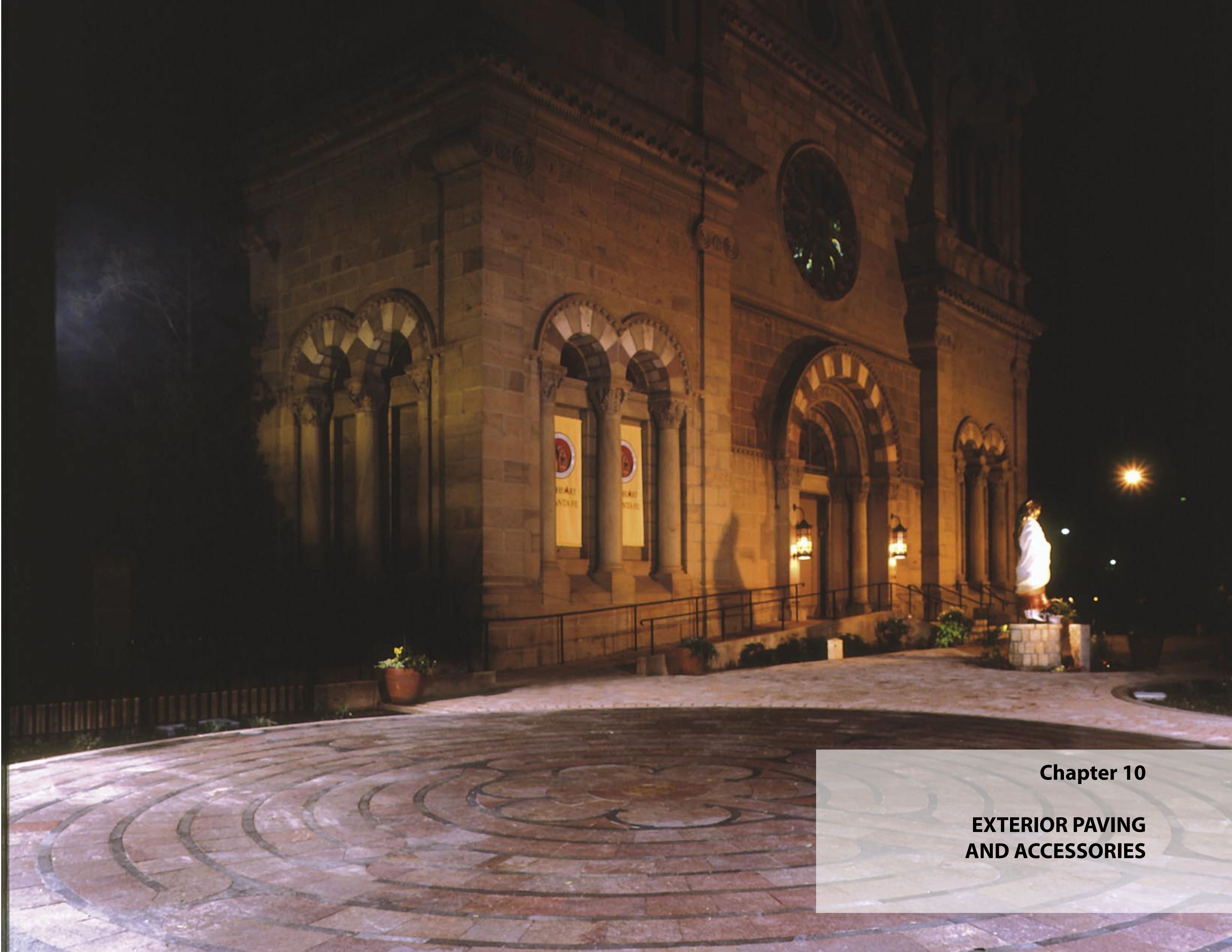
9.2. LAYING OF SMALL BLOCKS (“BINDERI”)

When small blocks (“binderi”) are used to delimit or border an area of paving, and for this reason are placed in straight lines, they will follow the same procedures as laying as kerb stones.

Small blocks (“binderi”) are often used to form channels for collecting rain water at the edges or at the centre of the road; often they are used to outline “lots” produced with other materials. In these cases, just an example of many other possible uses, they are laid in parallel lines and are replaced with the same procedure of tiles, especially if the work is done on a particularly sloping road.

In northern Europe “binderi” blocks are also used to form road paving in built-up areas, because it is a similar product to the one traditionally used there. In this case, they are laid with mortar, or more frequently with sand mixed with cement or just sand.





Chapter 10

EXTERIOR PAVING AND ACCESSORIES

10.1. LAYING OF STEPS AND STAIRS

The use of stone in the formation and dressing of vertical connections has always been more prevalent than any other material over the course of the centuries up until the present.
The reason is that stone materials are essentially durable and attractive, these characteristics are especially true in the case of porphyry.

Both for interiors and exteriors, stairs and steps are without doubt an interesting architectonic element that can have great expressive value so it is better to choose the type of product, the working and the finish most appropriate to the aesthetic and functional importance of the feature i.e. the steps or stairs.

Economising on the aesthetic and functional quality of steps or stairs is a mistake, because they are one of the most difficult architectonic elements to restructure or "re-arrange". They have to be thought of and designed as permanent structures, as in fact they are. So it is advisable to choose products that maintain a high aesthetic and functional standard for many years.

To produce porphyry stairs or steps with good quality products, and with more contained costs, since the raw material is readily available, the dimensions of its components should not be different from the ones now standardised due to common usage end include 90-120 cm x 28-33 cm x 3-4-5 cm in thickness. The design of steps in the shape of a fan, or other designs, means a great increase in cost. Almost always the dressing of steps is done after the building of the structure and therefore it will be adapted to the particular situation.
This can only happen with careful design and

attention to detail that starts with the form of the structure.

Most of the structures of modern stairs are made of reinforced concrete. Almost always there are imprecisions in mouldings, or many variations among components that should be the same, so that it is difficult to adapt them to the porphyry during the laying.

Obviously this causes an increase in cost. The reinforced concrete mouldings should be made as designed and have the necessary and sufficient tolerances of bedding (8 cm for a tread of 3-4 cm thick and 6 cm for riser including the dressing).

The price of the porphyry dressing for steps must be calculated on the definitive plan resulting from an accurate study of the structure, and not on the basis of a rough drawing in an unsuitable scale. A copy of the definitive plan and of the records of manufacture derived from it, must always be at the disposal of the supplier (quarry or workshop), the workman on the building site and client, in order to proceed with accurate and common data in solving possible problems or in controlling products and laying operations.

All the pieces that form the dressing of the steps must be marked with a number and/or a code shown on the executive plan. It is obvious that if at least a part of the steps is formed with the same elements, the work, the selection of pieces and the laying are easier and therefore less expensive. It is also true that the design possibilities for vertical connections, i.e. for the formation of steps, are numerous. Here we will illustrate the most commonly used and the ones which may be suitable for other projects. The most common solution, generally for buildings, is flights which are called "straight", where the steps have only a purely functional role.

The design of two flights of steps with intermediary landing and arrival level area is the most cumbersome, but it is also the one that is most easy to build, both for the structures and the dressing. When the intermediary level space is divided by a step it is better if its dimensions are standardised with the others.

On the other hand, when the intermediary level area is occupied by four or five steps in the shape of a "fan", it must be born in mind that:

• The connections are always more inconvenient, if not dangerous;

• The steps in the shape of a fan cost as much as an entire straight flight or even more;

• The installation is difficult because the mouldings are never perfect;

• The laying is more difficult and almost always requires adaptations and cutting during work;

• The search for pieces (above all for flights of several floors) and the organisation of work are more complicated, and therefore both time and costs increase.

Curved flights are almost always a choice that favours the aesthetic and functional aspects rather than the economic.

They can have:

• Circular plan in which steps are sectors of equal circles whose edges converge on the centre.

• Elliptical plan, in which the edges of the step converge upon two points, usually outside the flight.

In these cases the shape of the steps laid in relation to the formation of the dressing is rather complex, and it is often necessary to prepare stiff outlines ("dime") to be tried on the spot that are models or patterns for the production of the pieces in the workshops.

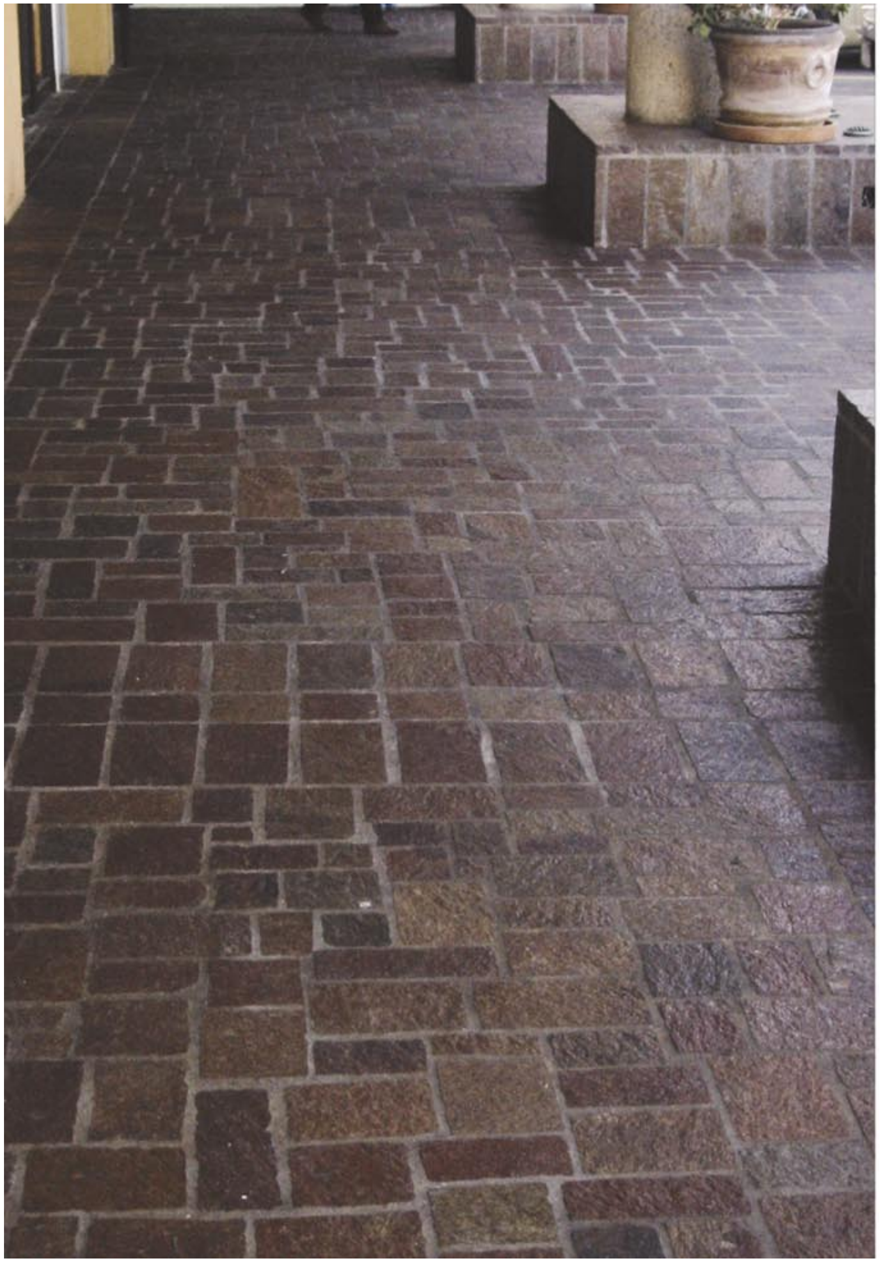
It is important to remember that a parapet close along the edge of the steps makes the laying easier and reduces costs, because the sort head ("teste") of the steps does not need to be finished. But an open parapet needs to be finished and laid in a perfect way, because every detail is visible and so too every little mistake in installation.

10.2. LAYING OF SKIRTING AND WAINSCOTING PANELS

Wainscoting panels and skirting with natural surface must be laid with cement mortar to compensate for the variable thickness. This kind of wainscoting is generally used for exteriors. The laying techniques for products with constant thickness (sawn surface, flame textured, polished, etc.) are the same as for similar stone products.

10.3. LAYING OF DOOR SILLS, LEDGES AND BORDERS

These may be either natural surface of worked surface. The products are laid on a semi-dry cement mortar bed suitably sprinkled with cement in order to encourage greater adhesion between stone and binder.



Chapter 11

DESIGN PROJECTS

DESIGN

The conception and the design of the pieces are the basis for any project in stone material. There is a large bibliography dealing with the installation of street furniture in general and dressings in particular, so it is advisable to refer to it for questions connected with the various theories of design. What we will provide here is a limited series of geometric patterns and free compositions that illustrate the infinite possibilities offered by this material.

We would like to break the porphyry –cube binomial and in paticular the system of laying overlapping arcs of cubes, in order to widen the perspectives and the potentialities of the product itself.

As one can see from the projects produced in northern Europe, where the technicians are more advanced than we are in the field of street furniture, the material can be used in many ways because it fits in well with the characteristics and the history of the place. It is important to progress from the schemes consolidated by tradition and to confront the new and complex problems of modern life, and also to adapt to the more advanced technologies offered by the porphyry industry. Today, in fact, all the types of working used for marbles and granites have been added to the classic systems of stone production based on the simple "breaking" of stones.

The designer must know that there are no limits (except economic limits) to the size and shapes of pieces and therefore there are no limits on their freedom to compose. Here is a list of the parameters that can be important in choosing a design. Some of them may be wrongly considered to be of secondary importance when in fact they influence the result in a relevant way:

- Pattern;
- Type, size, etc. of pieces;
- Colour and finishing.

PATTERN

In the other chapters the possibilities offered by the material have already been mentioned. In particular please refer to the diagrams, tables and photographs which serve to illustrate the potential offered by the material. The huge variety offered by using porphyry, from the smallest unit (a cube of 4 cm) to giant elements of several metres in area, permits a wide freedom of composition that can go from a small feature to large monumental works.

When a work of stone material has to be designed, some considerations must be taken into account about the distance between the elements.

The first consideration is if the work, paving or dressing, is inside or outside; the second is about the use for which it is designed; in the case of porphyry a third factor is also important, that is the kind of working required for the sides and edges, whether they are split of sawn.

The jointing will be different for the two cases. In the case of split sides, the edges will be irregular and imprecise so that the spaces between the elements can be more than one centimetre, also thus increasing the more "rustic" effect and cover any laying errors.

When a product with sawn sides is used, the piece so obtained will have tolerances of few millimetres and so the laying will require proportional attention.

The sawn sides can have sharp corners or have a bevel of 45° with variable width shich will also contribute to the general design.

PIECES

Porphyry, the only case out of all stone materials, can be used in various pieces that go from the smallest cube (side of 4-6 cm) to the larger cube (14-18 cm) that produces very expressive results. The same thing is true for tiles that go from a minimum size of 10 x 10 cm to a series of sizes of 60 x 60 cm or 70 x 70 cm, up to sizes that are more than one metre. It must be said that the bigger the size of the element, the larger the thickness.

When we say pieces, we mean both the choice offered by the standard material and the one that can be produced to order to a specific design. In this case the cost of the work will be calculated for each order as it is necessary to calculate the cost of production and the difficulties encountered due to the design.

COLOUR AND FINISHING

Porphyry has an extremely diversified chromatic range depending on the place where it is quarried, it goes from the classic grey- pale blue to the rust- red, and a particular range of dark reds and violets.

Therefore, by utilising just porphyry pieces compositions can be obtained with very different colours. To highlight some parts of a design, porphyry combines well with most other stone materials. However, it must be remembered that the wear and degradation characteristics are not the same for all materials and the hardness of porphyry is considerable.

Here we will not examine the aesthetic values and the composition potential offered by the material because it is a subject which is too complex to analyse. The design solutions must be discovered for every project, depending on the surroundings, landscape and architectonic characteristics of the "site".

In the following pages there is a series of laying designs that illustrate the extensive possibilities of composition for porphyry products.

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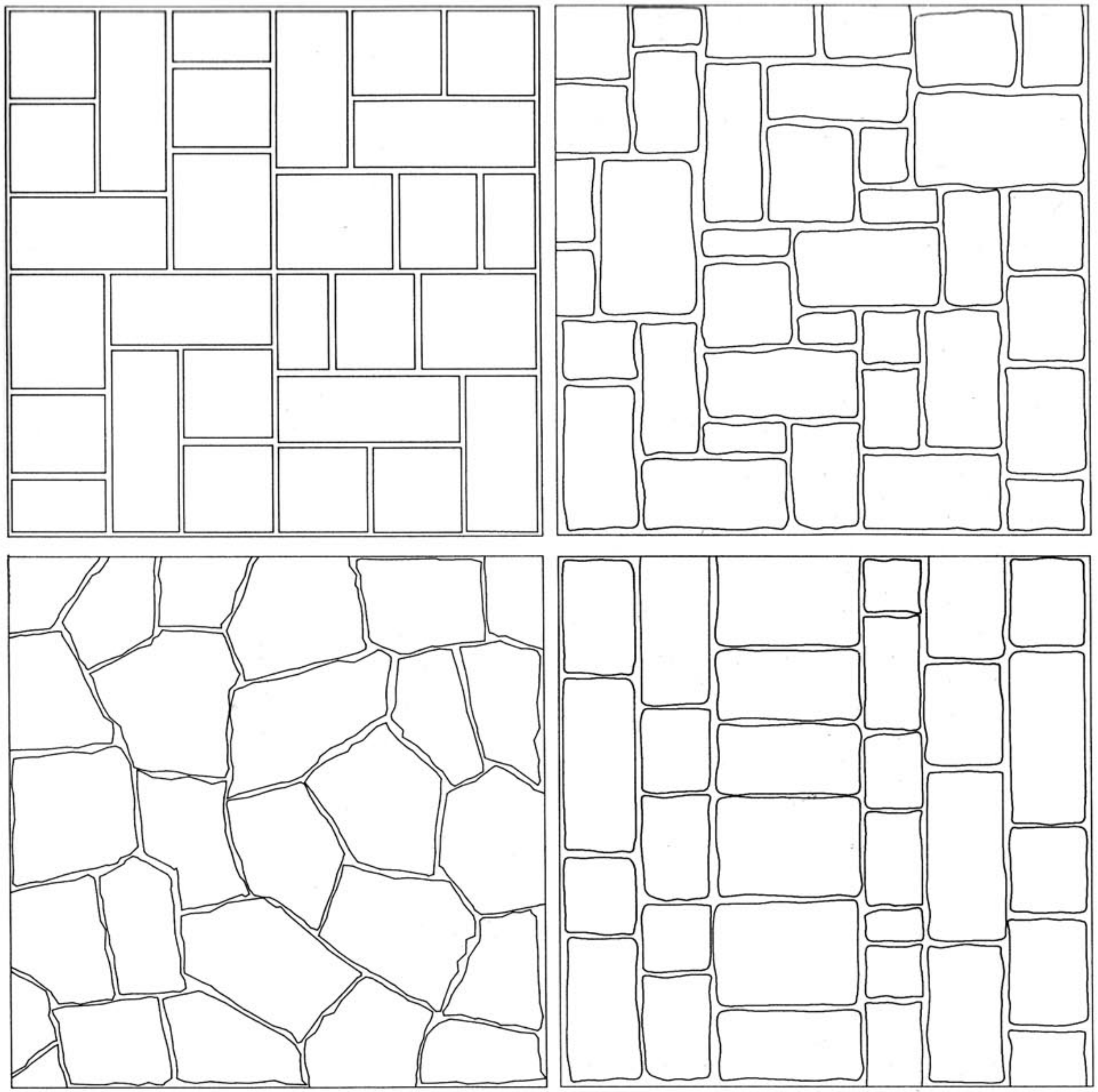

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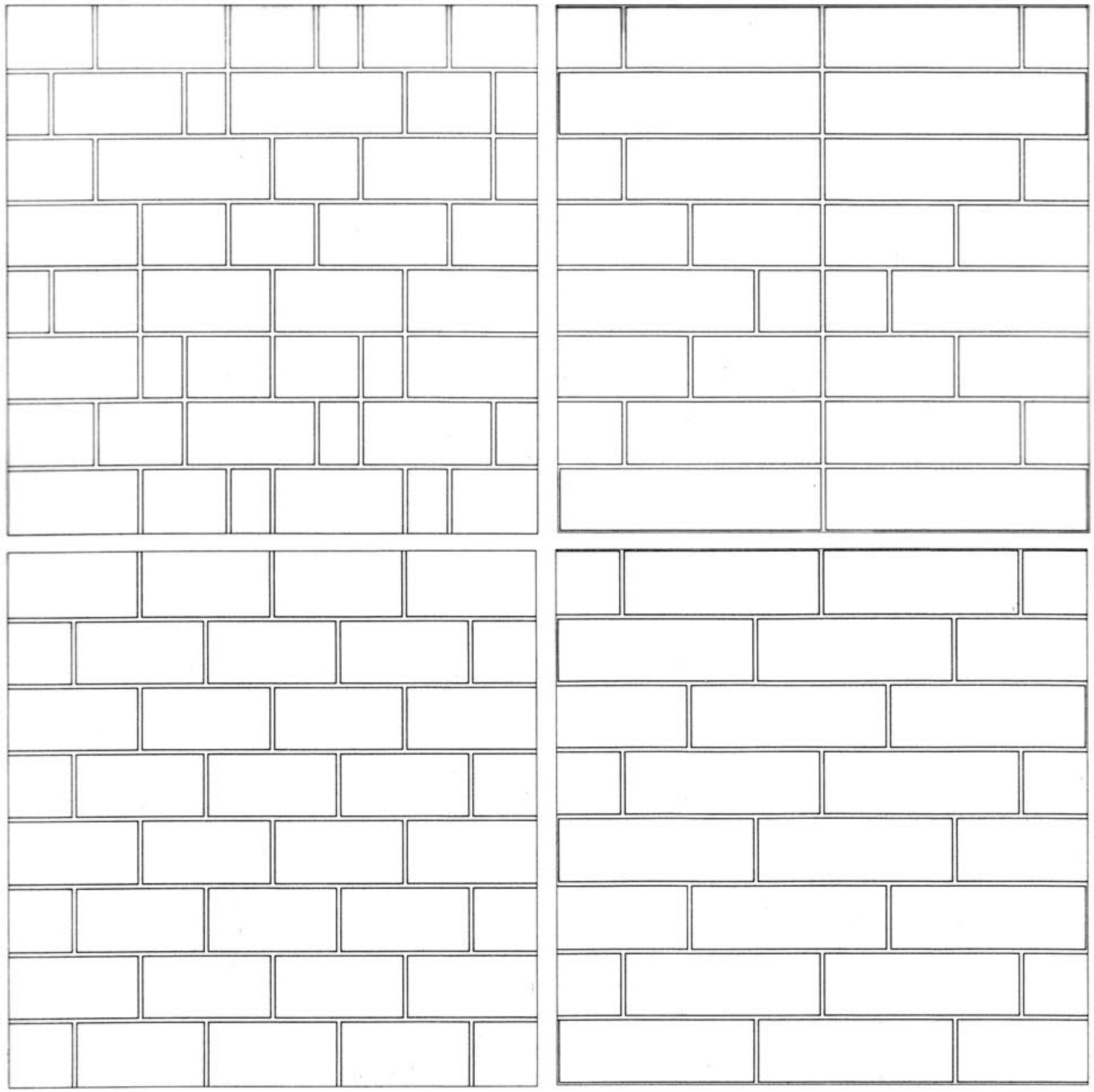

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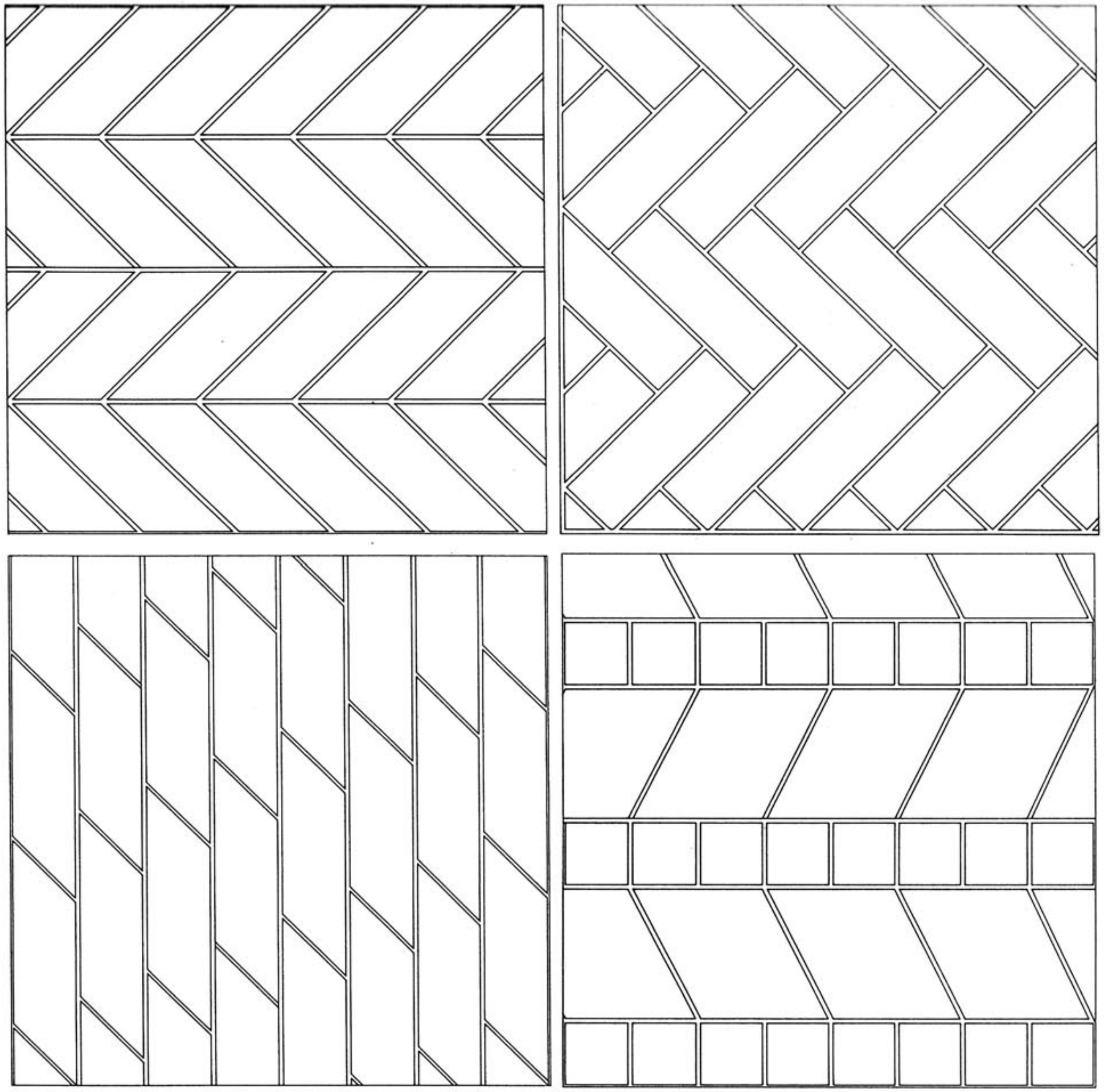

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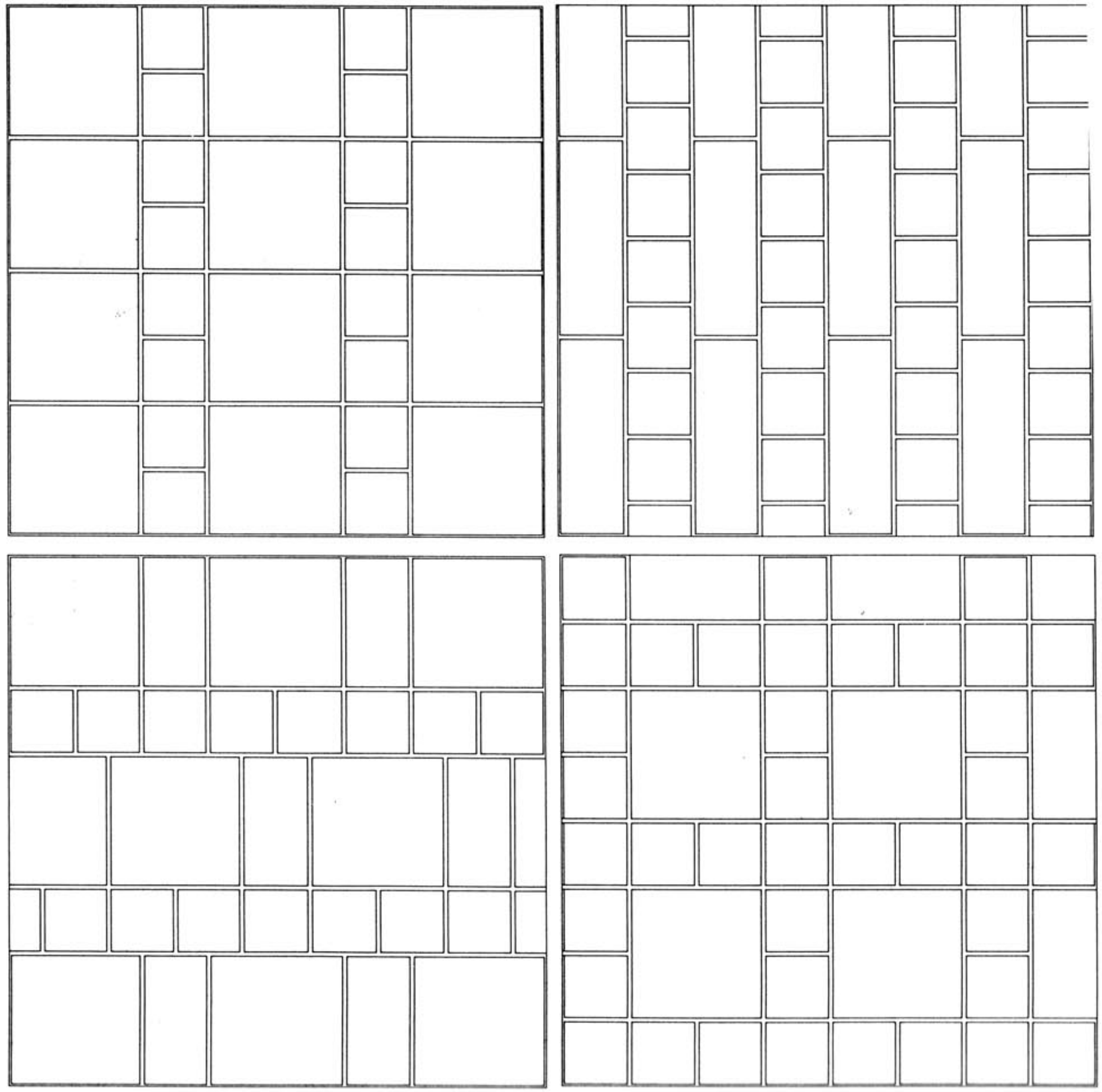

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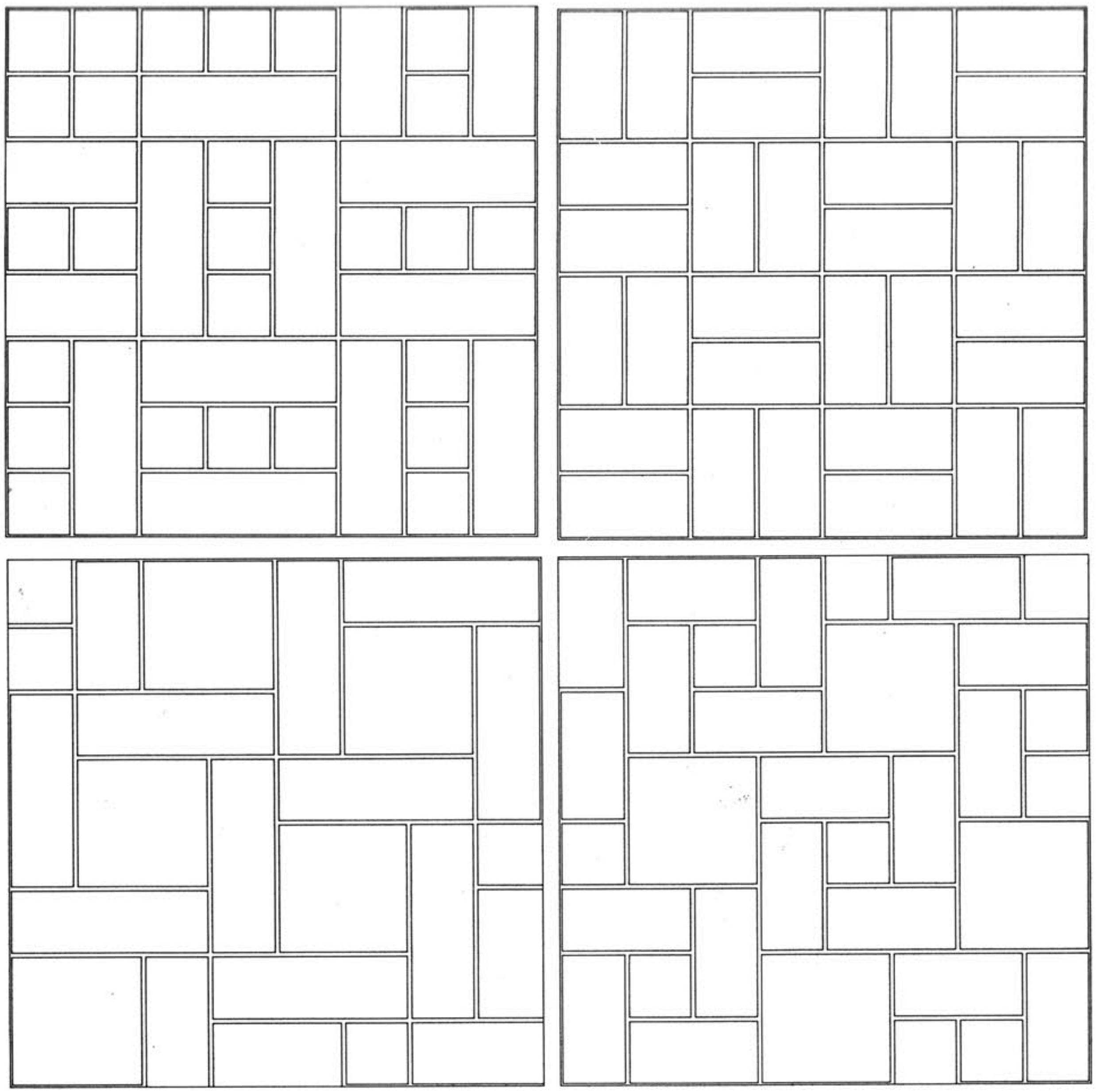

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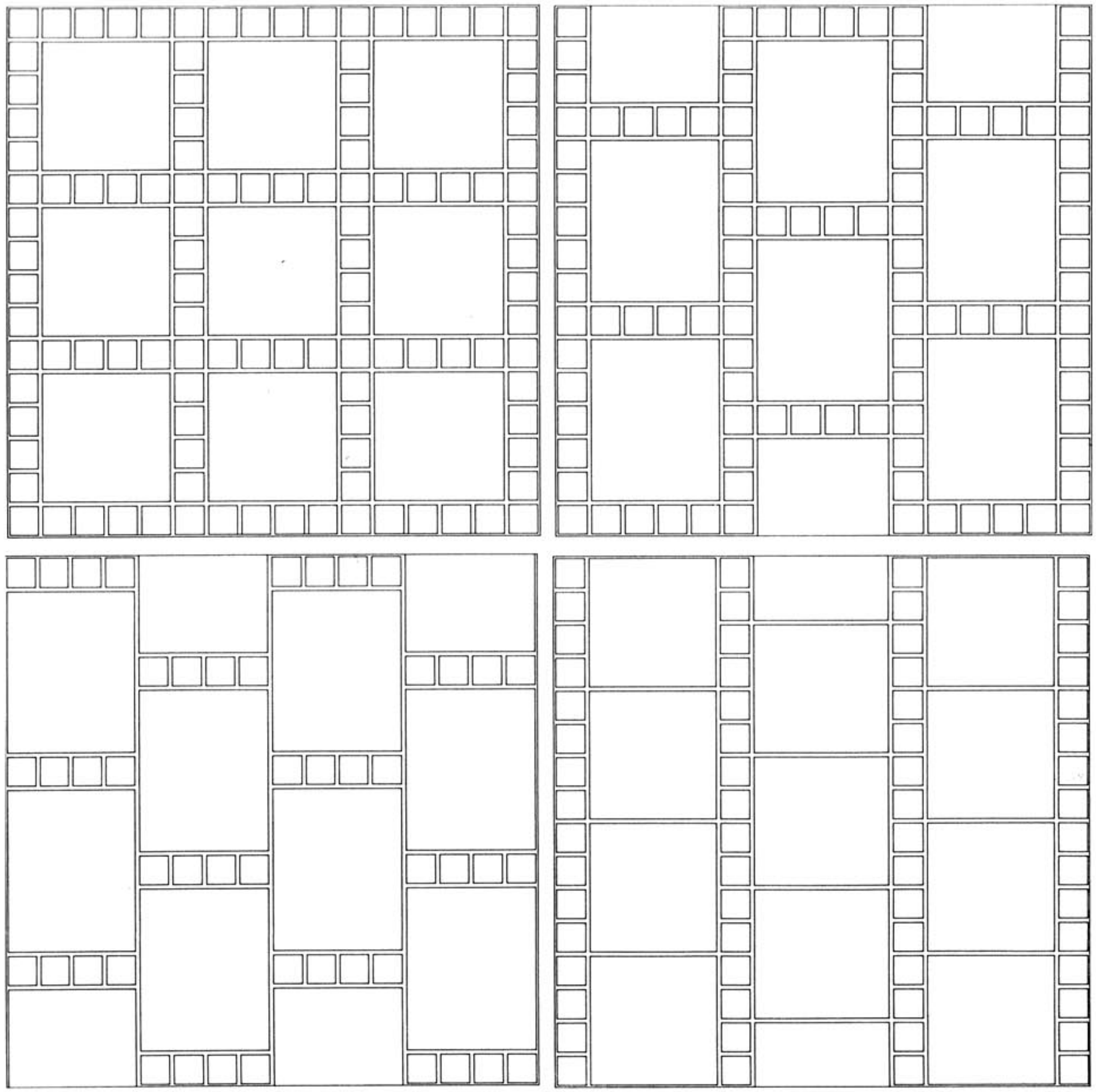

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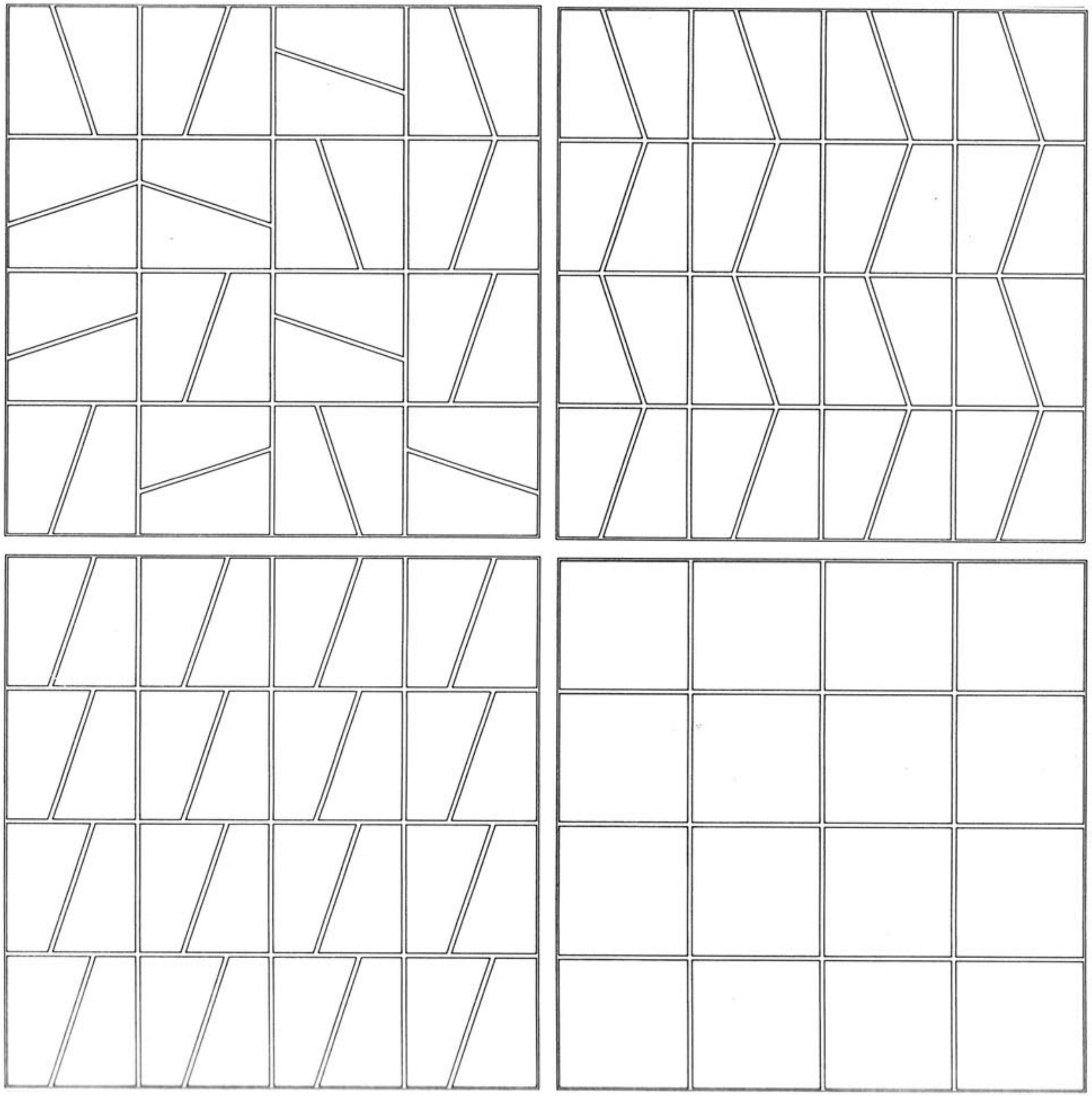

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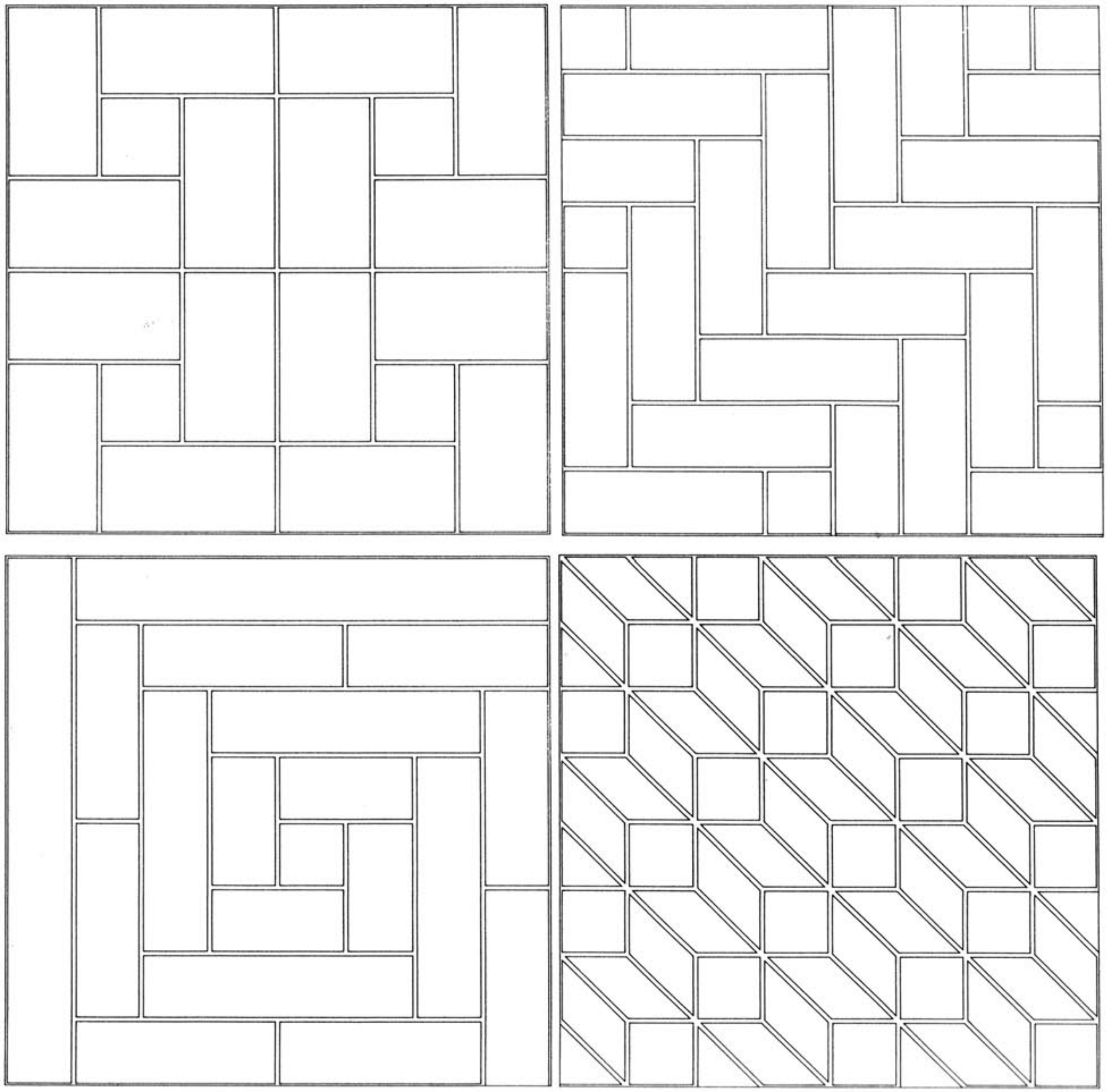

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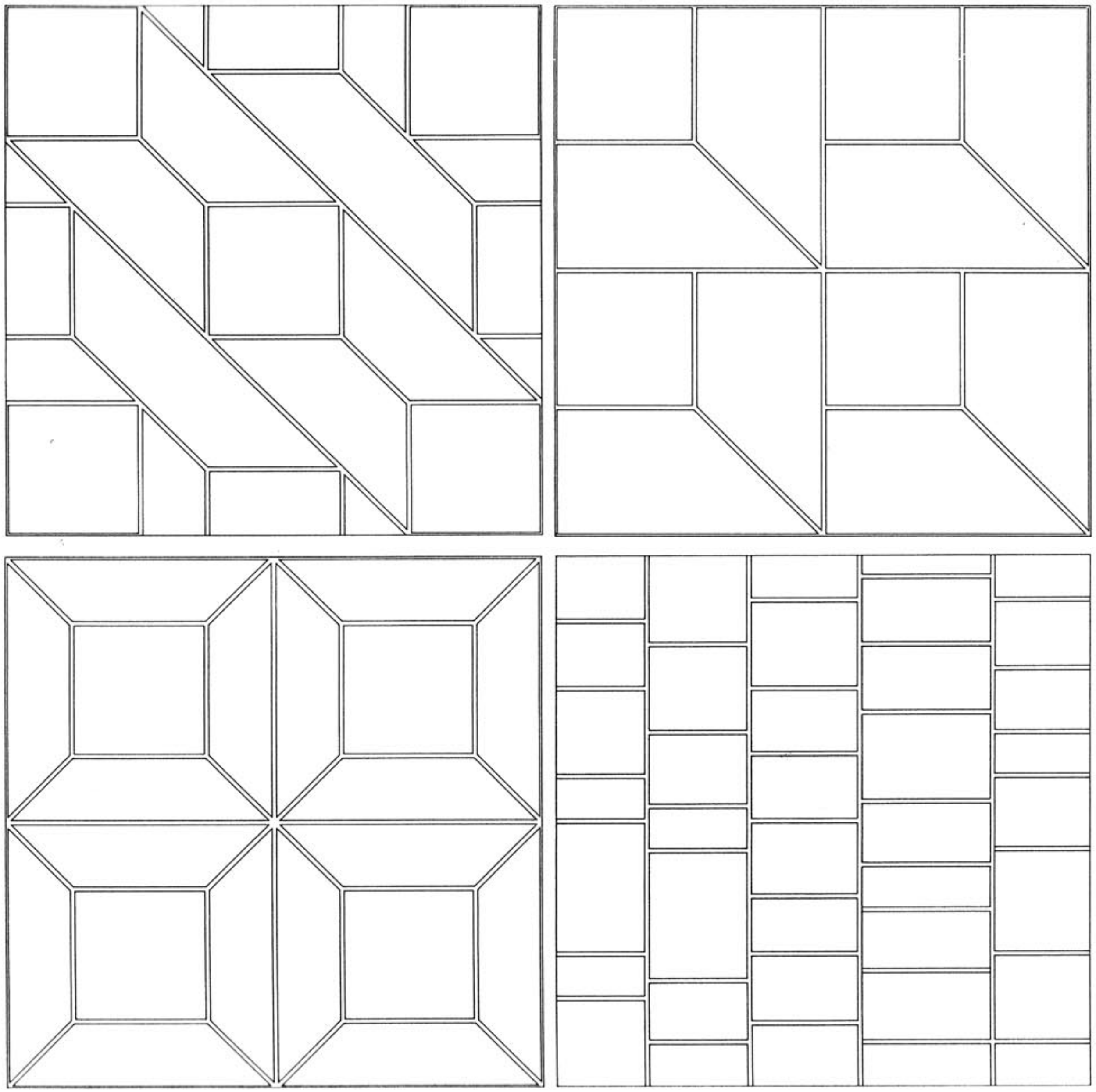

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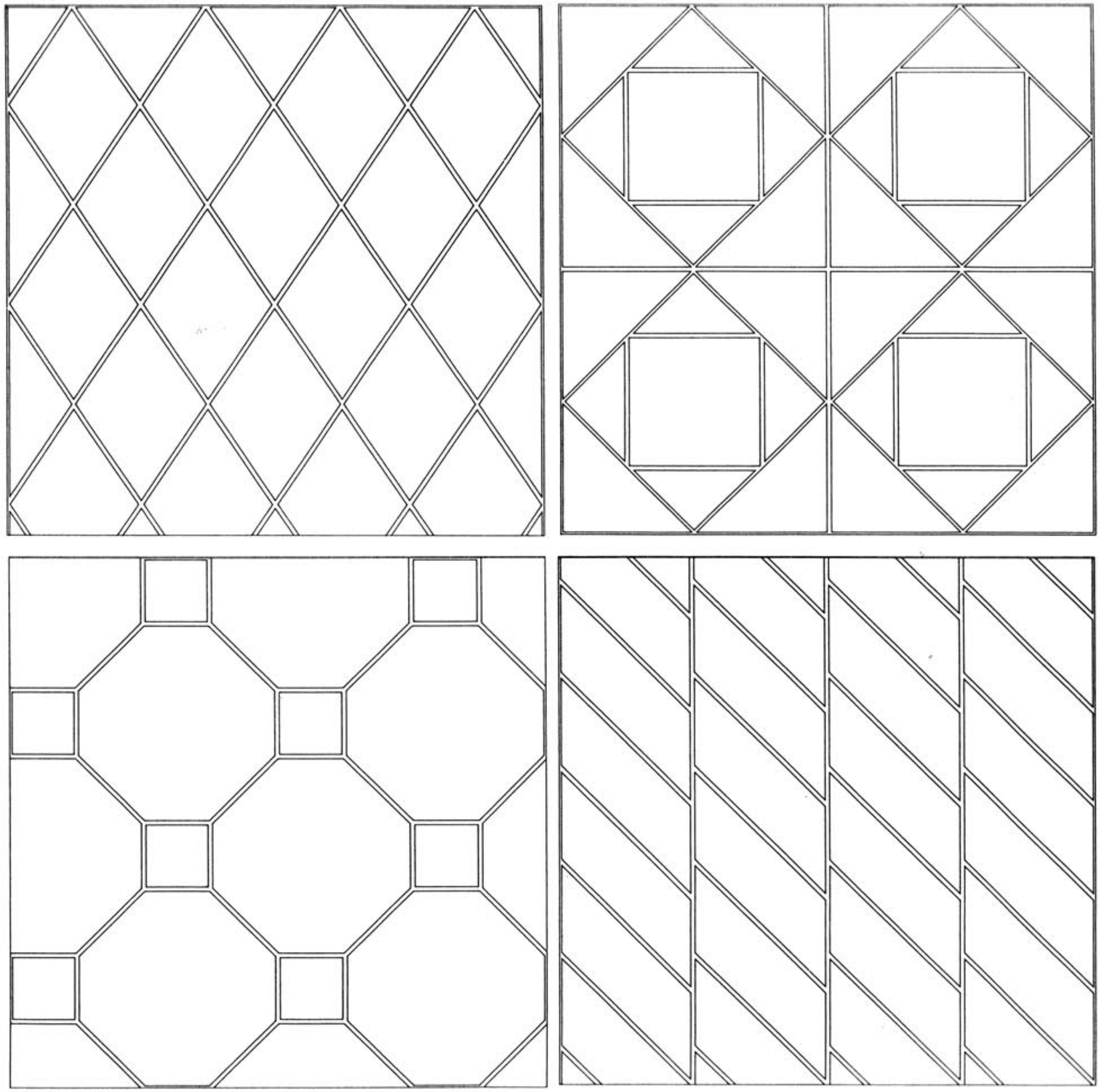

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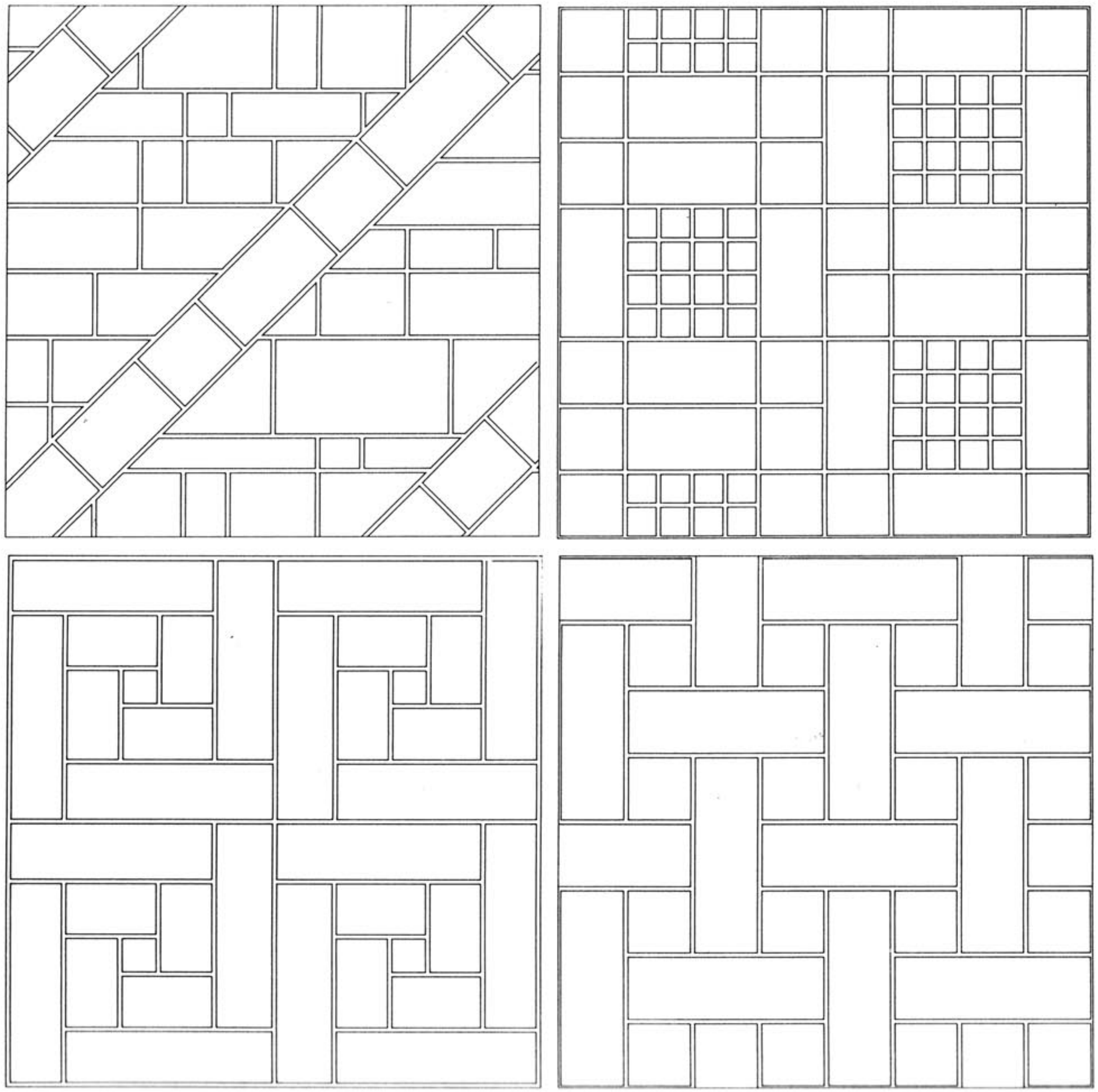

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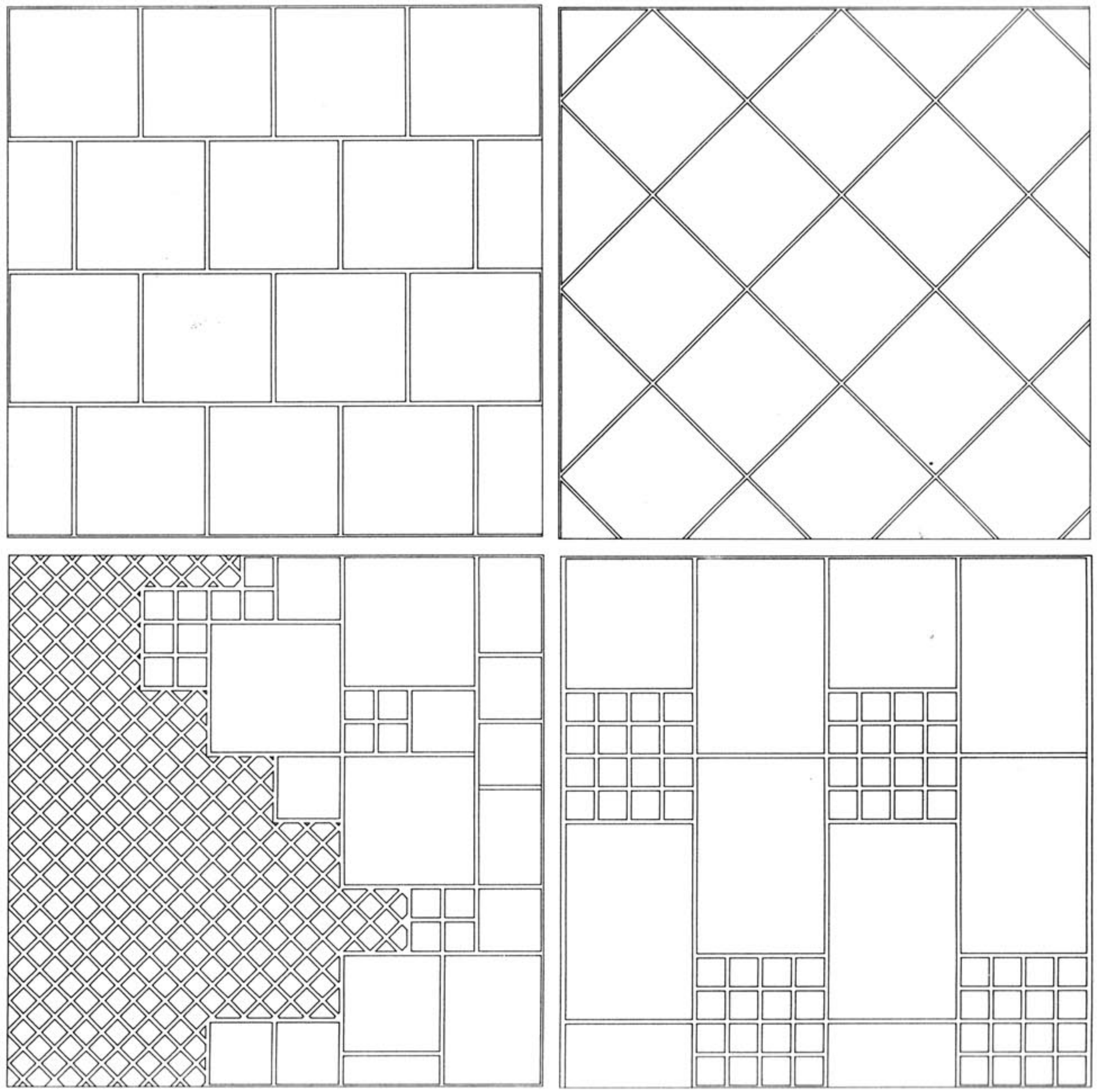

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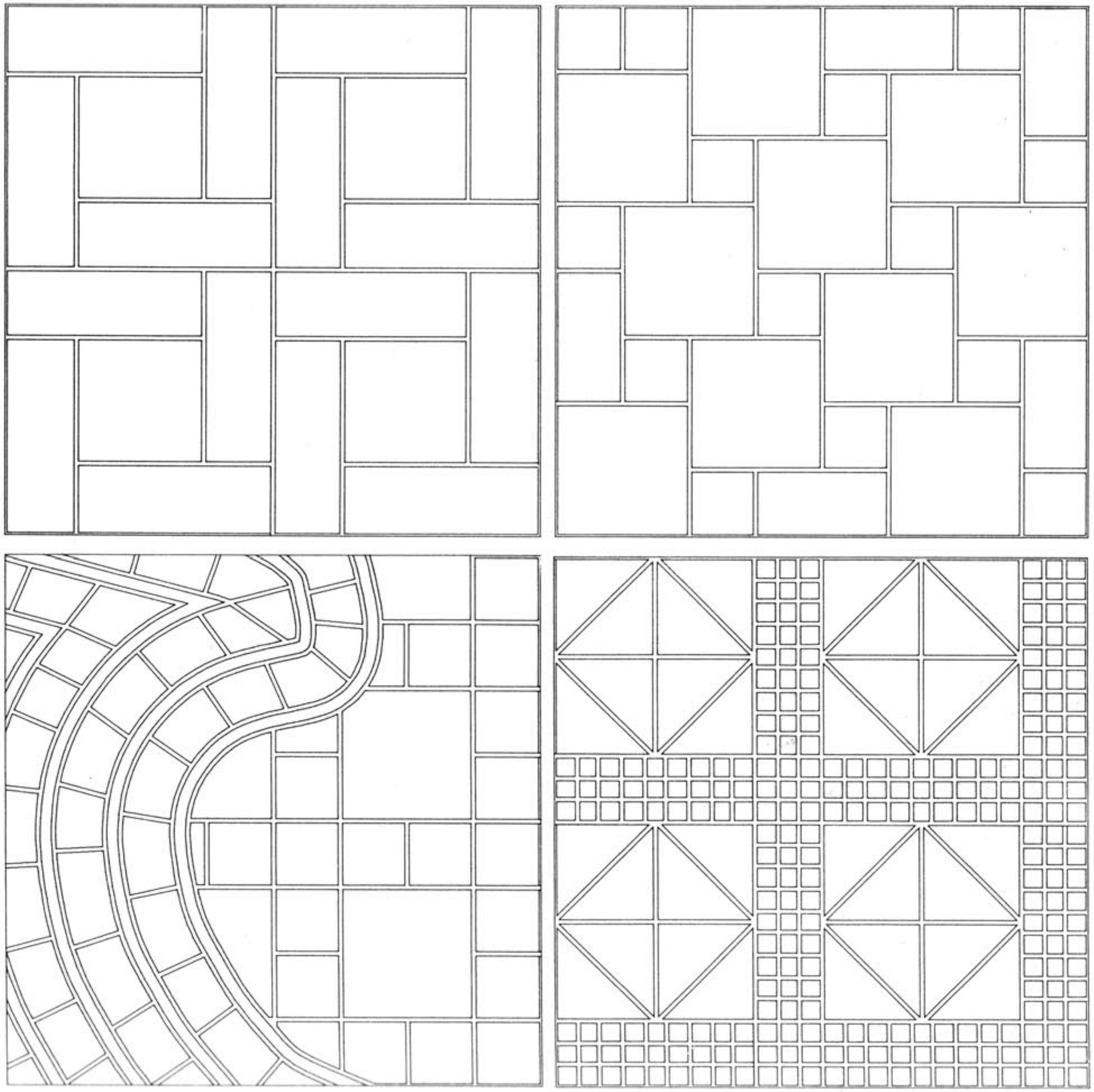

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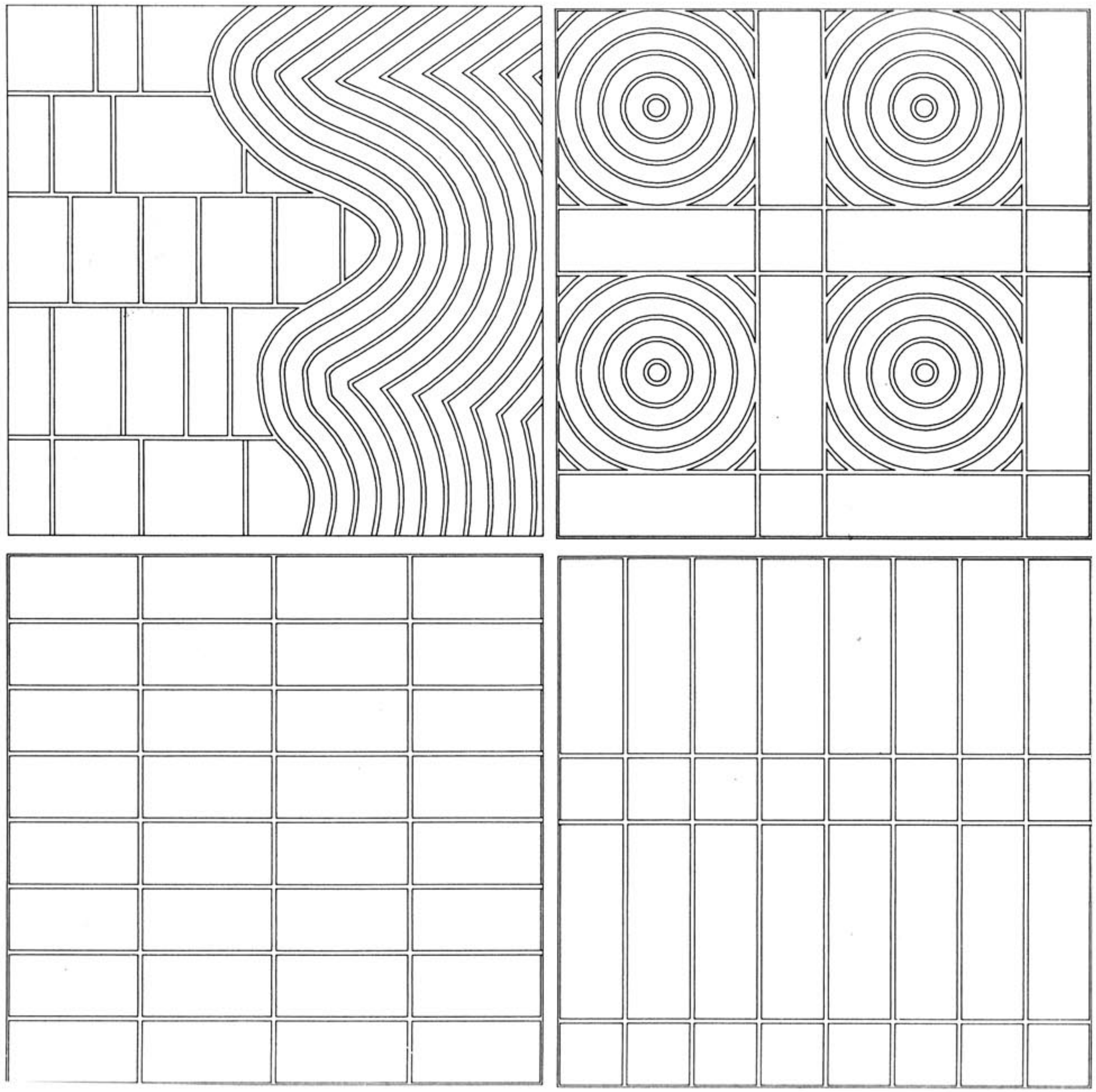
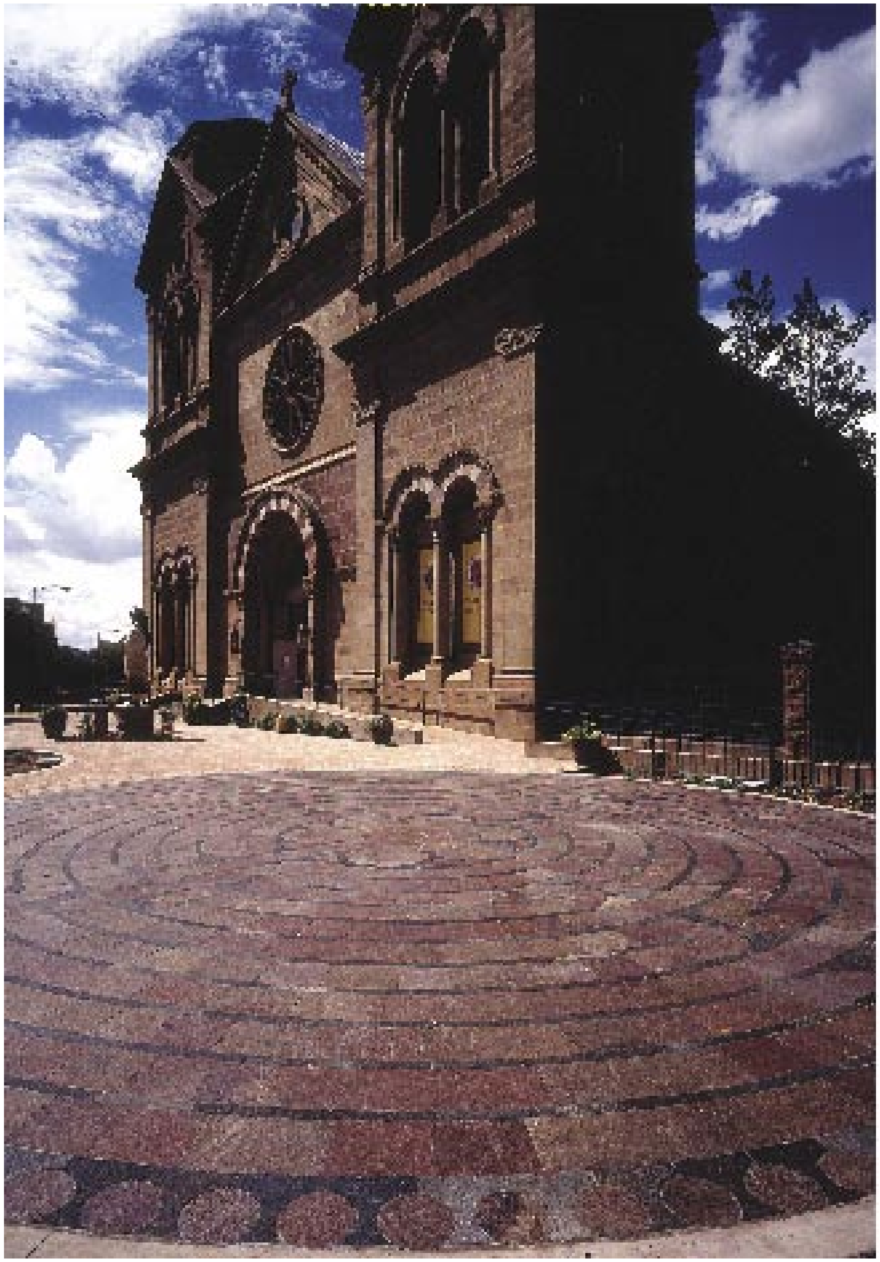
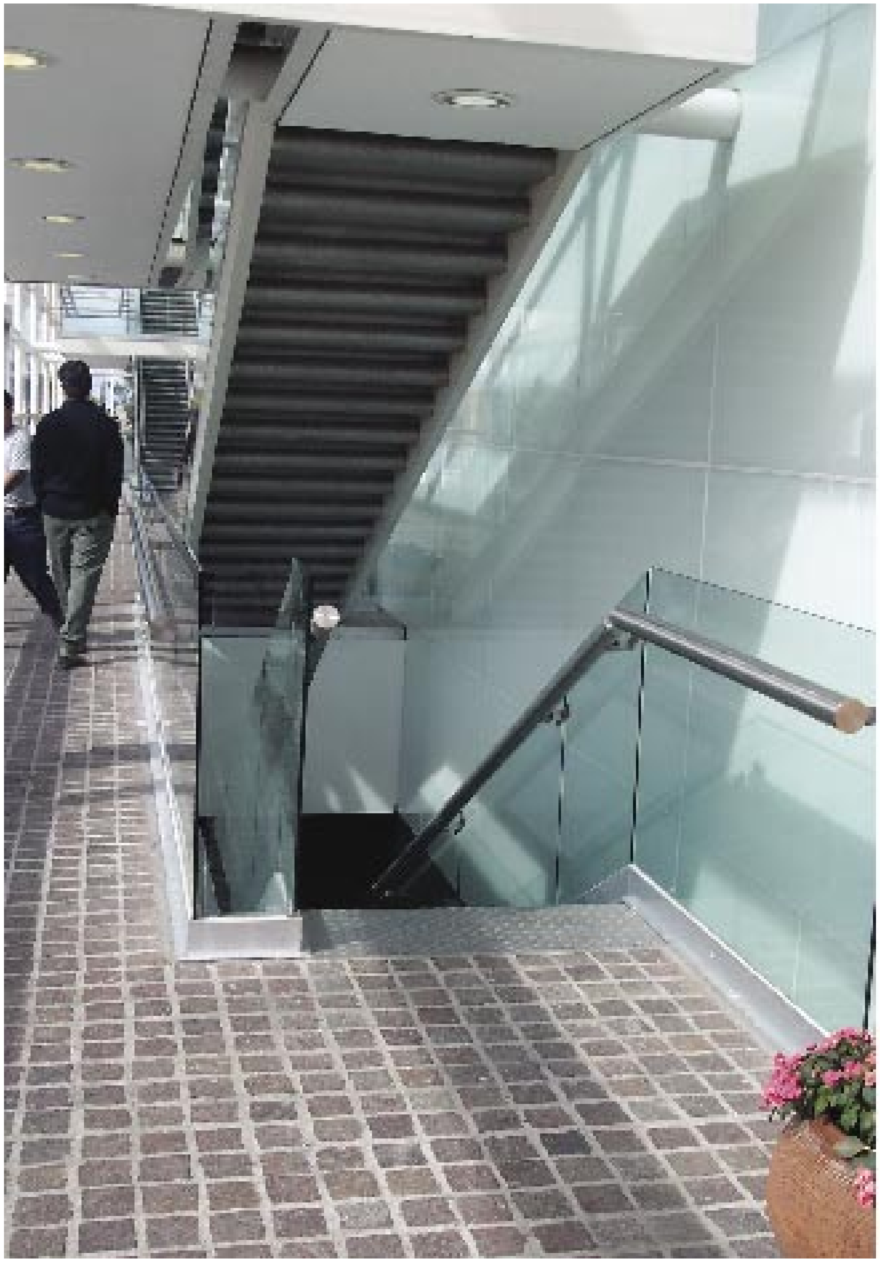




Maccaferri Office

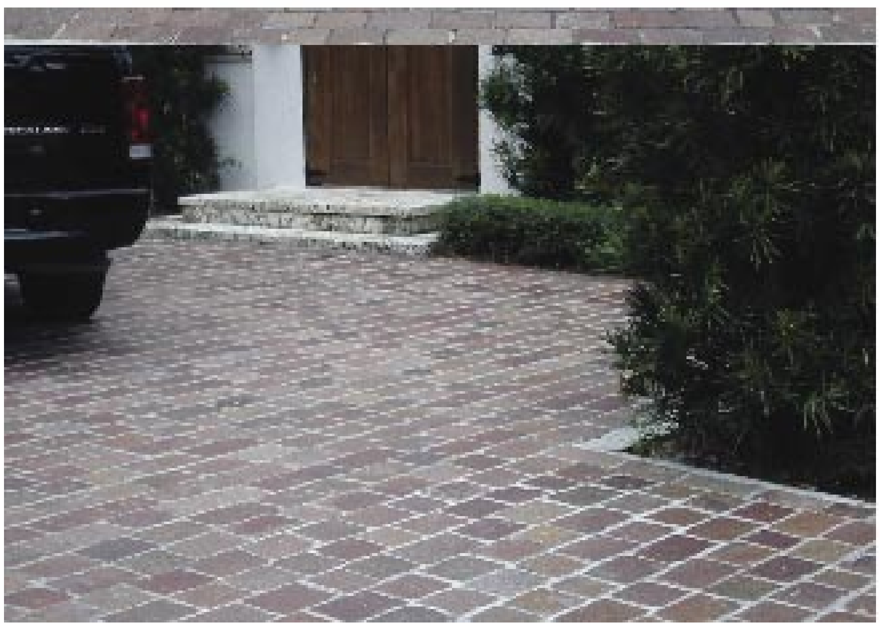
Liverpool, Qro.



La Negreta, Qro.

Toledo road

House in Miami



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