ORNAMENTAL STONES network

EUROPEAN COMMISSION
Competitive and Sustainable Growth Programme

**TOOLS AND EQUIPMENT SECTOR**

# Machines and Tools for Stone Quarrying and Processing

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# Preface

It is with much pleasure and satisfaction that I introduce the work performed in the last months by the Working Group of the Tools and Equipment Sector to prepare this Edition. The task to provide an objective and comprehensive overview of the current situation allowed me to visit and talk with large manufacturers as well as several small and medium sized enterprises both at their companies and within Stone Fairs. During these visits, I was able to confirm the European leadership but at the same time I sensed their concern about the increasing competition from manufacturers in low labour cost countries. In this framework the objective of this Edition is twofold:

- to provide machine users with an overview of what is available in the market and the relative range of performance in order to objectively identify, which machine is fitting their needs;
- to highlight the superiority of European manufacturers when compared to non-European competitors, stressing their worldwide leadership.

I hope that the quarries and stone workshops will find this Edition a valid tool as well as machine manufacturers a stimulus to innovation in order to improve the current situation in the tools and equipment sector.

I take this opportunity to thank again the Members of the Tools and Equipment Sector, who actively provided their contributions and a special acknowledgement to Mr. Adobati, who supported us in the difficult task to prepare a clear and detailed presentation of the tools used in the stone sector.

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# 1

# Sector Overview

STEFANO CAROSIO, SARA PARODI

## 1.1. INTRODUCTION TO THE TOOLS AND EQUIPMENT SECTOR

The Tools and Equipment Sector includes all the machines and devices used to extract stone blocks from earth and further work them by cutting and processing, before their final use in various building activities either structurally or for decorative purposes. With a world market estimated in 1,8 billions of Euro, the sector is dominated by small and medium size enterprises (SMEs), whose share represent 70% of the world market.

Although the European leadership of the sector, no major innovations have been recently introduced. This has been reflected in the reduction of the European exports, up to 30 % for Italy in 1998, caused by the sharp growth of the production in competitor countries, such as South-east Asia. The situation is not critical, due to the prospects of growth of the stone sector and of the investment availability (most of the world machinery park has already completed its ten years depreciation cycle). However, the sector representatives, mainly SMEs, are facing big obstacles in reaching the critical mass needed to introduce novel technologies and concepts within their production, “conditio sine qua non” to maintain a world-wide leading position.

The need for innovation in stone production was gathered by the EUROTHEN Network supported by the European Commission with the aim of creating a technological forum for the presentation and exchange of new research ideas and achievements in the extractive industry. Further initiatives have been recently launched, such as the HARSH ENVIRONMENT INITIATIVE of the European Space Agency, with the objective of determining to what degree technologies developed for space can be applied to overcome the economic and safety obstacles that the extractive industry confronts. Current researches aim at applying diamond tools for polishing, shape memory alloys for quarrying, ultra high pressure water jet for slate splitting, tele-robotics for underground excavation with the overall goals of increasing productivity and reduce the amount of material discarded, while improving working conditions for the operators.

In this framework, the objective of the OSNET Tool and Equipment sector is to build on previous experience and support the industry in implementing novel concepts and solutions to their production in order to maintain the world-wide leadership of Europe.

# 2

# Quarrying Equipment

GIANNI RIPAMONTI, STEFANO CAROSIO, SARA PARODI, DONATO ZANGANI, PAOLA POZZOLINI, FEDERICO BENETTI, FLAVIO LANATI

## 2.1. QUARRYING METHODOLOGY

The main purpose of the productive process in a stone quarry is the extraction of commercial blocks. Excavating a quarry entails a set of sequential operations, each of them requiring one or more specific kinds of equipment or machinery. Generally a quarry is worked from the top downwards, creating one or more terraces and involves the following operations:

- Primary cut: diamond wire cutters, chain cutters, drilling plus explosives and flame jet can be used, depending on the materials;
- Tip-over: splitting bags and hydraulic jacks can be used;
- Secondary cut or block cutting: diamond wire cutters, diamond belt cutting machines, chemical demolition agents, drilling plus explosives or water jet can be used.

Underground quarrying is diffusing because of its low environmental impact, although limited to some materials. The selection of the different equipment depends on the material, the environmental constraints and labour cost. In the following paragraphs we have considered marble and granite that represent soft and hard materials respectively. An overview of the machines available for different operations is reported in Annex 1.

## 2.2. DIAMOND WIRE CUTTERS

### *2.2.1. Description*

This machine consists of a motor/tow flywheel unit composed of an electric engine joined to an aluminium alloy flywheel mounted on a wheeled frame that allows it to move on tracks. The cutting tool is the diamond wire (see chapter 4.2). It is inserted into the rock formation through a set of perforations, it is closed into a loop and made to run. The flywheel's movement drives the wire which, kept taut against the rock mass, is able to cut it by gradually abrading it. The ability to rotate the motor unit makes it possible to make vertical, horizontal and oblique cuts at any angle. There is an electronic device that automatically controls the wire tension and measures how much power the main motor absorbs, trying to keep it as constant as possible. The necessary rushes of tension cause overstresses to the wire and it is the cause of the wear.

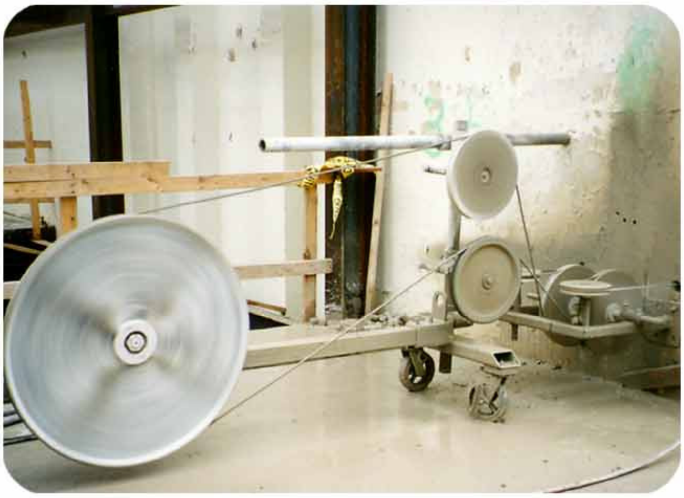


**Figure 1.** View of diamond wire cutter (Concrete)

### *2.2.2. Applications*

The diamond wire cutter machine is used for primary cutting, shaping and squaring-off of marble. In the granite quarries this machine is used for the primary cutting.

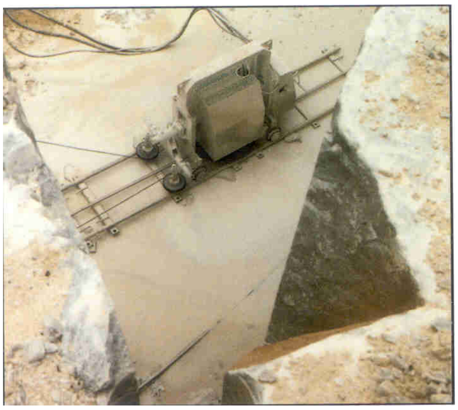


**Figure 2.** Primary cut with diamond wire

### *2.2.3. Characteristics*

The parameters that have to be considered in order to evaluate the cost-effectiveness are:

- Productivity expressed in $m^2$/hour;
- Duration of the wire expressed as the number of square metres cut per linear metre of wire employed ($m^2$/m).

The dimensions of primary cuts vary from 20 $m^2$ to 350 $m^2$, while a 50-70 HP motor is used. For granite, plasticated wire with sintered beads is used.

**Table 1.** Characteristics of diamond wire cutter

| Characteristics | Marble | Granite |
|---|---|---|
| **Beads per meter of wire** | 28-34 | 36-39 |
| **Linear wire speed** | 30-40 m/s | 25-30 m/s |
| **Average production** | 6-10 $m^2$/h, with peaks of 13-15 $m^2$/h | 2-4 $m^2$/h |
| **Average duration of wire** | 30-80 $m^2$/m | 6-10 $m^2$/m with peaks of 18 $m^2$/h |

### *2.2.4. Advantages/Disadvantages*

Advantages:

- The machine is versatile
- Lower staffing levels: one worker for start-up
- No powder or vibrations
- Productivity: very high absolute values (in particular for soft stone), relatively depending on the fracturing of the site
- Less wastes
- Excellent block quality for processing, very little supervision necessary, the quality of the cuts does not require squaring operations
- High sawing speeds for soft stone
- Cuts of large dimensions (up to 750 $m^2$)
- Rapid starting of the cut
- Low investment costs
- Low noise level (70dB instead of 130 dB of the flame-jet)
- Diamond wires allow to recover at least 10 % of the extracted material in respect with the loss of material caused by other techniques (flame-jet or drilling plus explosives)
- Good external inspection

Disadvantages:

- Water supply is required
- Relatively high operating costs for hard stone

## 2.3. CHAIN CUTTERS

### *2.3.1. Description*

Chain cutters are machines driven by electric motors resembling oscillating shaft-mounted power saws. The cut is performed by penetrating the rock through a pre-selected plane and moving the arm; the chain allows the cutting tool to abrade and remove rock chips. It can cut in all directions, thanks to the mobility of the arm.

The machine includes: a carriage, supporting all the electro-hydraulic equipment and the lubrication pump; the orientable arm; a drive system; a control panel; a cooling system. On the arm (up to 4.8 m) there is the chain, composed of interchangeable steel links and pieces to which the serrated supports are bolted. The cutting tools are widia or polycrystalline diamond plates, the last used for hard or abrasive rocks. The plates are composed of 6-7 pieces for a depth of 3.8 to 4.2 mm; the plates have a corner out 1 mm from the chain, enough to cut into and remove the rock by friction. The widia tools are rotated when a corner is worn down so that all four sides can be used; on the other hand, diamond tools wear much less quickly than widia.

**Figure 3.** View of chain cutter

### *2.3.2. Applications*

Chain cutters are used for working on benches and on tunnel advancement and only for marble and medium-hard materials (such as travertine, serpentine, and sandstone). They are used only for primary cutting.

### *2.3.3. Characteristics*

For underground quarrying the chain cutter is an indispensable device and often it is the main production system. The work stages do not require assiduous control and supervision of the machine, but operator skills are important to localise irregularities in hardness.

**Table 2.** Chain cutters characteristics

| Characteristics | Bench | Underground |
|---|---|---|
| **Chain speed** | 0-1.6 m/s | 0-3 m/s |
| **Machine advancement speed** | 4-10 cm/min | 4-10 cm/min |
| **Average duration of widia tools** | 350-400 $m^2$ | 350-400 $m^2$ |
| **Average duration of diamond tools** | 2000 $m^2$ | 2000 $m^2$ |
| **Depth** | 3.4 m | 2-2.5 m |

#### *2.3.4. Advantages/Disadvantages*

Advantages:
- High production; no theoretical limitation of cutting length
- No dust, no powder, vibrations; noise levels are relatively low
- Simple operation
- It is necessary to prepare only the surface
- No defect for the processing
- Good external inspection
- Indispensable for opening underground quarries

Disadvantages:
- Availability of water
- Limitation in depth
- Capital investment and operating costs rather high
- Quarry geometry must be regular
- Not suitable for granite

### 2.4. DIAMOND BELT CUTTING MACHINES

#### *2.4.1. Description*

It is a recent variant of chain cutters, powered by 60-75 HP electric motors. These machines have innovative elements:
- *The cutting elements*: they are sintered diamond segments, mounted in the perimeter of a belt in special plastic. The cutting elements do not need to be sharpened or changed; the whole chain is replaced when it has lost its abrasive power.
- *Lubrication and cooling system* of the belt on the arm are achieved using high-pressure water.

#### *2.4.2. Applications*

The diamond belt saw can be used on medium-hard, even high abrasive materials. Saws for vertical cuts only and saws for both vertical and horizontal cuts are available for underground quarrying.

**Figure 4.** View of diamond belt

*2.4.3. Characteristics*

The belt carries about 13 plates per linear meter.

**Table 3.** Characteristics of a diamond belt

| | **Data for marble Bianco Carrara** |
|---|---|
| **Cutting speed** | 2.5 cm/min |
| **Water consumption** | 100 l/min at 2.5 bar |
| **Belt wear** | 120 $m^2$/m |
| **Linear speed of diamond belt** | Up to 1.4 m/s |

**Table 4.** Vertical and horizontal depth

| | **Deep in marble** | **Deep in soft stones** |
|---|---|---|
| **Vertical cut** | 1.9 to 3.43 m | Up to 4 m |
| **Horizontal cut** | 1.9 to 3.05 | 3.43 m |

**Table 5.** Performance of diamond quarry belt saw

| **Stone type** | **Depth of cut (Inches)** | **Cutting speed** (inches/min) | **Total square feet** |
|---|---|---|---|
| **Verde antique** | 6′3″ | 2.5 | 3250 |
| **Sandstone** | 10′ | 2.5 | 7200 |
| **Bluestone** | 6′3″ | 2.5 | 4400 |
| **Indiana limestone** | 10′ | 3.5 | 30000 |
| **Domolitic limestone** | 6′3″ | 1.5 | 5000 |
| **Marble** | 6′3″ | 2 | 7000 |
| **Slate** | 8′9″ | 1.25 | 7000 |
| **Carrara marble** | 10′ | 1.2 | 13990 |

### 2.4.4. *Advantages/Disadvantages*

Advantages with respect to traditional chain saws:

- a single operator is sufficient to control the machine
- cuts even hard and abrasive materials
- requires very little maintenance
- low cutting cost
- pollution free, no oil, no grease

Disadvantage: availability of water and more expensive with respect to the chain cutter

## 2.5. FLAME-JET

### 2.5.1. *Description*

The operating principle is based on the action exerted on a given material by the thermal shock generated by a high temperature flame, fired at high speed along a pre-marked cutting line. The cutting tool consists of a 6 to 8 m long tube with two conducts. Gas oil circulates through one conduct, while compressed air circulates through the other. These two conducts join to form a combustion chamber. There is a burner on the tip of the jet, through which the flame and shock waves caused by the combustion, come out. The thermal dilatation differential of the crystals that make up the rock is the mechanism that causes breakage.

### 2.5.2. *Applications*

The flame-jet system is employed only for cutting granites, although its performance deteriorates when little or no quartz is present. It is used for primary cuts.

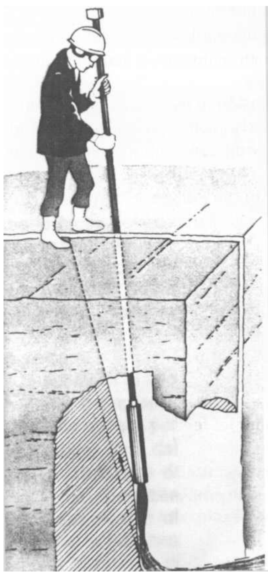


**Figure 5.** View of flame jet

### *2.5.3. Characteristics*

**Table 6.** Characteristics of flame jet

| | **Flame-jet** |
|---|---|
| **Compressed air** | 5-8 $m^3$/min |
| **Fuel** | 35-70 l/h |
| **Flame speed** | 1300 m/s |
| **Temperature** | 2000 °C |
| **Heat transfer capacity** | 40000 Kcal/h |
| **Cutting speed** | 1.5-2.5 $m^2$/h |
| **Cutting width** | 80-100 mm |
| **Cutting depth** | 6 m |
| **Average lifespan of nozzle** | 700-1000 h |

### *2.5.4. Advantages/Disadvantages*

Advantages:
- Easy transport
- No preliminary operations
- Easily and immediately used by workers
- Low initial cost

Disadvantages:
- High power costs
- Very high noise levels (120 dB), powder
- Low productivity
- Damage to the rock over significant thickness
- Strictly related to the chemical mineralogical composition of the rock

## 2.6. PNEUMATIC TOP-HAMMER

### *2.6.1. Description*

The top-hammer performs the holes through the action of one drilling bit, which receives percussion and rotation, and is transmitting those actions to the bottom of the hole, via one "drill rod".

The drilling equipment includes compressors, hammers drills (power drills, rock drills) and auxiliary equipment. The compressor is used to generate compressed air to feed power hammers. There are motor-driven compressors and electric compressors. The combination of a power hammer and a drill bit is the effective drilling device.

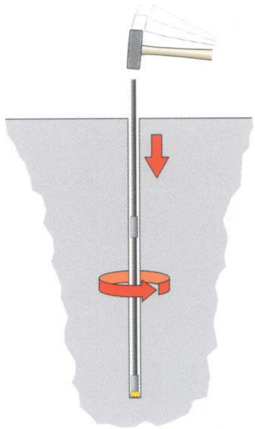


**Figure 6.** The rock drill is situated on the rig and works on top of the drillstring

In drilling operations, the power hammer transmits its energy to the rock through the drill bits, which are available in various types and lengths. Drill bits are the tools subject to the highest wear levels in the drilling process and must be sharpened at regular intervals. Drill cuttings are removed from the hole bottom to the surface by air blowing or water flushing.

Auxiliary equipment typically includes feeds that allow the installation, orientation and simultaneous operation of one or more power hammers. Feeds ensure regular drilling of long sequences of holes.

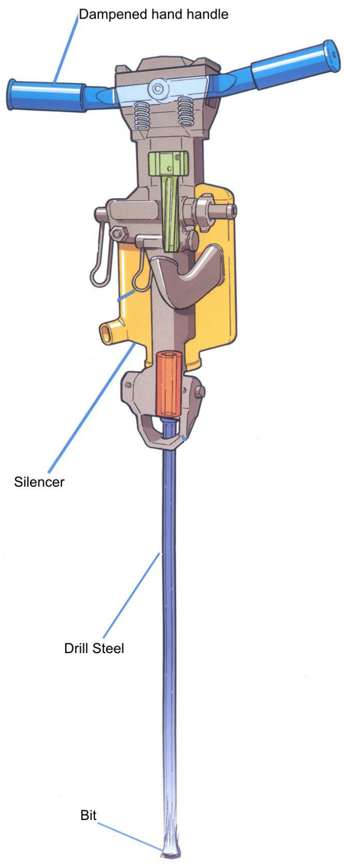



**Figure 7.** View of pneumatic top-hammer

### 2.6.2. *Applications*

Drilling can be used for auxiliary and preparatory operation in combination with other cutting techniques (such as diamond wire) or as an independent operation. Pure drilling is often the basis for the dynamic splitting (using explosives).

In a marble quarry the combination of drilling and explosives is almost always an integrative technique combined with other more efficient methods. In a granite quarry, drilling and explosives are still today the main technology employed for vertical and horizontal primary cut.

The feeds allow operations with one, two or more power hammers; this technique is common in granite quarries, where other technologies are less used. The holes are spaced at a distance that is 4 or 8 times their diameter. It is very important that the holes are perfectly aligned on the same plane. The explosive normally used is a detonating fuse with a pentaerythritol tetranitrate. As an alternative to explosives, mechanical or manually driven rock-splitting wedges or expanding cement can be used.

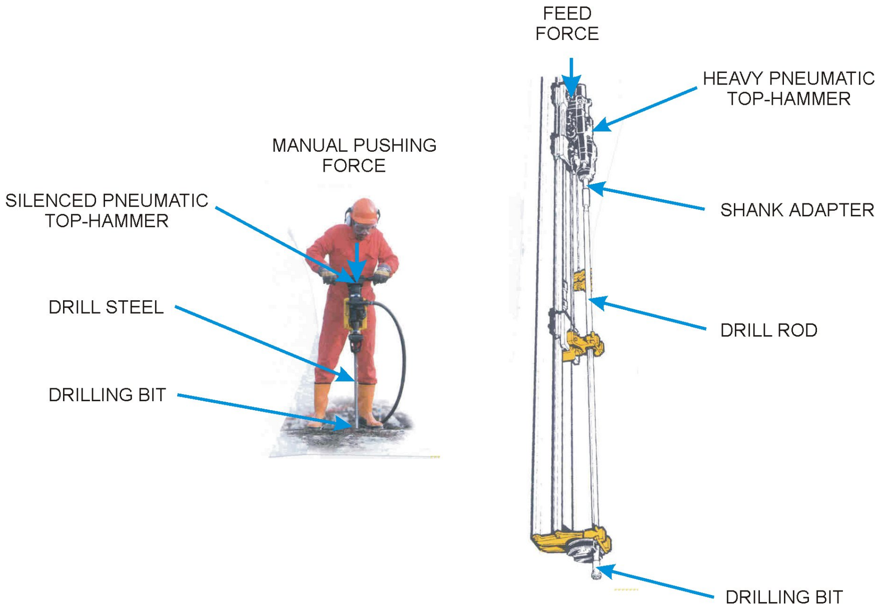



**Figure 8.** Top-hammer hand held, top-hammer feed mounted

### 2.6.3. *Characteristics*

In a pneumatic top-hammer the energy absorbed (for a 28 kg rock drill type) is about 39.9 kW.

**Table 7.** Characteristics of top-hammer

| Power hammer | Weigh (kg) | Use | |
|---|---|---|---|
| **Lightweight power hammer (jack hammer)** | 17 | Secondary and auxiliary quarry operation | Manual |
| **Intermediate power hammer** | 17-24 | Auxiliary and direct quarry operation | Intermediate |
| **Heavy-duty power hammer** | 24-31 | Primary cutting | Feed mounted |

**Table 8.** Characteristics of top-hammer

| Weight (Kg) | Frequency (6 bar Hz) | Air consumption (l/s) | Sound pressure level dB(A) | Sound power level dB(A) | Vibration ($m/s^2$) | Drilling speed (cm/min) |
|---|---|---|---|---|---|---|
| 10 | 42-45 | 22 | 100 | 111 | 23 | 15 |
| 12 | 42-45 | 22 | 100 | 111 | 17.5 | 20 |
| 16 | 42-45 | 22 | 100 | 111 | 3.5 * | 22 |
| 24 | 50 | 78 | 100 | 113 | 25 | 70 |
| 26-30 | 55 | 95 | 100 | 113 | 25 | 90 |

*Vibration: up to 24 Kg it can reduce to 3 $m/s^2$ with ergonomic system

**Table 9.** The correct flushing speed will be reached in respect with the following data (material having a density of 2 $t/m^3$ requires a flushing speed of at least 10 m/sec)

| | **Pneumatic rock drill up to 30 kg** |
|---|---|
| **Air flushing (l/min at 6 bar)** | 600 |
| **Water flushing (l/min at 5.5 bar)** | 20 |

Parameters that have to be considered in order to optimise the performance:
- Drilling speed of the rotary percussion hammers
- Spacing of the holes
- Workers' ability to complete the cut by loading and setting off the explosives

### *2.6.4. Advantages/Disadvantages*

Advantages:
- Versatility and adaptability to various quarry situations
- Simple operation
- No preliminary preparation
- Low capital investment costs
- The most intuitive and immediate method for unskilled workers, when there is no water and for irregular rock masses
- Remote control.

Disadvantages:
- Use of explosives, which may in some cases cause considerable damage to the rock
- High environmental impact: powder, noise and vibrations
- Very poor power efficiency
- High power costs
- Shape of blocks, surfaces not optimised for inspection
- Need for dust collection or water

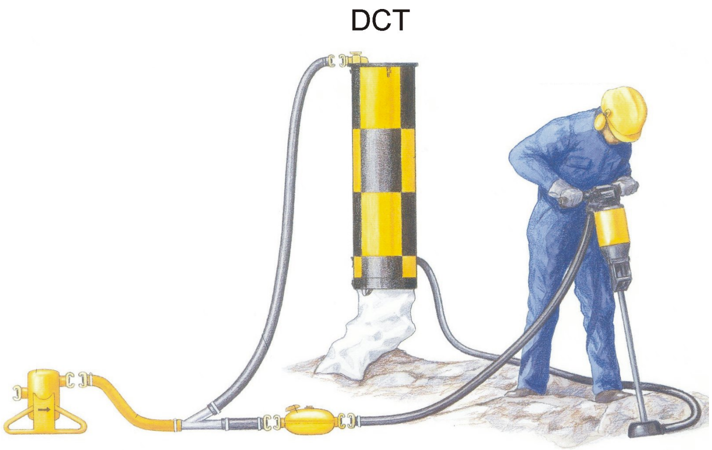



**Figure 9.** The minimum accessories for the pneumatic top-hammer: water separator and dust collector.

## 2.7. HYDRAULIC TOP-HAMMER

### *2.7.1. Description*

The fundamental characteristic of the hydraulic method is the replacement of the compressed air system, as the source of power, by a more efficient system, hydraulic oil, which cannot be compressed. Hydraulic drilling is more powerful than pneumatic drilling, with higher drilling speeds and lower power consumption. The hydraulic top-hammer is functioning through the oil, which is pumped from one suitable hydraulic system to the rock drill, actuating the percussion piston. The pressure of the hydraulic system can vary from 120 to 250 bar. The oil is incompressible and the elasticity is given to the system by a nitrogen accumulator, installed in the rock drill. One hydraulic motor is providing the rotation of the drilling rod, through the utilization of one oil flow separated by the percussion oil flow.

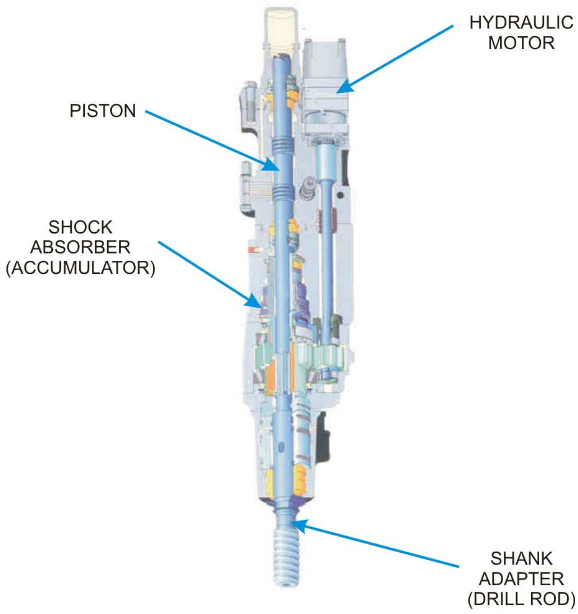



**Figure 10.** Hydraulic top-hammer

### *2.7.2. Applications*

The energy absorbed by a hydraulic top-hammer in a 50 kg weight rock drill is about 17.4 kW, which is less with respect to the pneumatic top-hammer. The hydraulic rock drills, when operated for many hours consecutively, are affected by overheating and this is not well accepted by the operators. In any case, due to the many advantages offered, in comparison to the pneumatic ones, the hydraulic rock drills are more and more utilised, installed on feeds and operated via remote controls.

As a last development, special drilling rigs have been produced, equipped with hydraulic rock drills, feeds, remote controls and dust collectors. The above units are designed taking into consideration the needs of drilling technology, instead of mounting everything on a normal excavator.

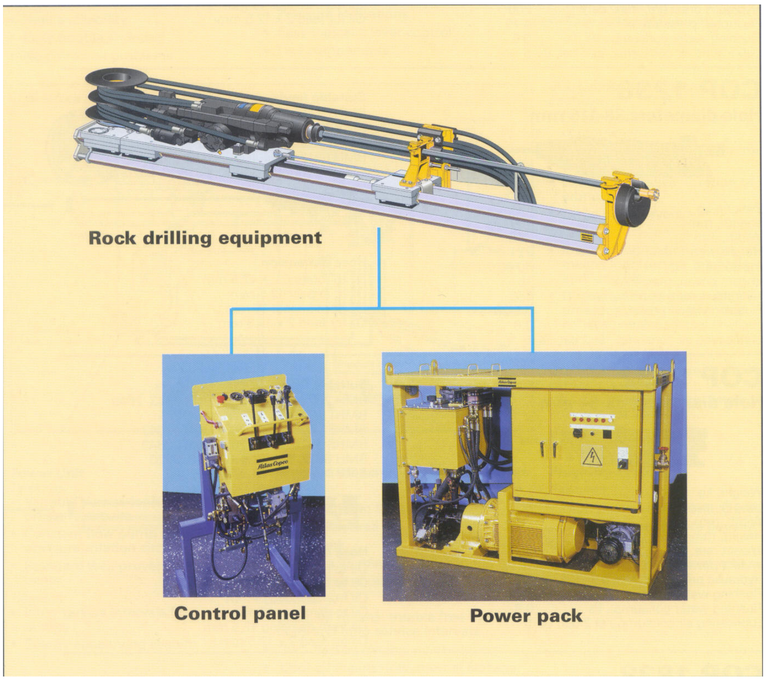



**Figure 11.** View of hydraulic top-hammer

### *2.7.3. Characteristics*

**Table 10.** Characteristics of hydraulic top-hammers

| Weight (Kg) | Oil consump. Percussion (l/min) | Oil pressure percussion (bar) | Oil consump. Rotation (l/min) | Oil pressure roration (bar) | Drill speed (m/min) |
|---|---|---|---|---|---|
| 40 | 50 | 120-150 | 15 | 100 | 1.2 |
| 50 | 50 | 140-180 | 18 | 80 | 1.5 |

**Table 11.** The correct flushing speed will be reached with respect to the following data (a material with a density of 2 t/m$^3$ requires a flushing speed of at least 10 m/sec)

| | Hydraulic rock drill 50-70 kg |
|---|---|
| **Air flushing (l/min at 6 bar)** | 1000 |
| **Water flushing (l/min at 5.5 bar)** | 40 |

### *2.7.4. Advantages/Disadvantages*

Advantages:
- No free emissions of compressed air
- Noise level is more reduced than pneumatic
- Remote controls
- Simple to maintain and trouble-shoot
- Better power efficiency than pneumatic

Disadvantages:
- Use of explosives which may at times cause considerable damage to the rock
- High environmental impact: powder, noise and vibrations
- High power costs
- Shape of blocks, surfaces not optimised for inspection
- Need for dust collection or water
- Oil consumption

## 2.8. DOWN-THE-HOLE HAMMERS.

### *2.8.1. Description*

The down-the-hole (DTH) hammer is a percussion hammer drill. This drill consists of a rotating head that drives the tubular drill rods (76 mm diameter and 1.5 m long) connected at the top to a pneumatic drill head (down-the-hole hammer) about 90 mm diameter, equipped with widia cutters. The air drilling devices exert a rotary-percussion action at the base of the hole as it is drilled. The workhead of the piston is always in direct contact with the drill bit. Generally the hammer’s running is pneumatic, but there are also models with an oil-driven rotating head.

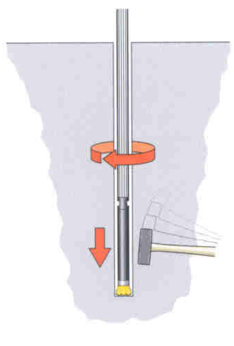


**Figure 12.** Down-the-hole principle

A DTH drilling device exerts a noiseless and vibration free rotating outside the hole, while the percussion is generated at the bottom of the hole as it is drilled. The hammering effect of the piston is directly trasmitted to the drill bit without any energy loss through the extension rods.

### *2.8.2. Applications*

The DTH hammers are used for making the large diameter holes needed for diamond wire passage. They are advantageous in drilling very deep holes and for hard materials. The DTH hammers are used, when it is needed, for the large continuous cut.

**Figure 13.** View of down-to-hole hammer

### *2.8.3. Characteristics*

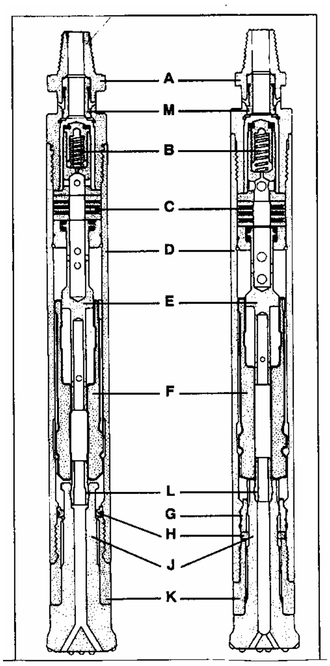



**Figure 14.** A: threaded top sub, B: check valve, C: compression ring, D: long cylinder, E: control tube, F: impact piston, G: bit bushing, H: stop ring, J: drill bit shank, K: driver chuck

**Table 12.** Characteristics of down-to-hole hammer -Bit 90mm

| | |
|---|---|
| **Reached depth** | 25-30 m |
| **Penetration speed (medium-hard marble)** | 10 m/h |
| **Air consumption** | -10 $m^3$/min |
| **Energy consuming** | 40-50 kW |
| **Vibration level** | 3 $m/s^2$ |
| **Noise level** | 80 dB |

**Table 13.** Characteristics between 3.5" – 4" – 5"

| **Hammer** | **3.5″** | **4″** | **5″** |
|---|---|---|---|
| **Length thread(mm)** | 954 | 985 | 1069 |
| **External diameter (mm)** | 83.5 | 98 | 120 |
| **Weight (kg)** | 27 | 38 | 57 |
| **Bit size (mm)** | 92-105 | 110-125 | 134-152 |
| **Feed force (kN)** | 3-12 | 5-15 | 6-17 |
| **Working pressure (bar)** | 6-25 | 6-25 | 6-25 |
| **Rotation speed (r/min)** | 30-90 | 25-80 | 20-70 |
| **Air consumption 6-25 bar (l/s)** | 46-200 | 54-255 | 71-345 |

| **Penetration rate Rock with compressive strength 2200 bar(mm/min)** | **3.5″** | **4″** | **5″** |
|---|---|---|---|
| **10.5 bar** | 295 | 310 | 320 |
| **16 bar** | 520 | 510 | 515 |
| **20 bar** | 720 | 640 | 640 |
| **25 bar** | 955 | 800 | 800 |

#### *2.8.4. Advantages/Disadvantages*

Advantages:
- No vibrations
- No noise after 1 m
- No deviation in long holes
- Low capital investment costs, similar to wire machine
- The most intuitive and immediate method for unskilled workers, when there is no water and for irregular rock masses
- The drilling rate is not crucially affected by the length or depth of the drill hole.

Disadvantages:
- High environmental impact: powder, noise and vibrations
- Poor power efficiency
- Shape of blocks, surfaces not optimised for inspection.

### 2.9. WATER-JET

#### *2.9.1. Description*

The water-jet system consists of a pressure generator and a nozzle, mounted on a rod. It is powered by either electric motors or diesel motors. The parameters to be considered in order to optimise the water-jet performance are:

- The hydraulic output of the system (pressure x nozzle delivery)
- Diameter and configuration of the nozzle (single or multiple)
- The kind of generating pump (single pump or two-stage pumps)
- The most effective working distance
- The characteristics of the water used

### *2.9.2. Applications*

The water-jet system separates the rock through a jet of water at very high pressure, up to 350 MPa. The rock is cut not by friction, impact or chip removal but through the destruction and detachment of the component compounds of the material.

### *2.9.3. Characteristics*

**Figure 15.** Granite surface cut by a water jet

The water speed is 700-800 m/s. The system is most used for granite rock, because of its petrographic characteristics, which enhance water-jet cutting operations. The cuts could be from 3.6 m to 8 m.

### *2.9.4. Advantages/Disadvantages*

Advantages:

- Cutting surface is very precise
- Low environment impact: no dust, no vibrations, low noise levels
- Future potential in underground granite quarries

Disadvantages:

- High initial capital cost
- High power costs
- Need to ensure optimal set-up
- Need engineering for set-up

This machine is used in particular in Canada, France and Sardinia where it is possible to obtain a good production of special soft rock. It can be proven to be the technology of the future. The technology with water and sand is under investigation.

# 3

# Processing Equipment

GIUSEPPE GANDOLFI, STEFANO CAROSIO, MASSIMILIANO MARCELLINO

## 3.1. STONE PROCESSING

After quarrying, the processing phase starts. The aim of this phase is to obtain large semi-finished products, which are used to produce a complete range of finished products of any shape and size requested by the market.

### *3.1.1. Processing different kind of stones*

The specific kind of natural stone must always be taken into consideration, because it determines the processing cycle, the choice of machinery, the technology employed, the processing cost and the commercial value of the products.

For technical and commercial convenience, natural stone is generally divided into two wide groups: “granite” and “marble”. Therefore, each machine or line in the following paragraphs will be qualified according to the kind of stone (in the wider sense) to which it applies. Each machine or line can only be compared with other machines and processes aimed to manufacture the same class of stone.

As far as the machine design specifications are concerned, such a rough approach can be better detailed as follows. Each one of the following branches includes a range of stones with variable features.

Petrographic description should follows prescribed standards, such as Italian national standard UNI, and should follows a set of tests carried out according to well defined testing methods, such as those  defined in the standard prEN 12057.

**A**) The class of **hard stones** are petrographically identifiable as igneous intrusive stones (like *Granite*) and igneous effusive stones (like *Basalt*), ipo-abyssal (like *Porphyry* and *Pegmatite),* metamorphosed igneous stones (like *Gneiss*). These stones are characterised also by their mineralogical composition, which generally may include *Quartz*, *Feldspar*, *Amphibole*, *Pyroxene*, *Garnet* and other minerals having Mohs hardness higher than 6.

Such petrographic and mineralogical identification is easy and quite effective, but not absolutely reliable, since some chemical-sedimentary quartz stone (like *Jasper*) can be classified among the hardest to process.

Stones deriving from the metamorphosis of sedimentary quartz stones (*Quartzite*) may be classified as "hard stones", especially because of the high tool wear.

Among the hard stones, those including less quartz (like *Gabbro*) are approximately on the low side of the toughness range. For such stones, the average dimensions of the grain size can give an indication of their hardness.

Since the classic hardness scale (Mohs) does not apply to stones (but only to minerals), these hard stones are often classified on a scale from 1 to 6 (it was set initially to 5 degrees, but later it was increased to 6), 6 being the most "hard" to process (granite with high content of quartz) and 1 stones which are less hard to process (like a *Gabbro* stone). In the recent years, this hardness grade for stones has been developed on a more scientific basis and can be considered as the most effective and reliable reference tool to classify the "hard stones", as far as processing is concerned. Tables and data sheets have been written, in order to link the stone types (identified usually by their commercial names) to their machinability.

**B**) The class of **soft stones** include calcite sedimentary (like *Limestone*, *Clay Marl*) and calcite metamorphic stones (*Marble*). *Calcite* is the main mineral in these stones, with a Mohs hardness near 3. Some sedimentary (not metamorphosed) silicatic stones (like *Sandstone*) can be also considered as part of this class, with some differentiation in the tool wear behaviour.

If compared to the "hard stones", where *Feldspars* (Mohs grade about 6) and *Quartz* (Mohs grade about 7) are often the main minerals, it appears to be very clear that processing is carried out on two extremely different basis, taking also into consideration that the Mohs scale is not linear but logarithmic in hardness. The percentage of hard minerals, such as *Quarz,* influences greatly the machinability of soft stones.

**C**) In machine design and process parameterisation, some stones that are in an intermediate position among the above two main classes must also be considered, being the reason for the development of some special processing techniques. The so called "green marble" can be included in this class, together with some kinds of siliceous slates. Actually, the "green marble" is often an *Ophiolite*, where the relative percentages of *Serpentine* and *Calcite* minerals determine the relevant differences in the processing behaviour. In general, a plant suitable to process such kinds of stones will include machines for granite and marble, and/or special machines.

In addition to the evaluation of machinability, the **tool wear** must be analysed, for tool design and tool selection. This parameter has also been studied recently upon rational basis, even through the related analysis techniques are still more close to proprietary protocols than to open standards.

The varying behaviour of stones must always be taken into consideration for machine design and process parameterisation: not only the stones are different, but often the same stone coming from the same quarry shows relevant differences from one block to another.

Stones are not complying easily to prescribed data sheets, because they are natural products coming from natural processes taking millions of years to develop and it is not possible to influence such processes. The raw material data sheets can only be written after the completion of such natural processes.

### *3.1.2. Processing stone blocks of different quality*

The actual condition of the stone blocks is another issue that influences the choice of the process.

**Fractures** ("chinks") can be visible or hidden inside the bulk ("vents"). When the material is heavily fractured, stones having great aesthetical features it is difficult to manufacture into finished marketable products (with acceptable yield). The process line may include means to overcome this limitation, that is, equipment designed to repair/consolidate the material.

**Cavities, micro- and macro- pores, empties** can be also present in a stone. The process line may include means to overcome this limitation, that is, equipment designed to repair/consolidate the material.

**Chemical alterations,** such as oxidation of inclusions, may result in a decay of the product value, at any stage: during stocking of the raw material, during processing, during stocking of the finished product and also after cladding or flooring.

**Geometry (flatness, roughness, irregular shape).** According to the desired final product, the manufacturing process should include means to regularize the material geometry, such as lone-standing machines (block-squaring blade cutter or wire cutter), or special operations (such as the block topping operation performed by a multi-disc block cutter).

### *3.1.3. Processing different geometry of finished and semi finished products*

The semi-finished or finished products that can be obtained during or at the end of the processing operations can be summarised in the Table 14, classified according to their size. In such a classification and characterisation, the following standards can be taken as an indication: Italian national standard UNI8458, European standard proposals prEN1467, prEN1468,prEN1469, prEN12057, prEN12058, prEN12059 .

Slabs can be final products (for flooring and cladding); in such cases they are generally squared. Slabs are also semi finished products (generally not squared), to be used for manufacturing dimensional stone products (e.g. kitchen tops) in a "stone laboratory workshop". Slabs are manufactured from the raw blocks in mass production by *Diamond cutting Frames*, *Gangsaws, Wire cutting machines, Giant Disc cutting machines*,. Before their delivery to a laboratory, slabs can be polished by means of polishing machines.

Strips are semi finished products. In the standard processing plants for mass production, strips are manufactured by *Multi Disc Block Cutters* from the raw blocks.

**Table 14.** Typical products of the processing phase

| **Product** | **Length (mm)** | **Width (mm)** | **Thickness (mm)** |
|---|---|---|---|
| **Slab** | 2500 - 3500 | 1300 -2000 | 20 - 80 |
| **Thin slab** | 2500 - 3500 | 1300 -2000 | 11 - 20 |
| **Not squared slab** | As above, edges not trimmed | | |
| **Squared slab** | As above, edges trimmed | | |
| **Strip** | 1000 - 3500 | 150 - 650 | 10-50 |
| **Tile (modular tiles)** | 150 - 650 | 150 - 650 | 10 - 12 |
| **Super thin (modular tiles)** | 150 - 650 | 150 - 650 | < 10 |
| **Skirting** | 1000 - 3500 | 50 - 200 | 8 - 15 |
| **Solid small block** | >> thickness<br>>> width | = thickness | = width |
| **Dimensional stone** | any | any | > 80 |

Skirtings can be considered as the finished counterpart of strips. Their finishing requires machines designed for this purpose, such as edge polisher and chamfering machines. Generally the standard modular tile processing line is not suitable.

Tiles are final products (for flooring and cladding). Modular tiles come in standard sizes. Tiles can be manufactured from strips using of mass production processing lines.

Solid small blocks are (generally) semi finished product for laboratory finishing. They are manufactured by *Diamond cutting Frames*, *Gangsaws, Wire cutting machines, Giant Disc cutting machines,* or even *Multi Disc Block Cutters,* according to their size.

Dimensional stones are finished products, typically manufactured from slabs or small blocks in small batches, according to a predefined design, in a “laboratory workshop”, or in the “laboratory department” of a bigger production plant. Typical dimensional products are: kitchen tops, bathroom tops, furniture elements, architectural elements, tombstones. A wide range of machines is available for laboratories, in order to virtually obtain any possible shape: bridge milling machines, contouring machines, polishers, edge polishers, lathes, water-jet cutter, engraving machines and wire profiling machines.

**Plant lay out.** Processing plants, when studied according to their lay out, can be divided in functional areas. Such areas are, in general, also located in different places in the plant.

Not all the plants include all the areas, and some plants may include more than one of each area. Small companies, including only the Stone Laboratory, are quite common. On the other hand, plants are always customized, and they can become quite complex because of the combination of many production requirements.

**Cutting center**. This is the first step, where stone blocks are transformed in to semi finished products. The typically machines installed in this area are **Gangsaws**, **Diamond Blade Frames**, **Multi Discs Block Cutters**, **Giant Disc Cutters, Diamond wire Cutters**. Auxiliary machines for handling the semi finished products are also installed here (**cranes**, **strip unloading machines** for block cutters, block carrying **trolleys**, **transporters** for such trolleys). Other machines may be installed here as ancillaries. For instance, in marble plants for tiles it is common to have a small **cross cutting machine** to cut both strips edges, in order to optimise the work of the subsequent steps of the process (finishing). In marble plants for tiles, a **Sectioning Machine** (also called **Splitting Machine**) can also be installed, in order to split each strip in two thinner ones. This step is often performed in order to increase the productivity or to reduce the risk of having broken strips.

The cutting machine operates in parallel. The productivity of the cutting center can be expressed in square meters per working hour. The yield of the cutting center can be expressed in square meters of strips/slabs per cubic meter of raw stone.

Another important parameter useful to evaluate the economic yield of the cutting center is the number of cubic millimeters of diamond sector employed per square meter of strip actually manufactured. This parameter is important for granite plants, not very important for marble plants (where the tool wear is much less) and it does not apply when diamond tools are not employed (gangsaws for granite slabs).

**Finishing lines for tiles** (modular tiles). Here the semi finished products (strips) are transformed in to finished product (tiles) by means of one or more mass production lines. A wide range of machines are installed here: **Calibrating, Polishing, Cross-cutting, Chamfering, Cleaning m/c, Drying m/c, packaging** (manual station or automatic packaging center). **Filling (Plastering)** units with drying ovens are also included, when the processed material requires filling with resins to be repaired.

The productivity of the line can be expressed in square meters per working hour, but the average speed of the conveying system is an effective productivity index, since all the machines are generally connected in series (the outlet of each machine is the inlet for the following one). This figure, multiplied by the width of the strips, gives the productivity in square meters per time unit.

**Finishing lines for slabs**. The semi-finished products (slab) are transformed into finished product, by means of one or more mass production lines. Unlike a modular tile plant, here the machines to be installed are quite more restricted in typology: usually, a **Slab Polishing Machine**, a **Slab Cross Cutting Machine**, a **Slab Trimming Machine** (lengthwise cut). Ancillaries for handling the slabs are usually also installed (**Slab Loaders** and **Unloaders, Cranes**). The productivity of the line can be expressed in square meters per working hour, and also here the average speed of the conveying system is an effective productivity index.

**Stone laboratory**. The semi-finished products are transformed in to finished products by machines operating in small batches or manually. A wide range of machines is available. These machines may require skilled manpower compared to a mass production finishing line or a cutting center. This manufacturing process is sometimes more related to artwork than to mass production. The productivity of the machines employed can vary among a wide range of values: from the low capacity of a manual machine up to a fully automated CN bridge milling machine.

All the plants mentioned above must be equipped with the services usually installed into industrial plants: electric power, pressurised air and industrial water. In addition, a water recycling plant must always be installed and equipped with filters and devices to control the additional compounds added to the water (such as flocculants) and the quality of the water (such as pH meters). Sufficient care must be paid to the means aiming to reduce the exposition of the operator noise, such as sound barriers and sound absorbing walls.

An overview of few basic layouts highlighting the machines included in a stone laboratory is illustrated in Figures 16-20. In the following paragraphs detailed descriptions of these machines are provided. There are of course literally thousands of possible plant lay outs, since the range of machines available is very wide and there is a huge amount of possible combinations of the many sub-processes.

NOTICE: the following schematic diagrams are given for illustration purposes only; therefore safety barriers, sound barriers, machine enclosures and similar are not mentioned.

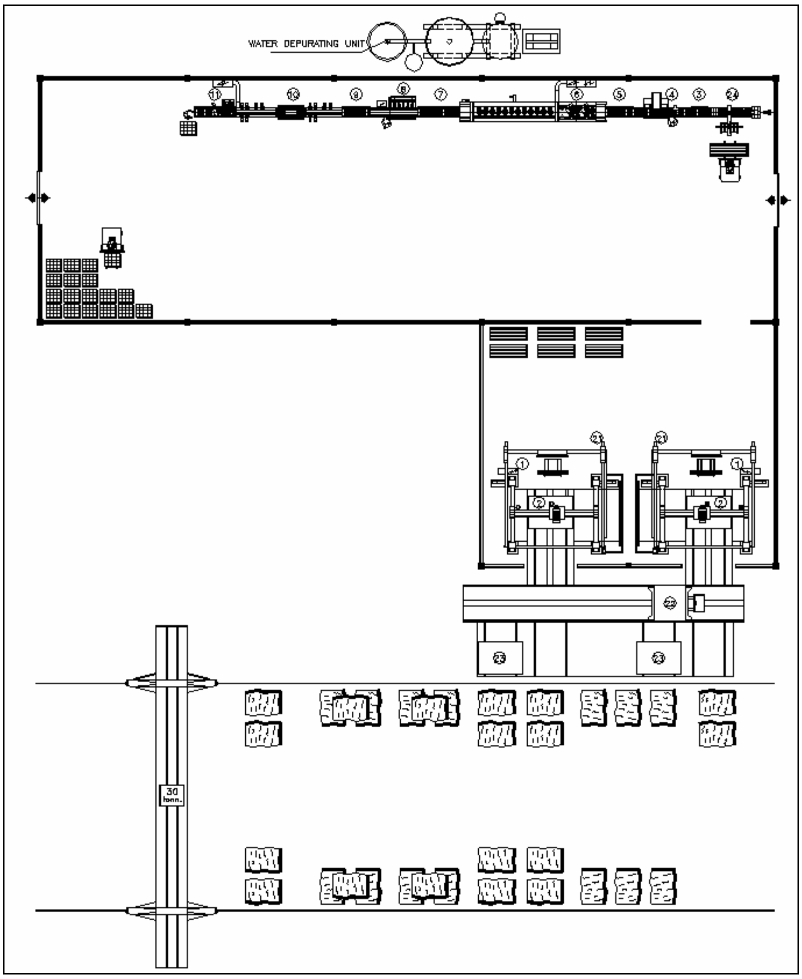



**Figure 16.** Lay out 1 - A basic granite plant, for mass production of modular tiles, with low-medium output.

*A stock area for stone blocks, with an overhead 30 000 kg crane can been seen.*

*The cutting center includes two 4-columns multidisc block cutters (2), equipped with automatic strips unloaders (1); a plurality of block supporting trolleys (23); and a single transporter for such trolleys (22).*

*In the above plant there is a single basic finishing line, including an automatic strip loader (24), a single disc cross cutting machine for strip pre-sizing (4), a combined calibrating-polishing machine (6), a cross-cutting machine to perform the tiles cutting (8), a chamfering machine (10), a cleaning and drying unit (11), followed by a manual packaging station. The strips feeding is ensured by means of auxiliary conveying roller benches (3-5-7-9).*

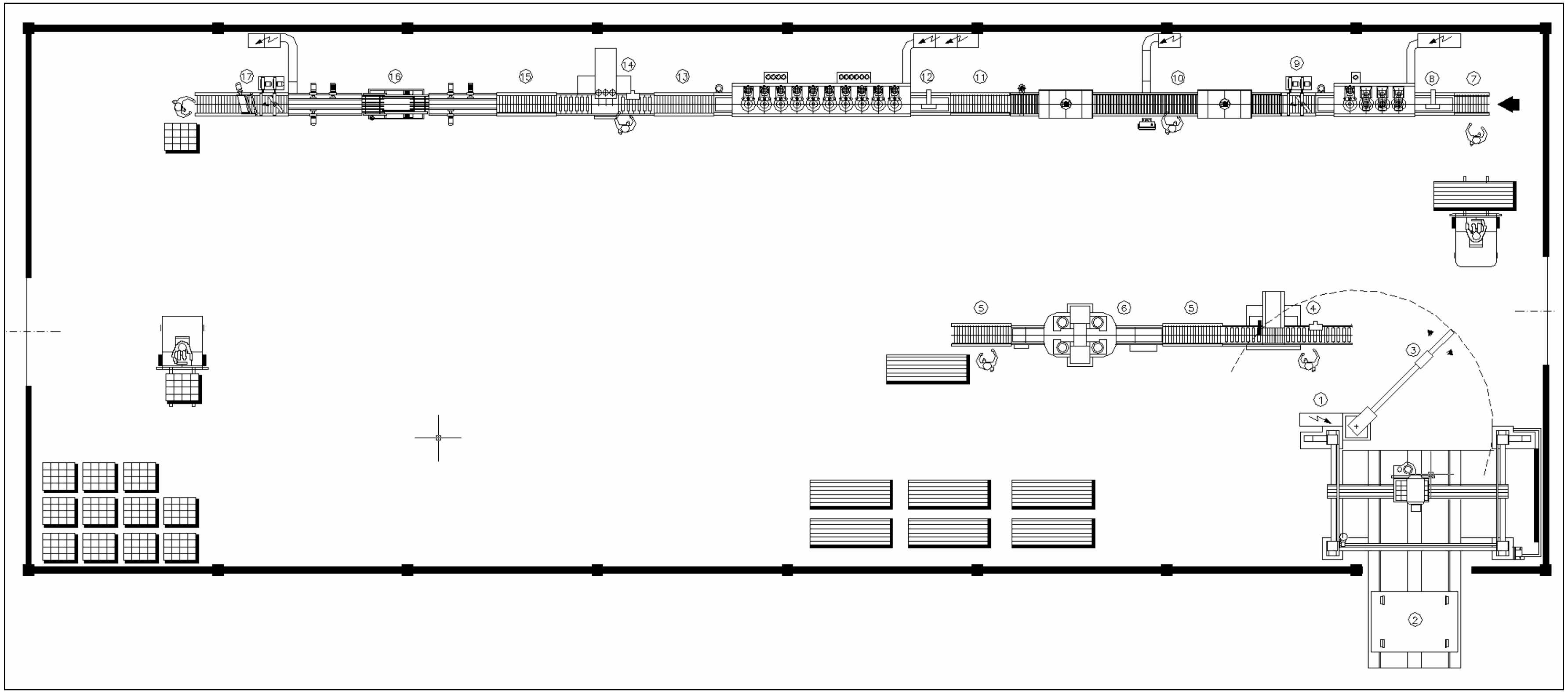


**Figure 17.** Lay out 2 - A marble plant for mass production of modular tiles.

*It is possible to see the cutting center, equipped with one 4-columns multidisc block cutter (2) with a stone block supporting trolley and a crane for manual strips unloading (3). The crane handles the strips to a short processing line including a single disc cross cutting machine for strip pre-sizing (4) and a splitting machine (6). From the roller bench (5) the strips are loaded on vertical pallets.*

*The finishing line starts with a calibrating machine (8), followed by a filling (plastering) center including a drying oven, a manual filling station and a final drying oven. Then the strips are polished (12) and cut to size into tiles by a 3-discs cross-cutting machine (14). A chamfering machine (16) and a cleaning/drying unit (17) carry out the final steps before packaging. The strip feeding is ensured by means of auxiliary conveying roller benches.*

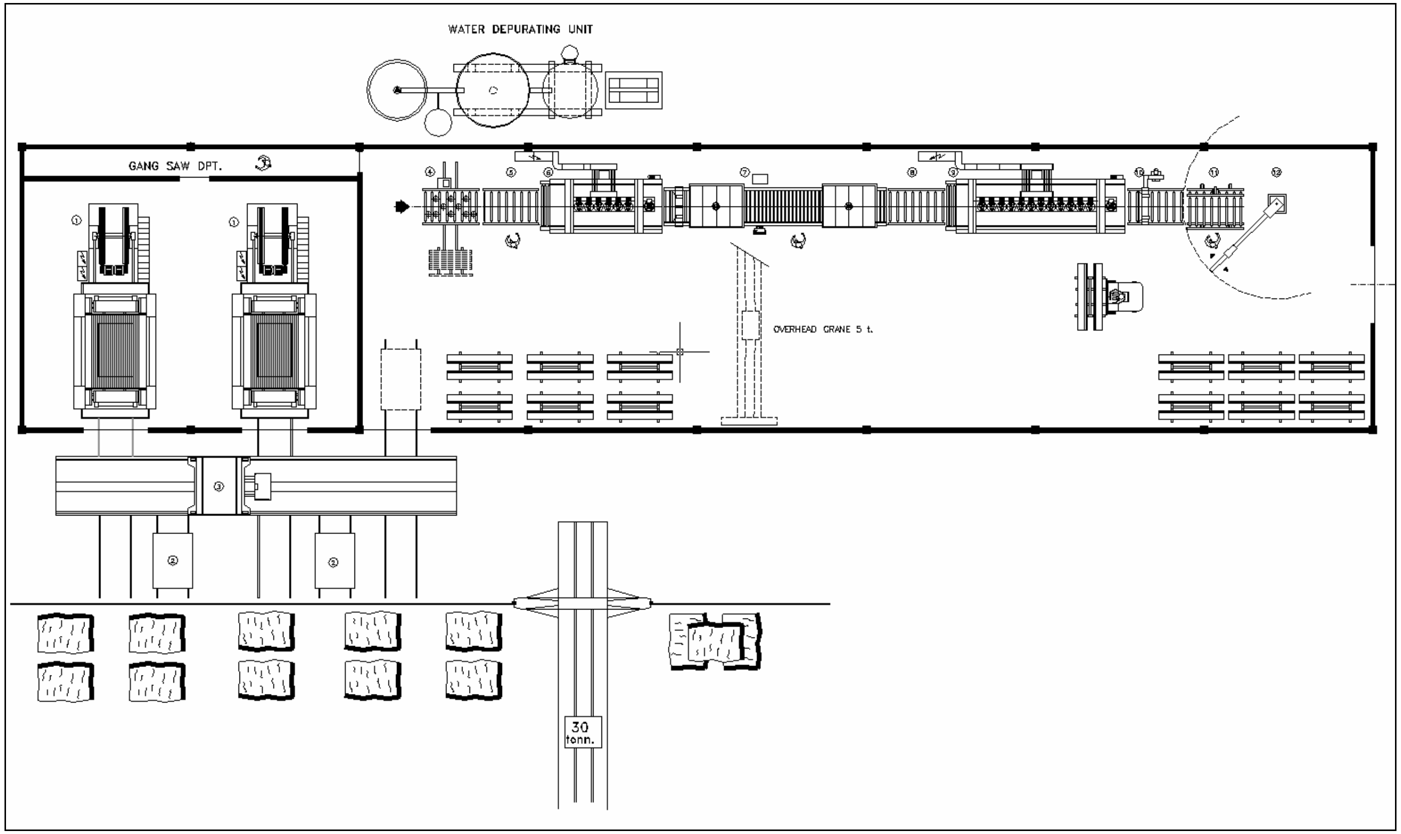



**Figure 18.** Lay out 3 - A marble plant for production of slabs.

*The cutting center includes two cutting frames with multiple diamond-tipped blades (1) and a plurality of blocks carrying trolleys (2) with a single transporter for such trolley (3). The finishing line is fed by means of the crane (12) to the polishing machine for slabs (9). A filling (plastering) center for slab (7-8) is followed by another polishing machine. An automatic unloader (4) handles the slabs to the storing pallets, in vertical position.*

*In this drawing the water depuration unit is also schematically represented.*

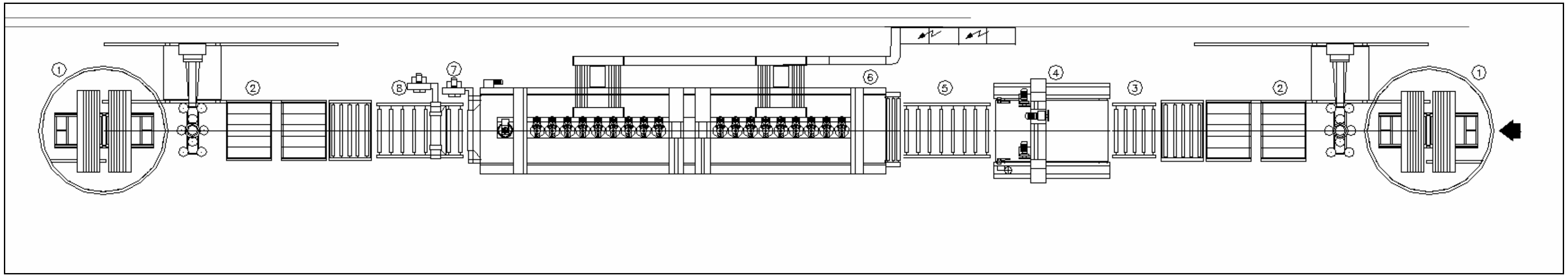



**Figure 19.** Lay out 4 - A marble slabs finishing line. Here the slabs are loaded and unloaded by means of automatic handling centers *(1). A single cutting center (4) performs both cross cutting and trimming (lengthwise cutting). The polishing machine (6) is the heart of the line.*

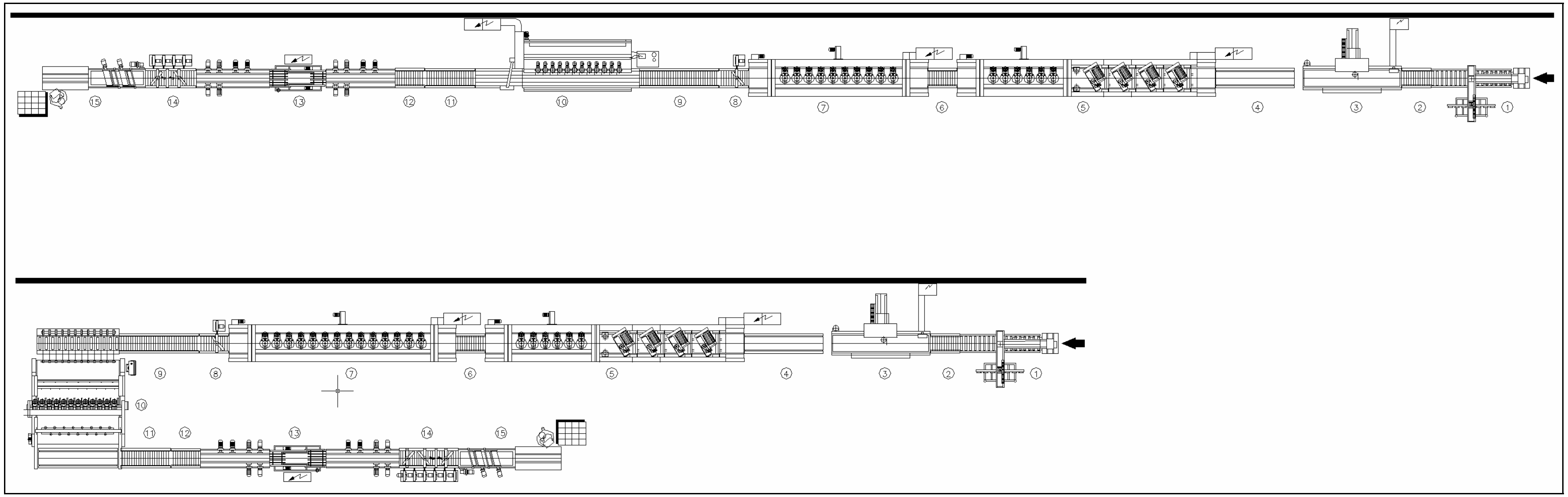


**Figure 20.** Lay out 5 - Finishing lines for mass production of granite tiles.

*Two typical possible layouts (in a line or U-bend) are represented here. The machines installed are similar in function. The different dispositions aim to fit into different spaces. Moreover, the line below should have a higher throughput, since the polishing machine has more heads, and the multi-discs cross cutting unit is a high productivity machine with continuous feeding flow.*

*The line includes an Automatic loader (1), conveyor belts or motorised roller benches(2-4-6-9-11-12), a single disc cross cutting unit for pre-cut (2), a granite calibrating unit (5), granite polishing machine (7), drying unit (8), cross-cutting machine (10), chamfering machine (13), drying unit (14) and a cleaning unit (15).*

## 3.2. PROCESSING METHODOLOGY

It is possible to design many alternative processing cycles, depending on the type of raw material and final products. It must be also taken into consideration that a production cycle can be (and often it is) tailored to fit special processing conditions, specifications of the final products, raw material features or limitations. This may result either in adjustment of any of the most common processing cycles or in the design of a new system from scratch.

Each one of the basic processing cycles has actually two versions: one for **granite** ("hard stones", as defined previously) and one for **marble** ("soft stones"). In some cases, the granite and marble plants require different kinds of machines to perform the same operation. In most cases, the same machine has two counterparts, one for granite and one for marble, which are often very different from many points of view: mechanical structure, tools and machining heads, process control. Even the underlying technology can be different.

The basic processing cycles are the following:

Cycle for slabs (finished products for flooring and cladding)

Cycle for slabs (semi finished products for delivery to the Stone Laboratory)

Cycle for tiles, from slabs

Cycle for mass production of modular tiles (finished products for flooring and cladding)

Manufacturing of dimensional stones (finished products, Stone Laboratory).

In the following paragraphs an overview of the different operations in each cycle is illustrated, highlighting the machines used. A detailed description of these machines is also provided.

### *3.2.1. Cycle for slabs (finished product for flooring and cladding)*

This cycle is intended to produce large slabs, polished and with trimmed edges, as finished products for flooring and cladding, starting from a regular or commercial-sized block.

The cycle can be summarised as follows:
- block squaring (when needed)
- block cutting (into slabs)
- cross cutting and trimming (cut to size)
- polishing
- auxiliary operations: handling

<u>Squaring off operation</u>

If a block presents a particular irregular shape, a preliminary operation of squaring off is necessary before cutting the block into slabs of the required thickness.

| | |
|---|---|
| Location: | Cutting centre |
| Granite Machines : | Diamond wire saw, Giant disc cutter |
| Marble Machines : | Single Blade Diamond Frames, Giant disc cutter |

Block cutting

Blocks have to be transformed into semi-finished product in the shape of large slabs. The cutting operation is considered as the cardinal point of the entire processing cycle. Generally the blocks are cut into slabs of 1 to 8 cm of thickness.

Location: Cutting centre
Granite Machines : Multi blade Gangsaw, Diamond multiwire saw, Giant disc
Marble Machines : Multi blade Diamond Frames, Giant disc cutter

Cut to size

The treated slabs are successively submitted to further cut in order to obtain a finished product with repetitive or customized dimensions.

Location: Finishing line for slabs
Machines: Trimming machine for slabs, Cross-Cutting machine for slabs. These machines may be installed on the polishing machine itself, or in two separate units, or in a single cutting unit.

Polishing

Polishing is the mechanical surface treatment aimed to reduce the roughness of the stone surface until good light reflecting properties are achieved. This process is fundamental for the exploitation of the aesthetic potential of an ornamental stone.

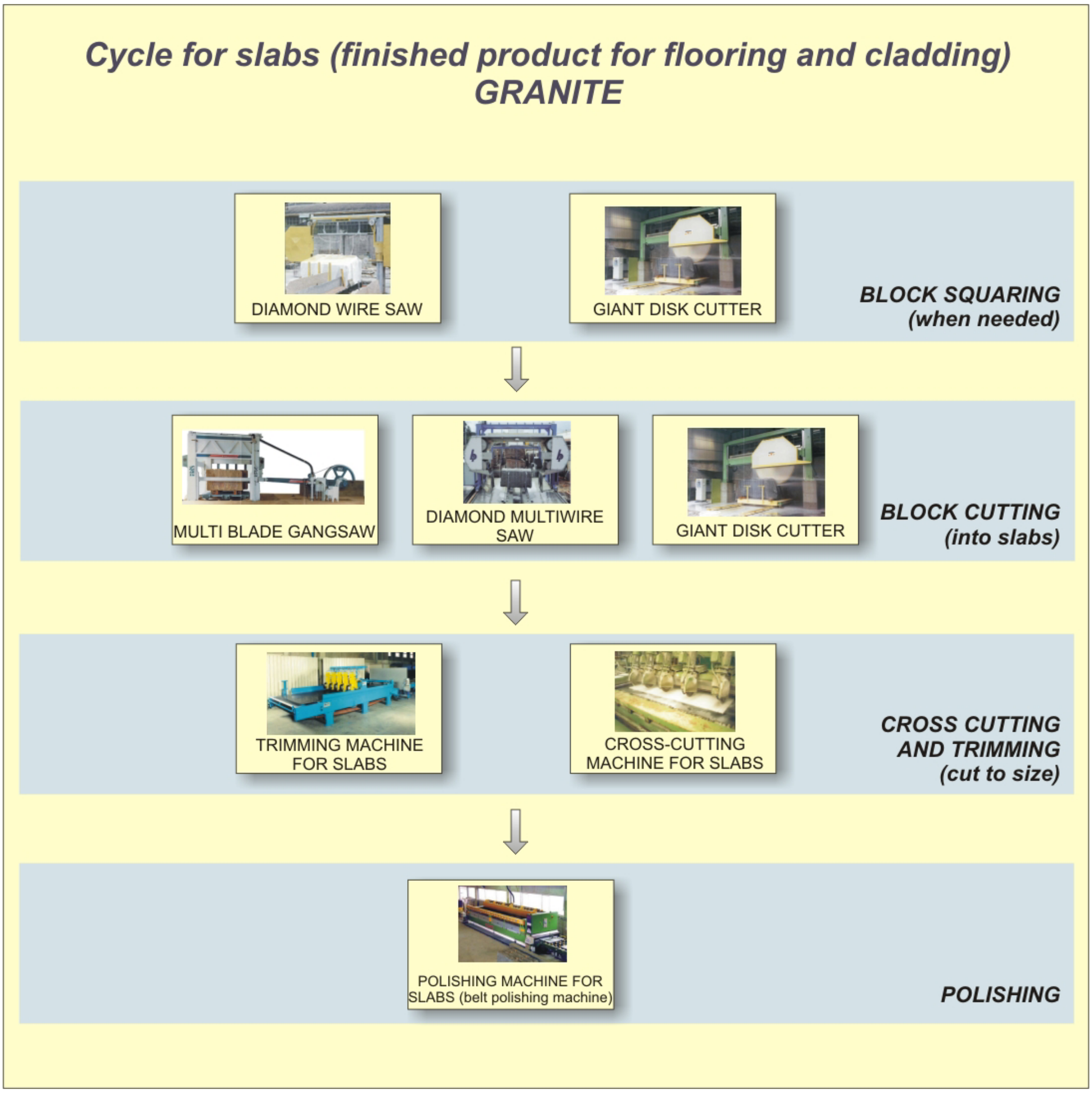
Location: Finishing line for slabs
Machine: Polishing machine for slabs (belt polishing machine).

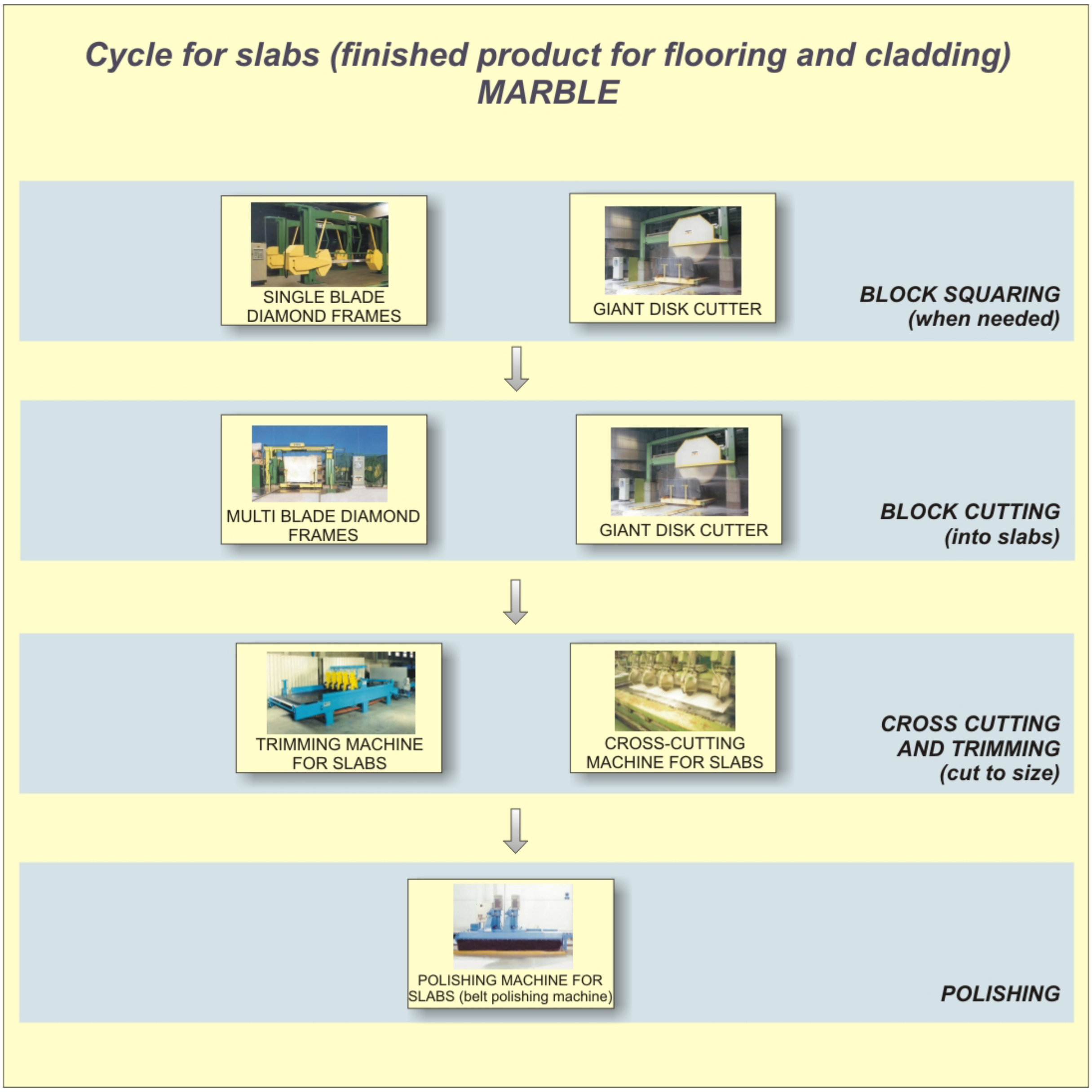
Handling

The slabs can be loaded / unloaded manually or automatically.

Location: Finishing line for slabs
Machines: Cranes, Automatic Loader and Unloader for slabs.

Cycle schematic diagram.






### *3.2.2. Cycle for slabs (semi finished product for delivery to the Stone Laboratory)*

This cycle is intended to produce large slabs, starting from a regular or commercial-sized block. The slabs will be eventually processed (in the Laboratory) in order to obtain finished smaller elements or customised elements.

The cycle can be summarised as follows:
- block squaring (when needed)
- block cutting (into slabs)
- polishing (when needed)
- auxiliary operations: handling

Squaring off operation

If a block presents a particular irregular shape, a preliminary operation of squaring off is necessary before cutting the block into slabs of the required thickness.

Location: Cutting centre
Granite Machines : Diamond wire saw, Giant disc cutter
Marble Machines : Single Blade Diamond Frames.

Block cutting

Blocks have to be transformed in semi-finished product in the shape of large slabs. The cutting operation is considered as the cardinal point of the entire processing cycle. Generally, the blocks are cut into slabs of 1 to 8 cm of thickness.

Location: Cutting centre
Granite Machines : Multi blade Gangsaw, Diamond multiwire saw, Giant disc
Marble Machines : Multi blade Diamond Frames, Giant disc cutter

Polishing

Polishing is the mechanical surface treatment aimed to reduce the roughness of the stone surface until good light reflecting properties are achieved. This process is fundamental for the exploitation of the aesthetic potential of an ornamental stone.

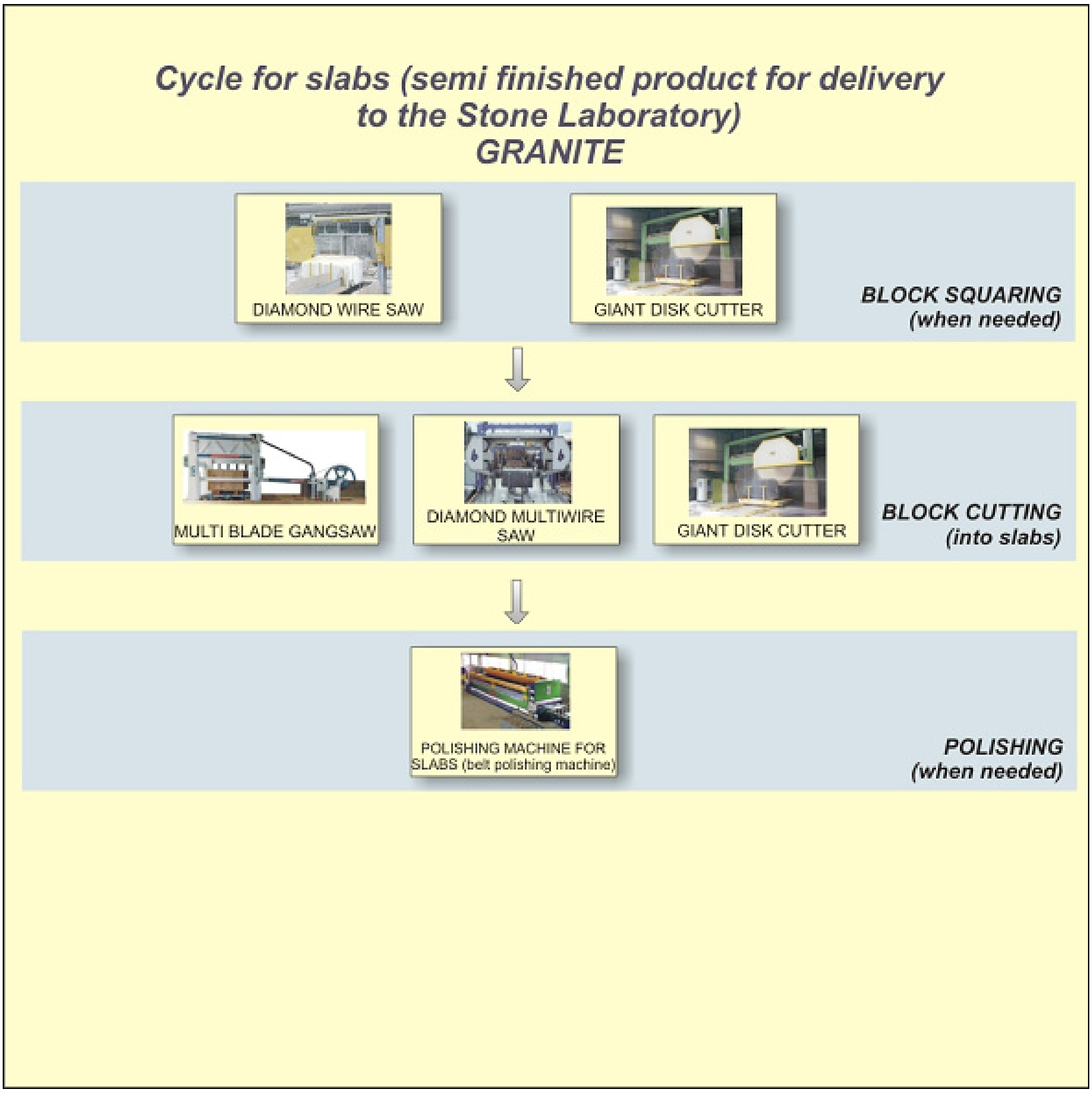
Location: Finishing line for slabs
Machine: Polishing machine for slabs (belt polishing machine).

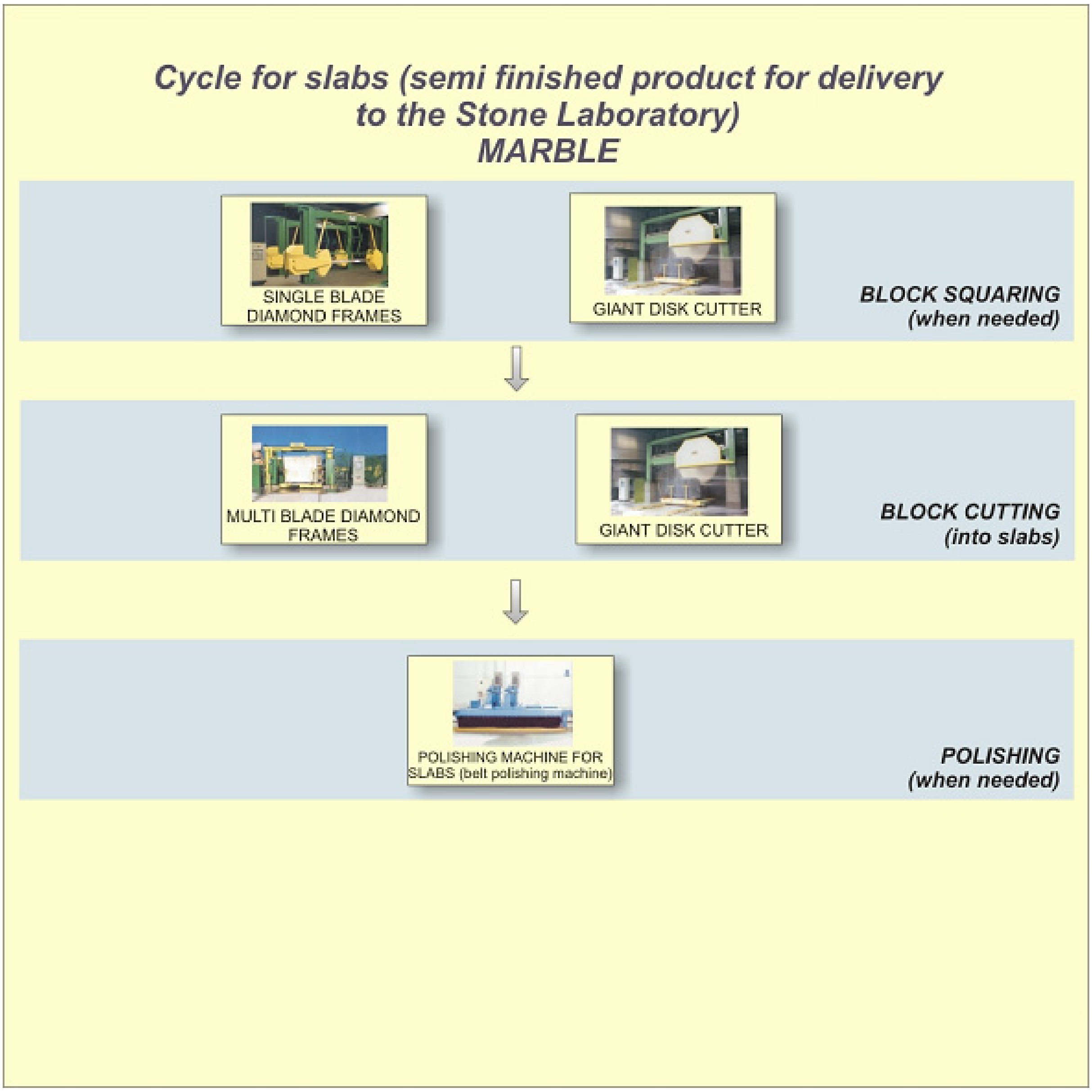
Handling

The slabs can be loaded / unloaded manually or automatically (current practice).

Location: Finishing line for slabs
Machines: Cranes, Automatic Loader and Unloader for slabs.

Cycle schematic diagram.






### *3.2.3. Cycle for solid small blocks (semi finished product for delivery to the Laboratory)*

This cycle is intended to produce small solid blocks, starting from a regular or commercial-sized block. The small blocks will be eventually processed (in the Laboratory) in order to obtain finished smaller elements or customised elements.

The cycle can be summarised as follows:

- block squaring (when needed)
- block cutting (into small blocks)
- polishing (when needed)
- auxiliary operations: handling

## Squaring off operation

If a block presents a particular irregular shape, a preliminary operation of squaring off is necessary before cutting it into slabs of the required thickness.

| | |
|---|---|
| Location: | Cutting centre |
| Granite Machines: | Diamond wire saw, Giant disc cutter |
| Marble Machines: | Single Blade Diamond Frame, Giant disc cutter |

## Cutting

Blocks have to be transformed in semi-finished products. The cutting operation is considered as the cardinal point of the entire processing cycle.

| | |
|---|---|
| Location: | Cutting centre |
| Granite Machines: | Diamond wire saw, Giant disc cutter |
| Marble Machines: | Multi blade Diamond Frames, Giant disc cutter |

## Polishing

Polishing is the mechanical surface treatment aimed to reduce the roughness of the stone surface until good light reflecting properties are achieved. This process is fundamental for the exploitation of the aesthetic potential of an ornamental stone.

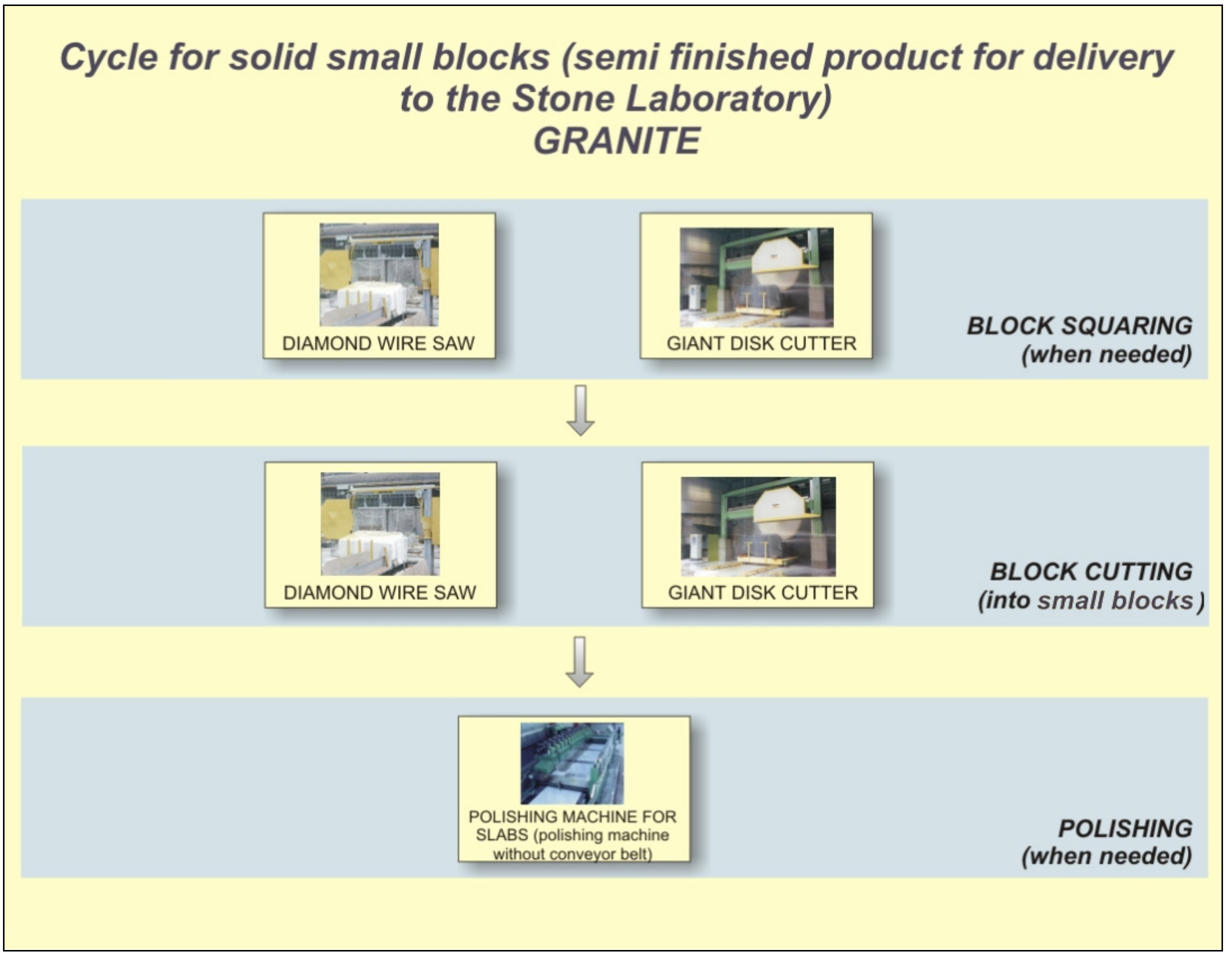
| | |
|---|---|
| Location: | Finishing line |
| Machine: | Polishing machine for small blocks (without conveyor belt). |

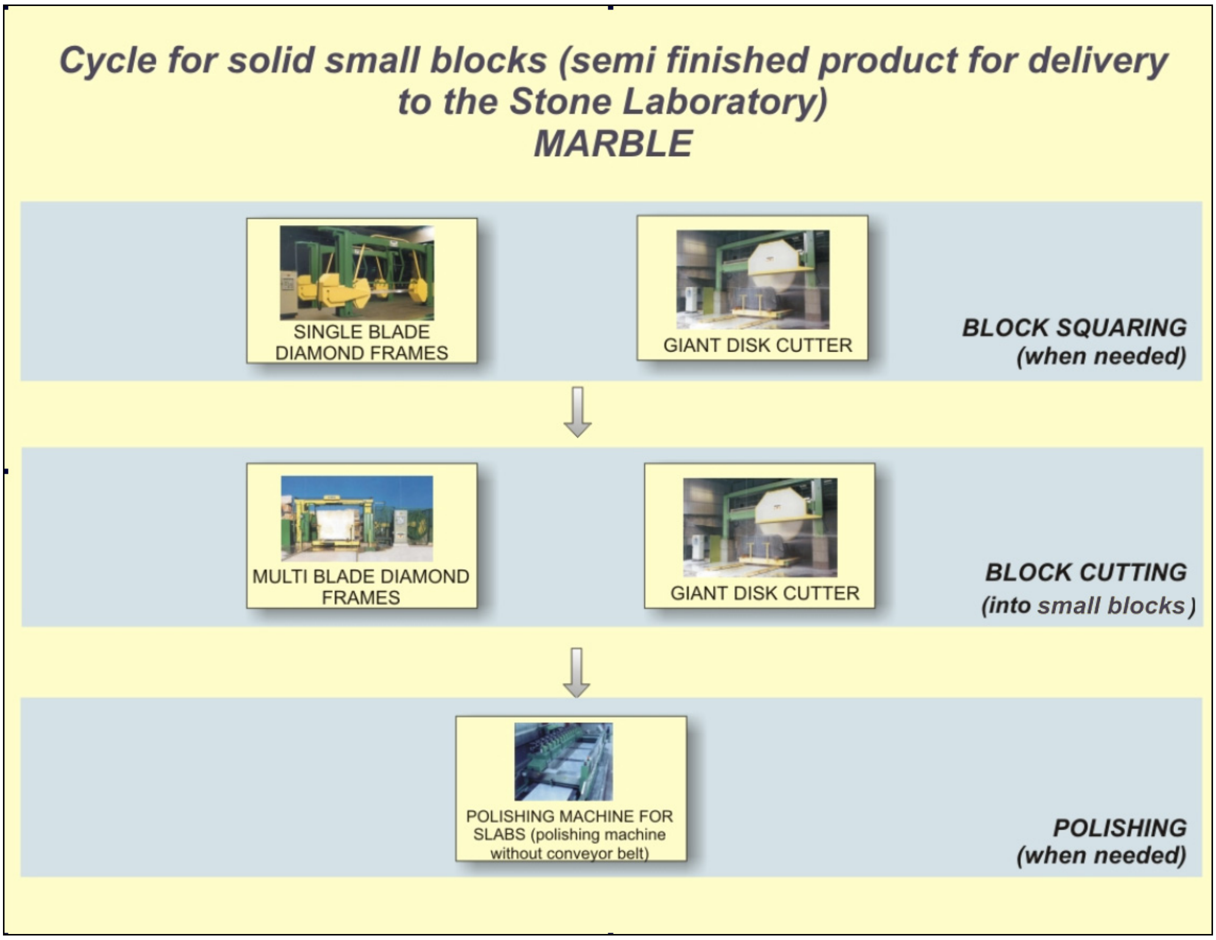
## Handling

The small blocks can be loaded / unloaded by means of cranes.

| | |
|---|---|
| Location: | Finishing line |
| Machines: | Cranes |

Cycle schematic diagram.






### *3.2.4. Cycle for tiles, from slabs*

This cycle is intended to produce tiles, after cutting the strips from slabs. The cycle begins with a regular or commercial-sized block. This cycle is not suitable for mass production of tiles, but it gives an additional degree of flexibility to a plant for slabs, allowing it to produce also tiles. It is intended that the finishing line in this cycle allows the same possible variations which apply to the finishing line of a cycle starting with a multi discs block cutter (mass production of tiles). See the relevant cycles for details.

A **granite** cycle can be summarised as follows:
- block squaring (when needed)
- block cutting (into slabs)
- (trimming) slabs cutting (into strips)

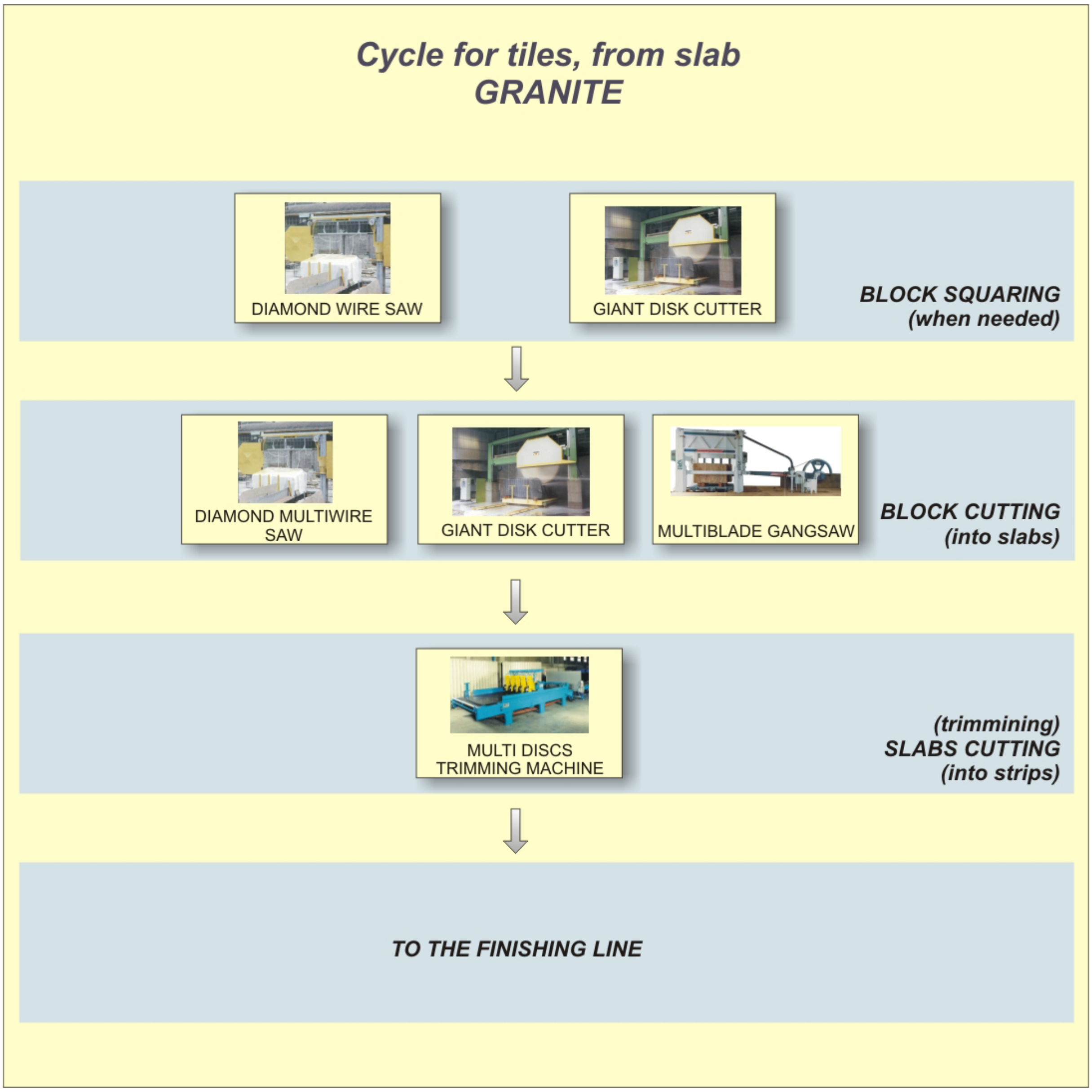
A finishing line for tile in a granite cycle includes:
- transport and load onto the finishing line
- strip pre-cut (lengthwise edges cross cutting)
- calibration
- polishing
- cut to size (cross-cutting)
- chamfering
- drying
- cleaning

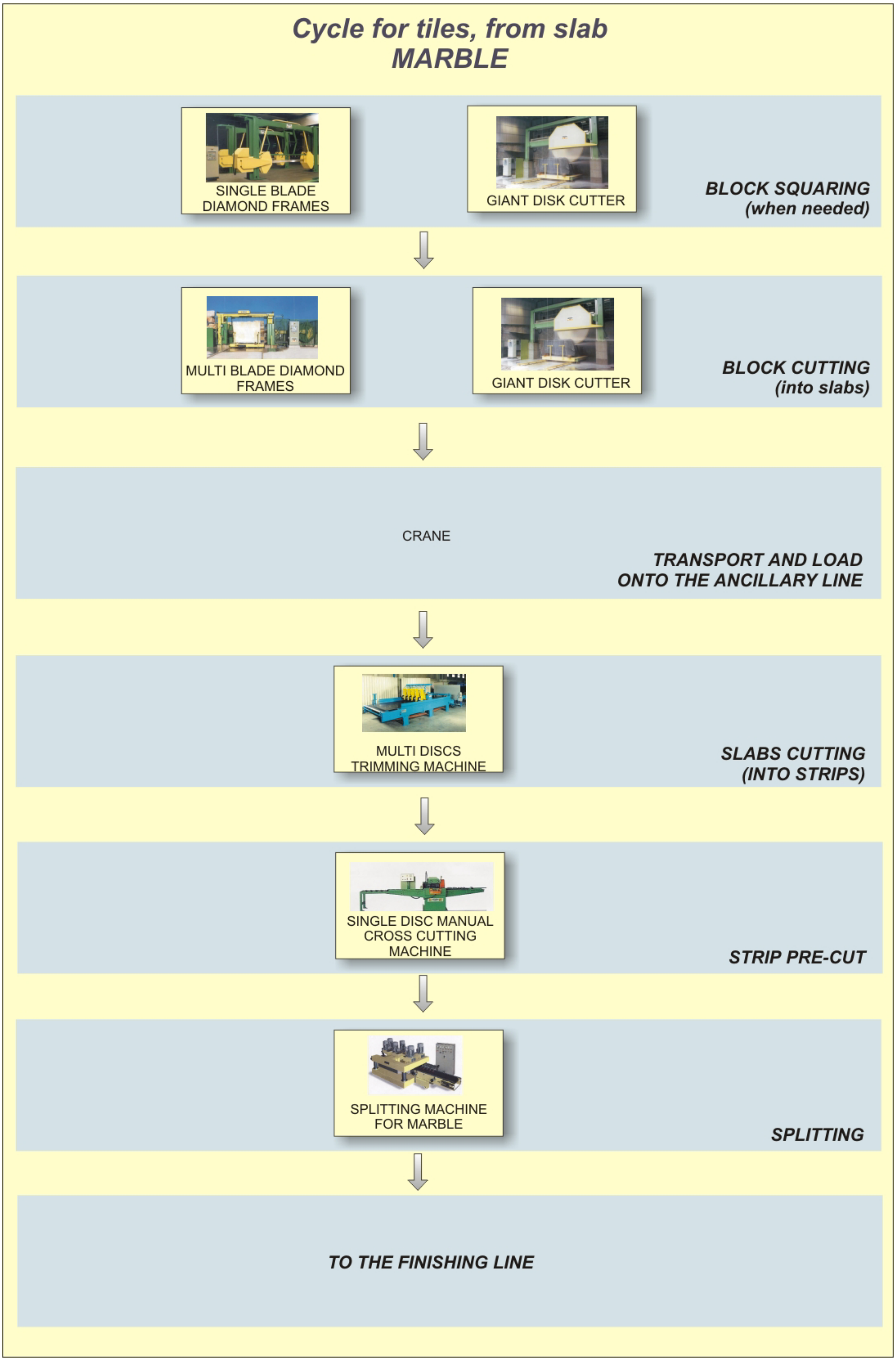
- packaging

A **marble** cycle can be summarised as follows:
- block squaring (when needed)
- block cutting (into slabs)
- transport and load onto the ancillary line
- (trimming) slabs cutting (into strips)
- strip pre-cut (lengthwise edges cross cutting)
- splitting (sectioning)
- transport and load onto the finishing line
- slabs cutting (into strips)

A finishing line for tiles in a marble cycle consists of:
- transport and load onto the finishing line
- strip pre-cut (lengthwise edges cross cutting)
- splitting (sectioning)
- transport and load onto the finishing line
- calibration
- polishing
- cut to size (cross-cutting)
- chamfering
- drying
- cleaning
- packaging

Cycle schematic diagram.




Cycle for tiles, from slab
MARBLE
SINGLE BLADE DIAMOND FRAMES
GIANT DISK CUTTER
BLOCK SQUARING (when needed)
MULTI BLADE DIAMOND FRAMES
GIANT DISK CUTTER
BLOCK CUTTING (into slabs)
CRANE
TRANSPORT AND LOAD ONTO THE ANCILLARY LINE
MULTI DISCS TRIMMING MACHINE
SLABS CUTTING (INTO STRIPS)
SINGLE DISC MANUAL CROSS CUTTING MACHINE
STRIP PRE-CUT
SPLITTING MACHINE FOR MARBLE
SPLITTING
TO THE FINISHING LINE

Squaring off operation

If a block presents a particular irregular shape, a preliminary operation of squaring off is necessary before cutting it into slabs of the required thickness.
Location: Cutting centre
Granite Machines: Diamond multiwire saw, Giant disc cutter
Marble Machines: Single Blade Diamond Gangsaw, Giant disc cutter

Cutting

Blocks have to be transformed in semi-finished products in the shape of large slabs. The cutting operation is considered as the cardinal point of the entire processing cycle. Generally, the blocks are cut into slabs generally of 1 to 8 cm of thickness.
Location: Cutting centre
Granite Machines: Diamond wire saw, Giant disc cutter, Multiblade Gangsaw
Marble Machines: Multi blade Diamond Framesl Giant disc cutter

(Trimming) slabs cutting (into strips)

The slabs are cut into strips.
Location: Cutting centre
Granite Machines: Multi discs trimming machine
Marble Machines: Multi discs trimming machine

Marble Splitting (sectioning)

This operation mainly aims to optimise the yield and productivity of the whole process. The strips are cut in the block cutter to double their thickness (plus process over size). Then, each thick strip is split into two thinner strips, which are fed to the finishing line.
Location: Cutting centre (ancillary line)
Machine (Marble): splitting machine for marble with horizontal discs

Strip pre-cut (edges cross cutting)

This operation mainly aims to optimise the yield of the finishing line. The strips are delivered to the finishing line after cutting the initial and final raw edges of the strip are cut away; moreover, the strips can be cut into length multiple of the final length (calculating also the length oversize).
Location: Cutting centre (ancillary line), Finishing line
Machine (Marble): single disc manual cross cutting machine
Machine (Granite): single disc, two discs automatic cross cutting machine

Handling

The slabs can be loaded / unloaded manually or automatically (current practice).
Location: Finishing line for slabs
Machines: Loader and Unloader for slabs

The operations described in the following are not mentioned above but are relevant to the ancillary and finishing line; see the relevant paragraph in the cycle for mass production of tiles.

### *3.2.5. Cycle for modular tiles (mass production)*

This cycle is intended to manufacture tiles that have standardised dimensions, starting from regular or commercial-sized blocks and also from damaged, below-size and irregular blocks.

It is possible to sketch few standard cycles encompassing marble and granite tiles, thin and super thin tiles and few other typical situations.

Typical cycle for marble tiles:
- cutting into strips
- transport and load onto the ancillary line
- strip pre-cut (edges cross cutting)
- splitting (sectioning)
- transport and load onto the finishing line
- calibration
- polishing
- cut to size (cross-cutting)
- chamfering
- drying
- cleaning
- packaging

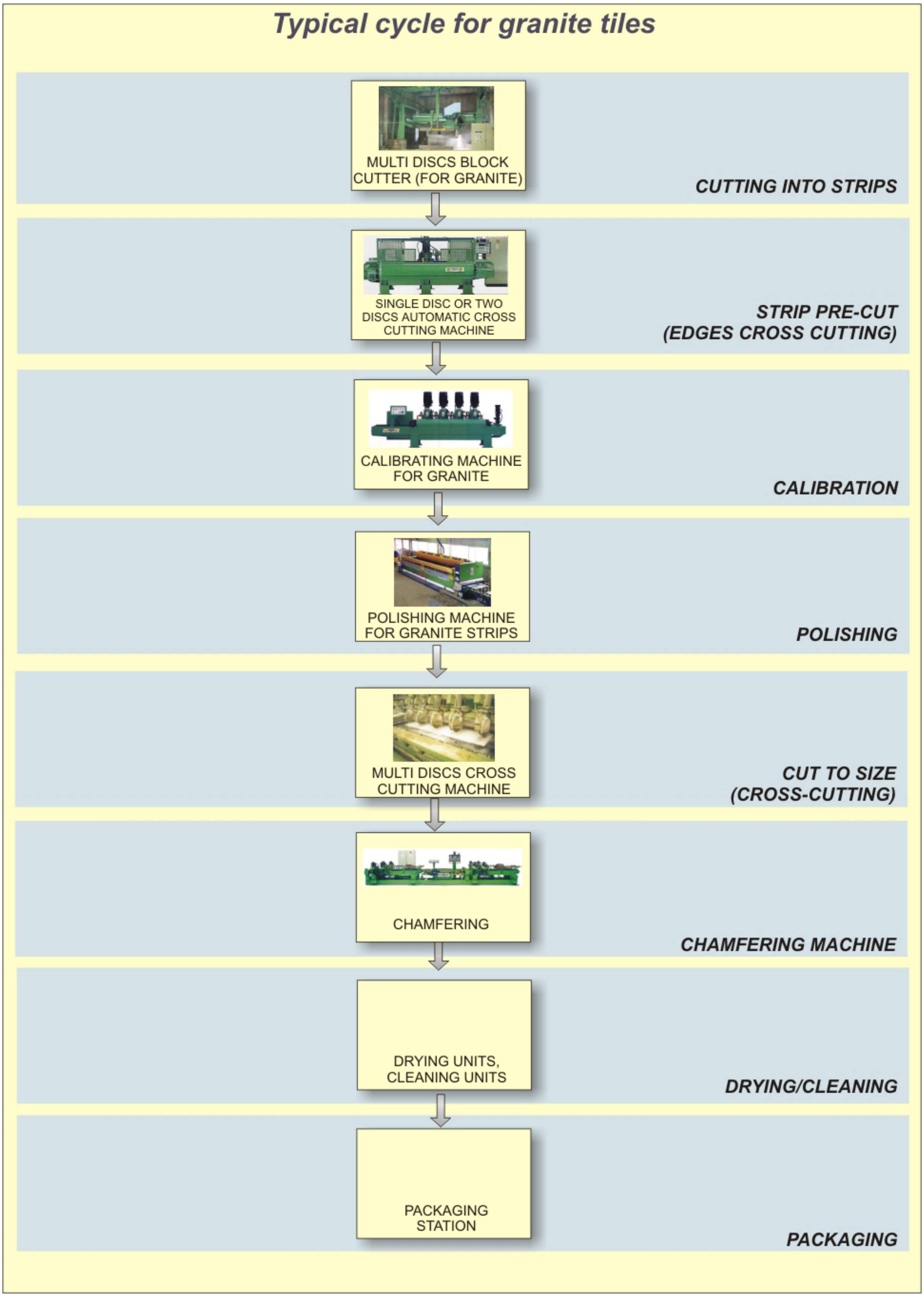
Typical cycle for marble tiles (with plastering/filling):
- cutting into strips
- transport and load onto the ancillary line
- strip pre-cut (edges cross cutting)
- splitting (sectioning)
- transport and load onto the finishing line
- calibration
- a) drying
- b) plastering (filling)
- c) drying of the filling compound
- polishing
- cut to size (cross-cutting)
- chamfering
- drying
- cleaning
- packaging

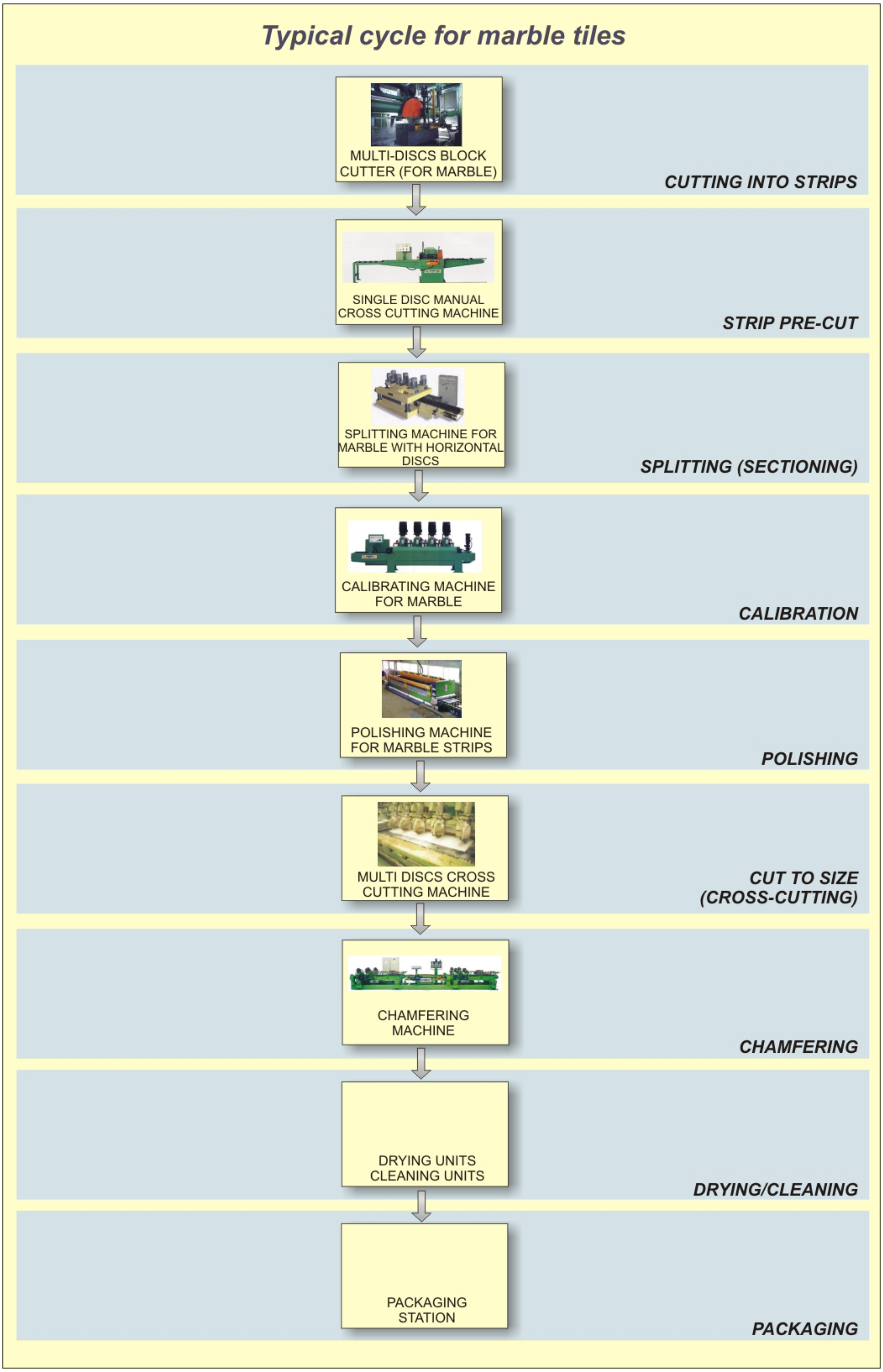
Typical cycle for granite tiles:
- cutting into strips
- transport and load onto the finishing line
- strip pre-cut (edges cross cutting)
- calibration
- polishing
- cut to size (cross-cutting)
- chamfering
- drying
- cleaning
- packaging

Typical cycle for granite super thin tiles:
- cutting into strips
- transport and load onto the finishing line
- strip pre-cut (edges cross cutting)
- calibration
- polishing (side 1)
- overturning
- polishing (side 2)
- splitting (sectioning)
- calibration (adjustment)
- cut to size (cross-cutting)
- chamfering
- drying
- cleaning
- packaging

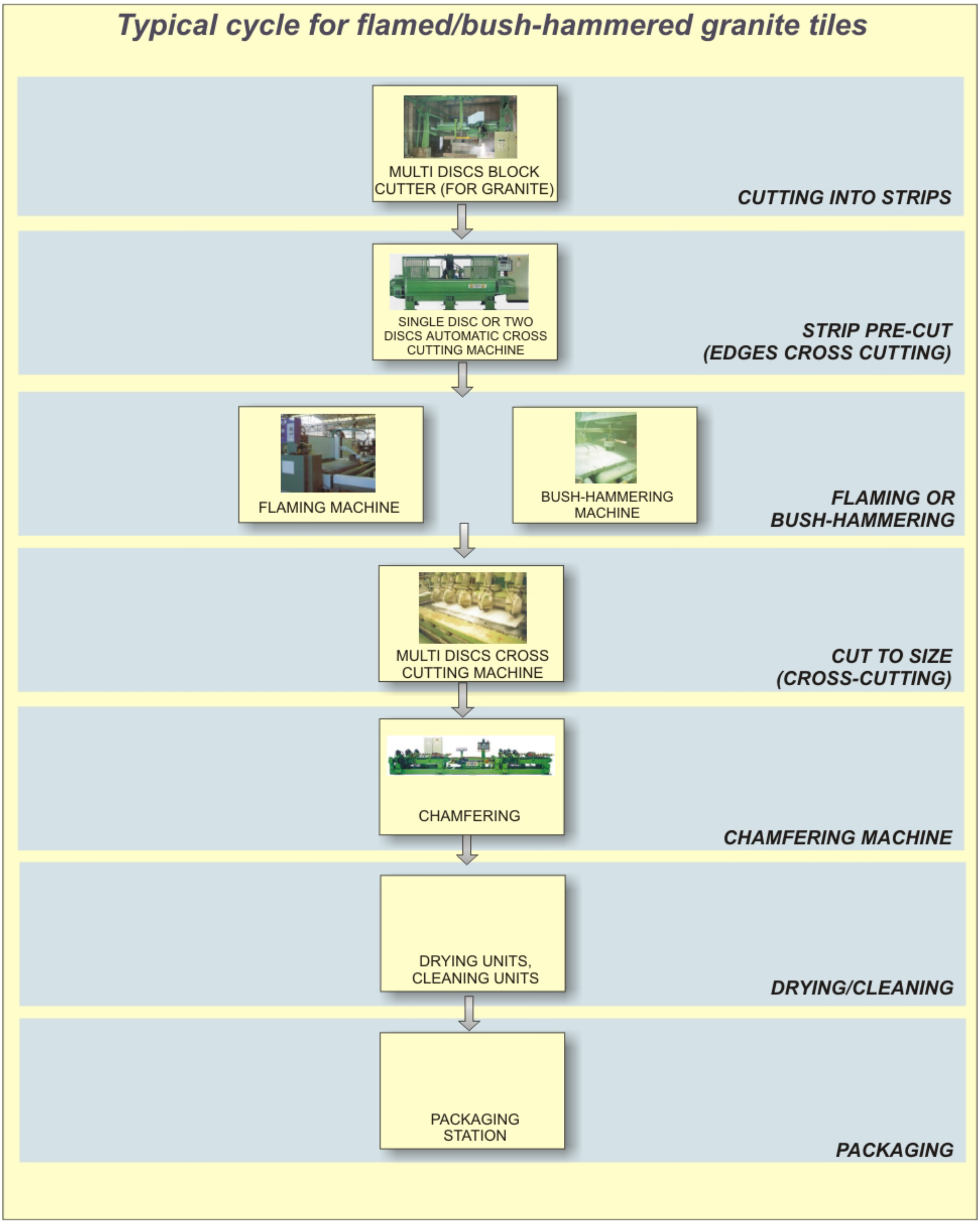
Typical cycle for flamed/bush-hammered granite tiles:
- cutting into strips
- transport and load onto the finishing line
- strip pre-cut (edges cross cutting)
- flaming or bush-hammering
- cut to size (cross-cutting)
- chamfering
- drying
- cleaning
- packaging

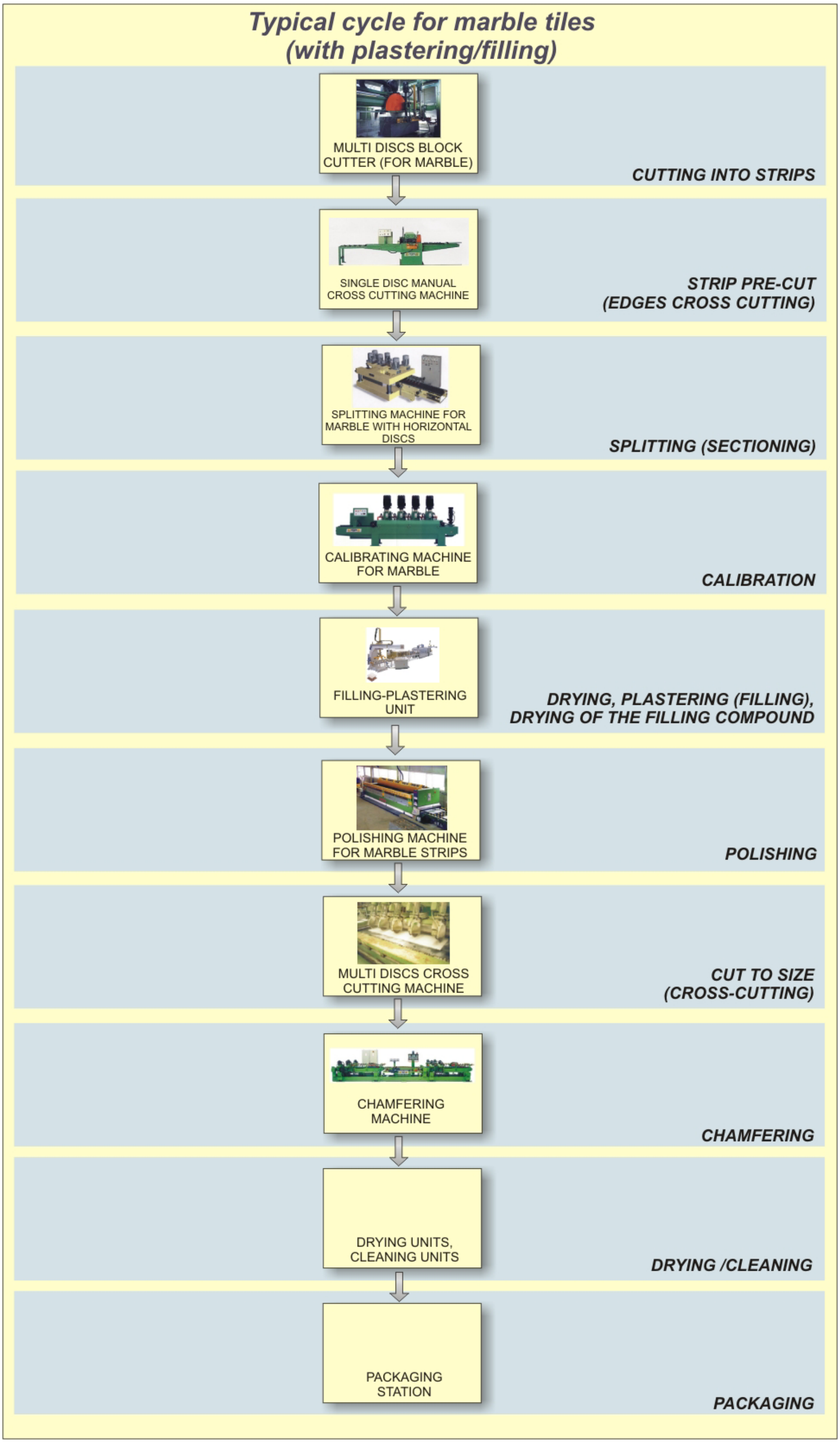
Cycles schematic diagrams.




Typical cycle for marble tiles
MULTI-DISCS BLOCK CUTTER (FOR MARBLE)
CUTTING INTO STRIPS
SINGLE DISC MANUAL CROSS CUTTING MACHINE
STRIP PRE-CUT
SPLITTING MACHINE FOR MARBLE WITH HORIZONTAL DISCS
SPLITTING (SECTIONING)
CALIBRATING MACHINE FOR MARBLE
CALIBRATION
POLISHING MACHINE FOR MARBLE STRIPS
POLISHING
MULTI DISCS CROSS CUTTING MACHINE
CUT TO SIZE (CROSS-CUTTING)
CHAMFERING MACHINE
CHAMFERING
DRYING UNITS CLEANING UNITS
DRYING/CLEANING
PACKAGING STATION
PACKAGING


Cycle for granite super thin tiles
MULTI DISCS BLOCK CUTTER (FOR GRANITE)
CUTTING INTO STRIPS
SINGLE DISC OR TWO DISCS AUTOMATIC CROSS CUTTING MACHINE
STRIP PRE-CUT (EDGES CROSS CUTTING)
CALIBRATING MACHINE FOR GRANITE
CALIBRATION
POLISHING MACHINE FOR GRANITE STRIPS
POLISHING (SIDE 1)
OVERTURNER
OVERTURNING
POLISHING MACHINE FOR GRANITE STRIPS
POLISHING (SIDE 2)
SPLITTING MACHINE FOR GRANITE
SPLITTING (SECTIONING)
CALIBRATING MACHINE FOR GRANITE
CALIBRATION (ADJUSTAMENT)
MULTI DISCS CROSS CUTTING MACHINE
CUT TO SIZE (CROSS-CUTTING)
CHAMFERING MACHINE
CHAMFERING
DRYING UNITS CLEANING UNITS
DRYING/CLEANING
PACKAGING STATION
PACKAGING


Typical cycle for flamed/bush-hammered granite tiles
MULTI DISCS BLOCK CUTTER (FOR GRANITE)
CUTTING INTO STRIPS
SINGLE DISC OR TWO DISCS AUTOMATIC CROSS CUTTING MACHINE
STRIP PRE-CUT (EDGES CROSS CUTTING)
FLAMING MACHINE
BUSH-HAMMERING MACHINE
FLAMING OR BUSH-HAMMERING
MULTI DISCS CROSS CUTTING MACHINE
CUT TO SIZE (CROSS-CUTTING)
CHAMFERING
CHAMFERING MACHINE
DRYING UNITS, CLEANING UNITS
DRYING/CLEANING
PACKAGING STATION
PACKAGING


Typical cycle for marble tiles
(with plastering/filling)
MULTI DISCS BLOCK CUTTER (FOR MARBLE)
CUTTING INTO STRIPS
SINGLE DISC MANUAL CROSS CUTTING MACHINE
STRIP PRE-CUT (EDGES CROSS CUTTING)
SPLITTING MACHINE FOR MARBLE WITH HORIZONTAL DISCS
SPLITTING (SECTIONING)
CALIBRATING MACHINE FOR MARBLE
CALIBRATION
FILLING-PLASTERING UNIT
DRYING, PLASTERING (FILLING), DRYING OF THE FILLING COMPOUND
POLISHING MACHINE FOR MARBLE STRIPS
POLISHING
MULTI DISCS CROSS CUTTING MACHINE
CUT TO SIZE (CROSS-CUTTING)
CHAMFERING MACHINE
CHAMFERING
DRYING UNITS, CLEANING UNITS
DRYING /CLEANING
PACKAGING STATION
PACKAGING

Squaring off operation

This operation is usually not needed, since the block cutter can generate a flat upper surface on the block with the first cutting operation, namely the "topping". Nevertheless, a previous block squaring may be considered as a viable option aiming to improve the productivity of the cutting centre.

Location: Cutting centre
Granite Machines : Diamond wire saw, Giant disc cutter
Marble Machines : Single Blade Diamond Frames.

Cutting into strips

This operation is performed in order to obtain preliminary products in the shape of strips, which have to be further refined.

Location: Cutting centre
Machine (Granite): Multi discs Block Cutter (for Granite)
Machine (Marble): Multi discs Block Cutter (for Marble)

Transport and load onto a finishing/ancillary line

Automatic downloader from the block cutters on pallets, which are then carried by operator driven fork trolleys.

Strip pre-cut (edges cross cutting)

This operation aims essentially to optimise the yield of the finishing line. The strips are delivered to the finishing line after cutting the initial and final raw edges of the strip; moreover, the strips can be cut into length multiple of the final length (calculating also the length oversize).

Location: Cutting centre (ancillary line), Finishing line
Machine (Marble): Single disc manual cross cutting machine
Machine (Granite): Single disc or two discs automatic cross cutting machine

Marble Splitting (sectioning)

This operation aims to optimise the yield and productivity of the whole process. The strips are cut in the block cutter to double the thickness (plus process over size). Then, each thick strip is split into two thinner strips, which are fed to the finishing line.

Location: Cutting centre (ancillary line)
Machine (Marble): Splitting machine for marble with horizontal discs

Granite Splitting (sectioning)

This operation mainly aims to manufacture super-thin tiles (8 mm or less). It can also aim to optimise the yield and productivity of the whole process, as in the marble plants.

Location: Finishing line
Machine (Granite): Splitting machine for granite

Calibration

This operation aims to adjust the strip thickness/flatness to a prescribed tolerance, in order to correct slight shape errors generated in the cutting centre. The grinding (calibrating) head must be accurately controlled in position. The machine structure must be rigid enough to absorb the heavy loads without deformations and without loosing the control on the position.

Location: Finishing line

Machine (Marble): Calibrating machine for granite
Machine (Granite): Calibrating machine for marble

Polishing

This operation is aimed to give light reflecting properties to the stone surface. Such feature is obtained by reducing the surface roughness to a very small average value, comparable with the wavelength of visible light. This is achieved by progressively grinding the stone surface with a sequence of many polishing heads, equipped with polishing tools having mesh of decreasing size. The load exerted by each head is carefully controlled in order to optimise the process, while each head must move vertically in order to follow the surface macro geometry.

Location: Finishing line
Machine (Marble): Polishing machine for granite strips
Machine (Granite): Polishing machine for marble strips

Note. The two operations (calibrating and polishing) can be performed at the same machine, in two subsequent sections, first calibration, then polishing.

Cut to size

The strips are cut into the required standard shape and dimensions.
Location: Finishing line
Machine (Marble): Multi discs cross cutting machine
Machine (Granite): Multi discs cross cutting machine

Chamfering

The machine calibrates first the opposite sides of each tile, in order to adjust the size in tolerance, by removing the left oversize. Then, the chamfers are machined on the four upper edges of each tile, at the desired inclination.
Location: Finishing line
Machine (Marble): Chamfering machine
Machine (Granite): Chamfering machine

Drying, Cleaning

These operations are necessary in order to deliver clean and dry tiles to the packaging station. In the whole process water is used as lubro-refrigerating fluid. Cleaning is generally performed by means of soft rotating brushes, while drying is performed by cold/hot air jets.
Location: Finishing line
Machine (Marble): Drying units, Cleaning units

Packaging

This operation aims to arrange the product in standard packages, as required for mass production.
Location: Finishing line
Machine (Marble): Manual packaging station
Automatic packaging machine (current practice)

Plastering (Filling)

This operation aims to repair and/or consolidate the surface of the tiles/strips by resins or similar products, in order to improve the aesthetical and/or mechanical features of the product.

This operation applies especially to some kind of limestone. Plastering (filling) includes generally one or more cleaning/drying units to prepare the surface, the proper plastering unit (where the resin compound is applied to stone surface) and other drying units, which are needed to solidify the plastering compound.
Location: Finishing line
Machine (Granite): Filling-Plastering unit

Flaming

Flaming aims to give a rough surface to the tiles, which therefore become suitable for anti-slipping applications (flooring of outdoors) or gain a special visual aspect (walls cladding). The Flaming Machine is also present as a lone standing laboratory machine, instead of being part of a mass production line.
Location: Finishing line (Stone laboratory)
Machine (Granite): Flaming machine

Bush-hammering

This operation aims to roughen the whole of part of the tiles surface as done by the Flaming process for similar applications. The rough finishing is achieved here by a mechanical machining tool head (the *bush-hammer*). The Bush-hammering Machine is also present as a lone standing laboratory machine, instead of being part of a mass production line.
Location: Finishing line (Stone laboratory)
Machine (Granite , Marble): Bush-hammering machine

Overturning, conveying and similar
The conveyors (and similar) can be on belts, rollers, or wheels. The technology is not specific of the sector. According to the layout and the specific need of the cycle Conveyors, Curves, Deviators or Overturners can be installed.

### *3.2.6. Manufacturing of dimensional stones (Stone Laboratory)*

The semi-finished products are transformed into finished products, a wide range of machines operating in small batches or manually. Usually these machines require skilled manpower, making this manufacturing process sometimes more related to artwork than to mass production. It is possible, but not very useful, to sketch typical cycles for this kind of processes, with the possible exception of those products which can be better manufactured in bigger batches using high productivity advanced machines (say kitchen tops), which are often manufactured by:
- CN Bridge milling machines equipped with disc and finger mill;
- CN machining centre
- Disc bridge milling machine, followed by a contouring machine;

See the paragraphs relevant to the machines for Stone Laboratory.

## 3.3. SINGLE DIAMOND BLADE FRAME

Material: Marble
Inlet: Stone blocks
Outlet: Squared blocks, Slabs, small blocks
Location: Cutting centre
Cycles: Slabs, small blocks, dimensional stones

### *3.3.1. Description*

This machine has a metal frame with a blade, which moves back and forward over the block. The blade is equipped with diamond segments and cuts the block with a constant supply of cooling water and an adjustable lowering speed. The blade tension can be applied by means of a hydraulic, mechanical, or pneumatic system (the last one is the current practice: faster, cleaner and reliable). The yellow pipe shown in Figure 21 is the compressed air pipe connecting the two sides of the movable blade tensioning system. The feeding motion is given by the vertical displacements of the blade holders (see Figure 21). Alternatively, it may come from the vertical displacement of the block carrier.

### *3.3.2. Applications*

This system is only used for marble and related soft materials. It is considered as an old-technology, and it could be replaced by diamond wire plants in case that the disadvantages of diamond wires are efficiently met.

### *3.3.3. Characteristics*

The features of Table 15 are an indication of the possible characteristics of this kind of machines.

**Table 15.** Characteristics of single blade plant

| | |
|---|---|
| **Cutting length (mm)** | 3000-4500 |
| **Cutting Height (mm)** | 2000-2100 |
| **Blade length (mm)** | 3600-5100 |
| **Blade stroke length (mm)** | 420-450 |
| **Flywheel revolutions (rpm)** | 100-160 |
| **Lowering speed (adjustable) (m/h)** | 0.4 -1.4 |
| **Cooling water consumption (l/min)** | 50-100 |
| **Main motor power (kW)** | 18-22 |
| **Lowering motor (kW)** | 2.2 |
| **Installed electric power (kW)** | 30 |
| **Machine length (mm)** | 8000 |
| **Machine width (mm)** | 1000 |
| **Machine height (mm)** | 5820 |
| **Machine weight (tn)** | 4-7 |

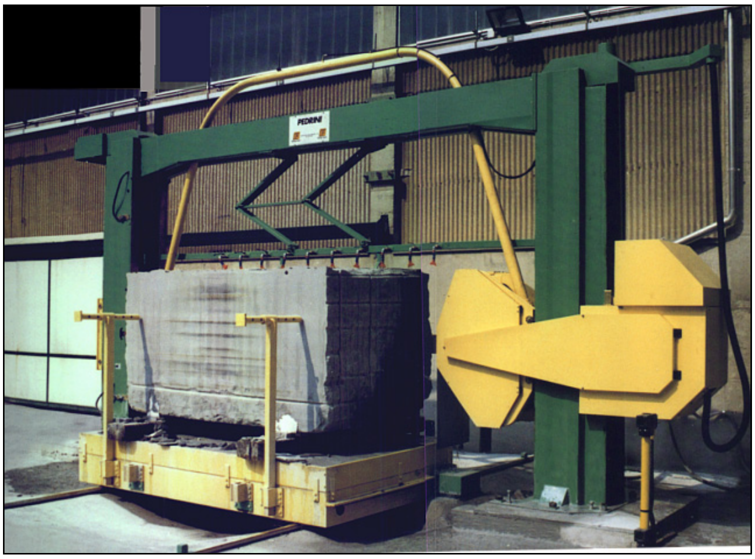


**Figure 21.** View of a single blade diamond frame

### *3.3.4. Advantages/Disadvantages*

The main limitation of this machine is that it can only work Marble and soft stones (not granite). Alternative machines are given below along with their advantages and disadvantages compared with the single blade diamond frame.

Giant disc cutter:
(+) also Granite
(+) Precise cut
(+) Higher productivity
(+) lower cost of tool
(-) Limitations in height (about 1.7 m)
(-) Wider cut (less yield)

Single Diamond wire:
(+) also Granite
(+) higher productivity
(-) Wider cut (less yield)
(-) Less precise cut
(-) Higher cost of tool

Multiblade diamond frame:
(+) Higher productivity
(-) Higher investment cost

The multiblade is preferred for slabs, not for block squaring.

## 3.4. Stationary Diamond Wire Frame (or Cutter)

| | |
|---|---|
| Material: | Marble, granite |
| Inlet: | Stone blocks |
| Outlet: | Squared blocks, Slabs, small blocks |
| Location: | Cutting centre |
| Cycles: | Slabs, small blocks, dimensional stones |

### 3.4.1. *Description*

This machine, performing the same function as the single blade machine, consists of a steel frame and two large diameter wheels to guide the diamond wire taut. It has an open structure and the block to be squared is positioned under the wire in the most appropriate way. The sawing mechanism is the same with that used in the case of diamond wire cutters for quarry work, and, as for quarrying, it requires a supply of cooling water.

### 3.4.2. *Applications*

Unlike single diamond blade frame, this machine is appropriate to cut both granite and marble.

### 3.4.3. *Characteristics*

The following features shown in Table 16 are an indication of the possible characteristics of this kind of machines.

**Table 16.** Characteristics of a stationary diamond wire plant

| | | |
|---|---|---|
| **Cutting length (mm)** | 3500 | 4000-4500 |
| **Cutting Height (mm)** | 2100-2200 | 2100-2200 |
| **Wire length (mm)** | 19 | 19-21 |
| **Drive flywheel motor (kW)** | 15 | 15-22 |
| **Lowering feed motor (kW)** | 2.2 | 2.2 |
| **Wire speed (m/s)** | 5-40 | 5-40 |
| **Lowering speed (adjustable) (m/h)** | 0.1-5 | 0.1-5 |
| **Flywheel diameter (mm)** | 2000-2150 | 2000-2150 |
| **Cooling water consumption (l/min)** | 15-100 | 15-100 |
| **Machine length (mm)** | 8500-9000 | 8500-9500 |
| **Machine width (mm)** | 1200 | 3200 |
| **Machine height (mm)** | 5200 | 5700 |
| **Machine weight (tn)** | 3-4 | 3-4 |

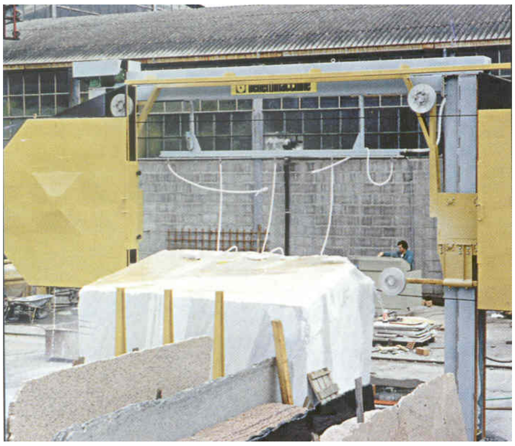


**Figure 22.** View of diamond wire plant

### 3.4.4. *Advantages/Disadvantages*

This machine is preferred for block squaring. It can work Marble and Granite. Alternative machines compared with the stationary diamond wire frame, are given below (at the state of the atr).

Giant disc cutter:
(+) narrow cut (better yield)
(+) Precise cut
(+) lower cost of tool
(-) Limitations in height (about 1.7 m)

Single Blade cutting frame:
(+) Narrow cut (better yield)
(+) Precise cut
(+) Lower cost of tool
(-) lower productivity
(-) marble only

## 3.5. MULTIWIRE FRAME (OR CUTTER)

| | |
|---|---|
| Material: | Marble, granite |
| Inlet: | Stone blocks |
| Outlet: | Slabs, small blocks |
| Location: | Cutting centre |
| Cycles: | Slabs, small blocks, dimensional stones, tiles |

### 3.5.1. *Description*

This is a promising machine whose application is addressed to cut blocks into slabs using multiple diamond wires instead of blade gangsaws. Its structure is very similar to that of the monowire plant, but with separate and independent flywheels. The wires speed is adjustable using an inverter and the entire system operation is completely automatic and PLC managed.

**Figure 23.** Multiwire diamond frame with 60 wires

### *3.5.2. Applications*

The machine can be used to cut into slabs both marble and granite. Minor vibration and noise level and possibility to cut both granite and marble by simply changing the configuration of the wire make this machine particularly competitive.

### *3.5.3. Characteristics*

The following features (Table 17) are an indication of the possible characteristics of this kind of machines.

**Table 17.** Characteristics of multiwire plant

| | |
|---|---|
| **Max number of wires** | 60 |
| **Slab thickness (min-max) (mm)** | 21-516 |
| **Working width (mm)** | 3500 |
| **Working height (mm)** | 2100 |
| **Wire speed (m/s)** | 0-40 |
| **Wire length (m)** | 24.4-25.4 |
| **Wire diameter (mm)** | 8 |
| **Flywheel diameter (mm)** | 2350 |
| **Installed power (kW)** | 55-200 |
| **Machine length (mm)** | 11500-12000 |
| **Machine width (mm)** | 2650 |
| **Machine height (mm)** | 5300 |
| **Machine weight (tn)** | 30 |

### *3.5.4. Advantages/Disadvantages*

This machine is competitive for slabs cutting and should therefore being compared with Multiblade diamond frames (marble). Multiblade gangsaws (granite), Giant disc cutter (marble and granite) and single blade diamond frames (marble).

Giant disc cutter:
(+) Narrow cut (better yield)
(+) Precise cut
(+) Lower cost of tool
(+) Very reliable
(-) Limitations in height (about 1.7 m)
(-) Much lower productivity

Multi Blade diamond cutting frame:
(+) Narrow cut (better yield)
(+) Precise cut
(+) Lower cost of tool
(+) More reliable
(-) Only marble
(-) Lower productivity

Single blade diamond cutting frame:

(+) Narrow cut (better yield)
(+) Precise cut
(+) Lower cost of tool
(+) More reliable
(-) Only marble
(-) Much lower productivity

Multi Blade gangsaw:
(+) Precise cut
(+) Lower cost of tool
(-) Much lower productivity
(-) Specific for granite

## 3.6. MULTI-BLADE CUTTING FRAME, WITH DIAMOND BLADES

Material: Marble
Inlet: Stone blocks
Outlet: Slabs, small blocks
Location: Cutting centre
Cycles: Slabs, small blocks, dimensional stones

### *3.6.1. Description*

A block, after being squared, is cut into large slabs of small-medium thickness. The multi-blade cutting frame is the most common technology for this purpose, basically consisting of a large and heavy frame, a blade carrier frame and a set of blades, which are moved back and forward alternatively along the cutting surface, with a programmed downcut speed. The rotation of a heavy flywheel controls the alternative movements of the blade holder frame: two cranks connected to the flywheel axis extremities generate the length of the cutting movement, which is transmitted to the blade holder frame by two connecting rods.

There are two major types of gangsaw: the diamond blade to saw marble and other soft stones and the grit gangsaw used for granite and hard stones. The two types of machine are not interchangeable.

### *3.6.2. Applications*

In case of marble cutting, the sawing is obtained through the action on the stone of the diamond segments brazed on the blade. The cut is performed during the motion of the blade, in both directions (back and forward cutting). This technique can be applied in sawing of “soft stones” (marble), because of their higher machinability; in granite sawing this technique is not applied. Furthermore, the machine for marble needs to exert less pressure and therefore, the overall mechanics and frame are more lightweight, if compared with a similar machine for granite.

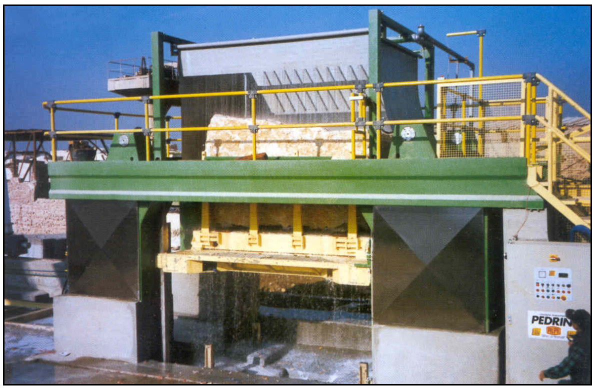


**Figure 24.** View of multi-blade diamond frame for marble


**Figure 25.** View of an 80 blades diamond frame for marble

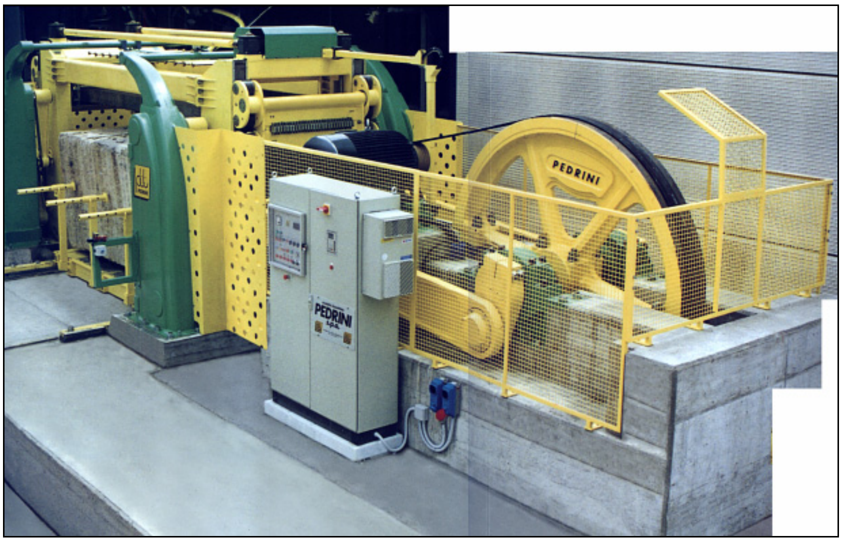



**Figure 26.** View of a 40 blades diamond frame for marble

### 3.6.3. *Characteristics*

The following features (Table 18) are an indication of the possible characteristics of this kind of machines.

**Table 18.** Characteristics of multi-blade cutting frame for marble applications

| **Marble** | | | | |
|---|---|---|---|---|
| **Blade Number (2cm thickness)** | 30 | 40 | 60 | 70-100 |
| **Blade length (mm)** | 3400-4000 | 3400-4000 | | 4200-4300 |
| **Cutting length (mm)** | 2600-3200 | 2600-3200 | 3200 | 3250 |
| **Cutting Height (mm)** | 1800-1900 | 1800-1900 | 2000 | 1800-2000 |
| **Cutting width** | 900-1100 | 1300 | 1700 | 1800-2000 |
| **Drive flywheel motor (kW)** | 55 | 75 | 90 | 110-130 |
| **Lowering motor (kW)** | 3 | 3 | 5 | 7 |
| **Blade stroke length (mm)** | 500 | 500 | 520 | 600-800 |
| **Blade strokes (rpm)** | 90-100 | 90-100 | 90-100 | 90-120 |
| **Lowering speed (adjustable) (cm/h)** | 0-40 | 0-40 | 0-40 | 0-50 |
| **Flywheel diameter (mm)** | 2500 | 2800 | 3000 | 3300 |
| **Cooling water consumption (l/min per blade)** | 9-10 | 9-10 | 9-10 | 9-10 |
| **Machine length (mm)** | 13000 | 13000 | 13000-15000 | 13000-15000 |
| **Machine width (mm)** | 3700 | 3700 | 4500 | 3700-4500 |
| **Machine height (mm)** | 3000 | 3000 | 4400 | 3000-5400 |
| **Machine weight (tn)** | 22 | 25 | 30 | 40-50 |
| **Blade Tension** | hydraulic | hydraulic | hydraulic | hydraulic |

### 3.6.4. *Advantages/Disadvantages*

This machine is competitive for Marble slabs cutting only, and should therefore being compared with Giant disc cutter (marble and granite), Single Blade diamond frames and partly with Multiwire frames.

Giant disc cutter:
(+) Also Granite
(+) Lower cost of tool
(-) Limitations in height (about 1.7 m)
(-) Lower productivity

Single blade diamond cutting frame:
(+) Narrow cut (better yield)
(+) Precise cut
(+) Lower cost of tool
(+) More reliable
(-) Only marble
(-) Much lower productivity

Multi wire:

(+) Also granite
(+) Higher productivity
(-) Wider cut (less yield)
(-) Less precise cut
(-) Higher cost of tool
(-) Less reliable

## 3.7. MULTI-BLADE GANGSAW

| | |
|---|---|
| Material: | Granite |
| Inlet: | Stone blocks |
| Outlet: | Slabs, small blocks |
| Location: | Cutting centre |
| Cycles: | Slabs, small blocks, dimensional stones |

### *3.7.1. Description*

A block, after being squared, is cut into large slabs of small-medium thickness. The multi-blade gangsaw is the most common technology for this purpose, basically consisting of a large and heavy frame, a blade carrier frame and a set of blades, which are moved back and forward alternatively along the cutting surface, with a programmed downcut speed. The rotation of a heavy flywheel controls the alternative movements of the blade holder frame: two cranks connected to the flywheel axis extremities generate the length of the cutting movement, which is transmitted to the blade holder frame by two connecting rods.

There are two major types of gangsaw: the diamond blade to saw marble and other soft stones and the grit gangsaw used for granite and hard stones. The two types of machine are not interchangeable.

### *3.7.2. Applications*

In the case of granite, the cut is obtained through the friction created by the combined action of steel blades and an abrasive slurry (composed of water, lime and grit). The cutting action is performed by the grit. The slurry is fed continuously from the top of the machine and is maintained in efficient working condition by replacing the exhausted parts with fresh fluid.

In current practice, it is impossible to mount diamond segments on the blade, which are therefore purely steel. The cutting action is performed by the grit. The reason for that is the following: the reciprocal motion of the diamond tipped tools on the hard stone is harmful for the diamond segment, because each diamond crystal is subjected to an alternate action, which prevents the formation of a stabilising microstructure (the “tail”) between each diamond crystal and its support (the bond). On the other hand, in discs cutting, the sense of motion is always the same and the diamond reaches steady performance condition after a short running period, while in marble cutting, the stone is soft enough to allow such reciprocal motion without damaging the diamond segments.

Many different solutions have been tried to solve this problem, in order to apply diamond tools for cutting slabs with alternate motions, but (so far) none of them was completely successful.

The blade carrier may be characterized by a swinging movement added to the downward movement, resulting in a violent contact between the blades and the block surface. During the backward movement of the blades, allowing the cutting, the blade carrier frame continues its downward movement to maintain the blades-block contact.

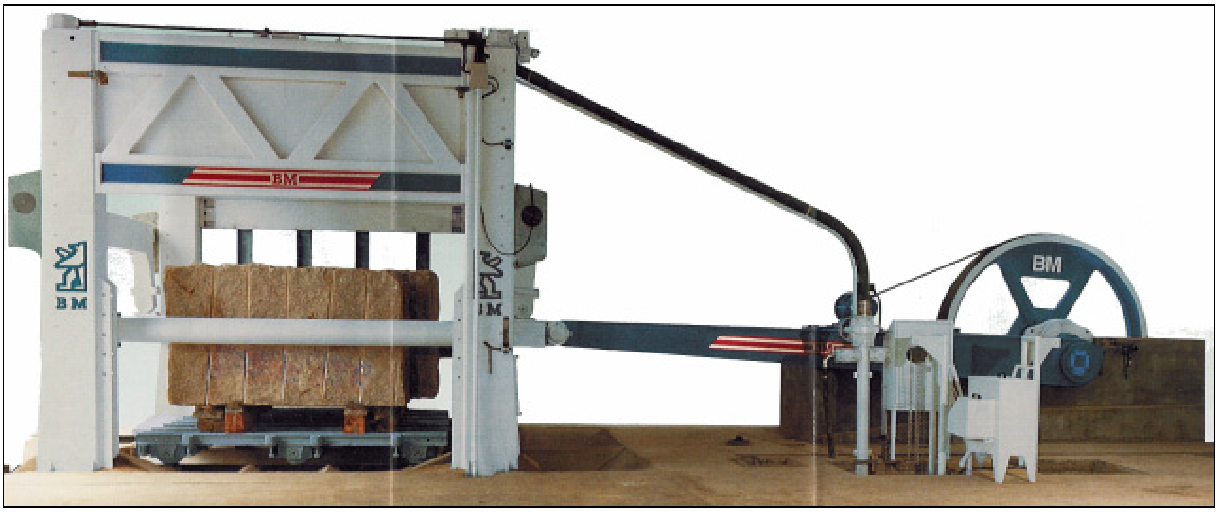



**Figure 27.** View of multi-blade gangsaw for granite

### *3.7.3. Characteristics*

The following features (Table 19) are an indication of the possible characteristics of this kind of machines.

**Table 19.** Characteristics of multi-blade gangsaw for granite applications

| **Granite** | | | | |
|---|---|---|---|---|
| **Blade Number (2cm thickness)** | 130 | 140 | 150 | 170-230 |
| **Blade length (mm)** | | | | |
| **Cutting length (mm)** | 2500-4000 | 2500-4000 | 2500-4000 | 2500-3600 |
| **Cutting Height (mm)** | 2200 | 2200 | 2000-2200 | 2100-200 |
| **Cutting width** | 3500-3800 | 4200-4500 | 3000-4500 | 4900-6400 |
| **Drive flywheel motor (kW)** | 55 | 55 | 75 | 90-170 |
| **Lowering motor (kW)** | 4 | 4 | 5.5 | 7.5 |
| **Abrasive mixture motor power (kW)** | 30 | 30 | 37 | 45-55 |
| **Blade stroke length (mm)** | | | 450-600 | |
| **Blade strokes (rpm)** | 75 | 75 | 70-80 | 60-75 |
| **Lowering speed (adjustable) (cm/h)** | 0-5 | 0-5 | 0-5 | 0-5 |
| **Flywheel diameter (mm)** | | | | |
| **Cooling water consumption (l/day)** | 3000 | 3500 | 3500 | 4000 |
| **Machine length (mm)** | 16000-17000 | 16000-17000 | 17500-18500 | 17000 |
| **Machine width (mm)** | 5700-6000 | 6400-6800 | 5700-7000 | 5000-6000 |
| **Machine height (mm)** | 5800 | 5800 | 6000 | 6000 |
| **Machine weight (tn)** | 70 | 80 | 950 | 100-110 |

#### *3.7.4. Advantages/Disadvantages*

This machine is competitive for Granite slabs cutting only and should therefore being compared with Giant disc cutter (marble and granite) and Multiwire frames.

Giant disc cutter:

(+) Higher productivity
(-) Limitations in height (about 1.7 m)
(-) Higher cost of tool

Multi wire.

(+) Higher productivity
(-) Wider cut (less yield)
(-) Higher cost of tool
(-) Less reliable

### 3.8. GIANT DISK CUTTING MACHINE

Material: Granite, Marble
Inlet: Blocks
Outlet: Slabs (limitation in size), Small blocks
Location: Cutting centre
Cycles: Slabs, small blocks

### *3.8.1. Description*

This cutting machine is composed of a robust frame and a longitudinal beam, where a large diameter diamond disk is installed. The disk cuts the block positioned underneath into thick slabs of the same height as the block. Only one cut is performed at a time.

The slabs are produced either by the movement of the beam or by the displacement of the plate where the block is positioned (also rotating). The optimization of the positioning is obtained by an optical device (encoder).

### *3.8.2. Applications*

This machine is used to cut both granite and marble (and hardness materials of similar hardness). Its employment is above all dedicated to the production of thick slabs, starting from defective, irregular or undersized blocks, typically required in the holy art field.

### *3.8.3. Characteristics*

The features of Table 20 are an indication of the possible characteristics of this kind of machines.

**Table 20.** Characteristics of giant disk cutting

| | |
|---|---|
| **Max vertical disks diameter (mm)** | 2000-3500 |
| **Max cutting depth (mm)** | 750-1500 |
| **Number of disks** | 1 |
| **Cutting length (mm)** | 3500 |
| **Vertical disk motor (kW)** | 22-55 |
| **Installed electrical power (kW)** | |
| **Feed speed (mm/min)** | 0-15 |
| **Water consumption (l/min)** | 120 |
| **Machine length (mm)** | 9400 |
| **Machine width (mm)** | 6000 |
| **Machine height (mm)** | 5400 |
| **Machine weight (tn)** | 18 |


**Figure 28.** View of giant disk

### *3.8.4. Advantages/Disadvantages*

This machine can be employed for **Granite slabs, Marble slabs, Marble and granite block squaring**, and should therefore be compared with Single wire cutters, Multiwire frames, Multi blades diamond frame (marble only) and Multi blades gangsaws (granite only) .

Multi wire:

(+) No limitations in height
(+) Higher productivity
(-) Wider cut (less yield)
(-) Less precise cut
(-) Higher cost of tool
(-) Less reliable

Single blade diamond cutting frame:

(+) No limitations in height
(-) Only marble
(-) Low productivity
(-) Wider cut (less yield)
(-) Less precise cut
(-) Higher cost of tool

Multi blade diamond cutting frame:

(+) No limitations in height
(-) Only marble
(-) Wider cut (less yield)
(-) Less precise cut
(-) Higher cost of tool

## 3.9. DISC BLOCK CUTTERS

| | |
|---|---|
| Material: | Marble, Granite |
| Inlet: | Stone blocks |
| Outlet: | Strips, small blocks (limited in size) |
| Location: | Cutting centre |
| Cycles: | Tiles, dimensional stones |

### *3.9.1. Description*

Block cutters are especially applied in tile manufacturing processes. The performance of a modern block cutter in terms of productivity and precision has no comparison to any slab-cutting machine, with the limitation that no strip wider than about 650 mm (at present) can be cut. Block cutters include one or more vertical steel discs, mounted on a cutting head, carrying brazed diamond segments on their circumference.

The vertical discs deliver the cutting rotational motion. The cutting head moves to and from along a beam bridge, delivering the feeding motion and thus allowing cutting of the block to a certain depth, dividing its length into a series of strips. The downward motion is usually performed by the beam bridge, but in certain models this can be performed by lowering the cutting head.

The side displacement (needed in order to cut the full surface of the block) is given by the side motion of the bridge onto two traverse beams, although in some models the bridge is fixed and the block can move on its supporting trolley. Otherwise, the movement of the block holding carriage is needed only to put the block in position before the cutting operation, and then it is kept steady and locked until the cutting operation is completely performed.

Once the block has been sawn with vertical disks, one or more horizontal discs are used to cut these strips at the base, thus obtaining a semi-finished product, which will be subsequently finished to produce the final product ready for installation. Evidently, the diameter of the vertical disks is chosen in relation to the dimensions of the desired final product.

The last operation is the strips download from the block cutter, which is currently performed by automatic strip unloader mechanically integrated into the machine itself, and totally controlled by the block cutter control logic and software.

### *3.9.2. Applications*

Block cutters are used for mass production of standardised products (generally strips and tiles). They allow sawing of damaged, irregular or undersized blocks, which are not suitable for slab production. The cutting operation is performed directly on the blocks, and no squaring operation is usually carried out when block cutters are used. It is important to note that even when using block cutters, the differences between marble and granite processing are evident:

- The full depth of a Marble strip can be easily cut in a single pass; this may also be possible with granite, but it requires special equipment and technology.
- Granite block cutters are usually equipped with several disks (up to 100), thus compensating the long time needed to perform each cut. Marble block cutters on the contrary have a few disks, usually 2 coupled discs with different diameters.
- Granite strips are usually cut into the required thickness, while marble strips can be cut into thicker strips (the required thickness will be obtained by means of the splitting machine located downline – see relevant Paragraph for its description). The same cycle can be also applied to granite, but usually it is considered to be practically viable for large plants with a productivity of 1000 square meters per day or more.

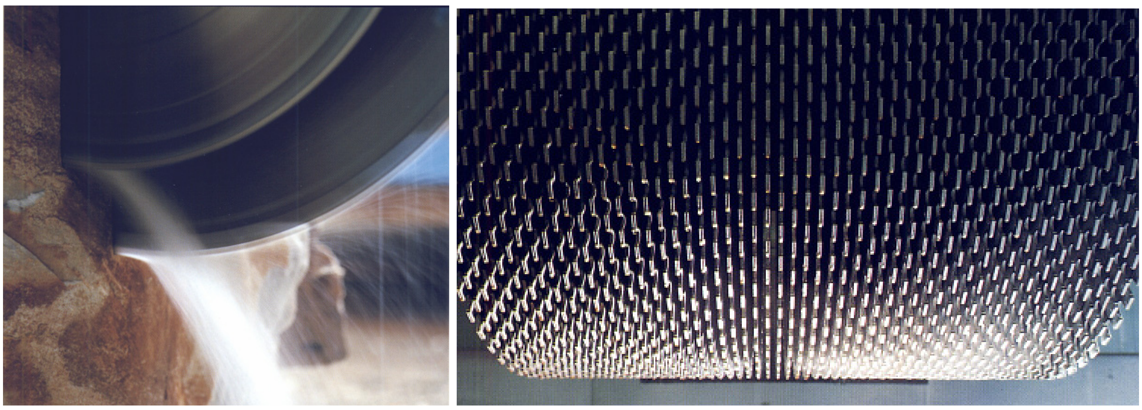


**Figure 29.** (Left) set of discs for Marble - (Right) set of discs for granite

The Block Cutters can be classified according to their construction, as shown in the followings.

**Light 4-columns machine for marble.**

The discs holding spindle is held by the carriage, moving on the bridge. The cutting speed is about 2-4 m/min. The bridge moves on its supporting traverse, not during the cut, but between two cuts during positioning along the lateral axis. The horizontal disc can move vertically in order to adjust its position to the width of the strip to be cut; such disc will cut away the strip from the block.

The machine is equipped with a fully integrated strip unloader. In Figure 30 the yellow plate of the suction pad holder, which will grasp the strip after cutting is visible. A block carrier trolley is also integrated in the machine.

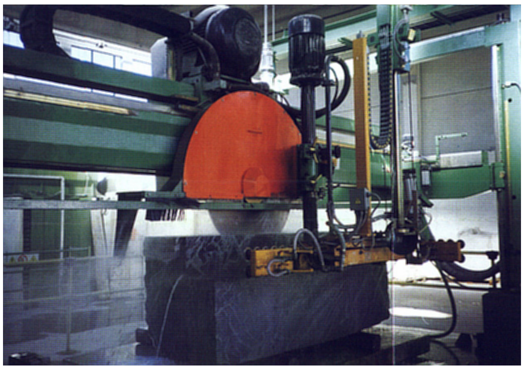


**Figure 30.** View of a 4-columns block cutters for marble

**4-columns machine for granite.**

The design is similar to the marble block-cutter; its size is bigger and it structure is more rigid. The spindle is long enough to support  up to (about) 60 discs, and the carriage structure is designed accordingly. The speed range of the carriage on the bridge reaches 15-20 m/min in alternate motion. The horizontal disc can move vertically in order to adjust its position according to the width of the strip to be cut. The machine is equipped with an integrated strip unloader. In Figure 31 shows the plate of the suction pad holder, which carries each strip after cutting. A block carrier trolley is also integrated in the machine.

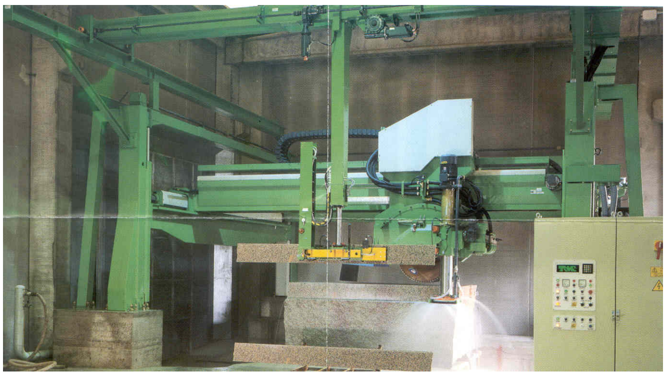


**Figure 31.** View of 4-columns block cutters for granite

**Advanced high productivity “Arch” Plant for granite.**

The philosophy of this system aims to achieve the maximum productivity with the highest level of quality, in order to fulfill the demand for advanced high volume mass production plants for tiles. The cutting process is splitted into three units, conglomerated in a single structure:

(1) the vertical cutting unit, that performs only the vertical cuts, which are the core of the process. The spindle is designed to support up to 80-100 discs. The cutting bridge is holding the carriage and is reinforced by the yellow steel arch structure, shown in Figure 32. The whole structure is designed for maximum sturdiness and stability.

(2) a unit which performs only the horizontal cutting and (according to the models) the "block topping". Horizontal cutting is performed by means of one or more horizontal discs. Topping can be performed by a special set of vertical discs having different diameters in the same set (increased by few centimeters).
(3) another unit includes a bridge with the strips unloader.

The plant is completed by one or two block holding trolley, moving side to side on independent parallel ways. The three units move independently on supporting slide ways. The working cycle is fully programmable in order to improve productivity and yields. Central control logic unifies the independent operation of the three units.

**Figure 32.** Two views of an "Arch" block cutter for granite

### *3.9.3. Characteristics*

The features of Table 21 and 22 are an indication of the possible characteristics of this kind of machines.

**Table 21.** Characteristics of "column" granite block cutters

| **Granite** | | | | |
|---|---|---|---|---|
| **Number of disks** | 14 | 32-34 | 50-56 | 60 |
| **Max vertical disks diameter (mm)** | 1000-1600 | 1300-1700 | 1300-1700 | 1300-1700 |
| **Min vertical disks diameter (mm)** | 900 | 900 | 900 | 900 |
| **Max cutting depth (mm)** | 610 | 660 | 610 | 610 |
| **Vertical disk set width** | 240 | 580-600 | 925-1010 | 1100-1250 |
| **Horizontal disk diameter (mm)** | 350 | 350-400 | 350-400 | 400 |
| **Cutting depth (mm)** | 150-600 | 150-650 | 150-650 | 150-650 |
| **Cutting length (mm)** | 3500 | 3500 | 3500 | 3500 |
| **Cutting width (mm)** | 2500 | 2500-4000 | 2000-4000 | 5000-7000 |
| **Cutting height (mm)** | 2250 | 2000-2250 | 2100-2250 | 2100 |
| **Vertical disks motor (kW)** | 90 | 132 | 132-160 | 160-200 |
| **Horizontal disk motor (kW)** | 15 | 15 | 15 | 15 |
| **Installed electrical power (kW)** | 118 | 160 | 192 | 230 |
| **Beam speed (cm/min)** | 0-25 | 0-25 | 0-25 | 0-25 |
| **Blade speed (m/min)** | 0-18 | 0-18 | 0-18 | 0-18 |
| **Water consumption (l/min)** | | 500 | 1100 | |
| **Machine length (mm)** | 10000 | 10000 | 10000-12000 | 11000-15000 |
| **Machine width (mm)** | 6500 | 6500-8600 | 7200-9200 | 8000-9000 |
| **Machine height (mm)** | 5300 | 5500-5700 | 5500-6000 | 5500-6000 |
| **Machine weight (tn)** | 17 | 18-28 | 25-35 | 30-35 |

**Table 22.** Characteristics of marble block cutters

| **Marble** | | |
|---|---|---|
| **Block size (m)** | 3.6 x 2.1 x 2.25 (h) | 3.6 x 2.1 x 2.25 (h) |
| **Strip size (mm)** | 460 x 60 | 610 x 60 |
| **Max vertical disks diameter (mm)** | 800-1300 | 800-1600 |
| **Horizontal disk diameter (mm)** | 400-500 | 400-500 |
| **Useful spindle length** | 100 | 160 |
| **Vertical disks motor (kW)** | 90-160 | 90-160 |
| **Horizontal disk motor (kW)** | 18-22 | 18-22 |
| **Installed electrical power (kW)** | 120 -190 | 120 -190 |
| **Cutting carriage speed (m/min)** | 0-5 | 0-5 |
| **Water consumption (l/min per disc)** | 50 | 50 |
| **Machine length (mm)** | 8000 | 10000 |
| **Machine width (mm)** | 6300 | 6500 |
| **Machine height (mm)** | 5000 | 5500 |
| **Machine weight (kg)** | 10 000 | 10 000 |

### *3.9.4. Advantages/Disadvantages*

Block cutters are specifically used for mass production of tiles; the production of large slabs is not possible. The advantages and disadvantages refer mainly to the choice of the right number, kind and size of block cutter to fit the kind of processed stone, the specifications of the output product and the quantity demand. Specific calculation systems should be available at the manufacturer site in order to carry out such kind of evaluations.

### 3.10. SPLITTING MACHINE FOR MARBLE

| | |
|---|---|
| Material: | Marble |
| Inlet: | Strips |
| Outlet: | Strips |
| Location: | (ancillary line of the) cutting centre |
| Cycles: | Tiles (and dimensional stones) |

#### *3.10.1. Description*

This machine is located immediately down line in respect with the block cutter for marble. The marble strips are sawn by a series of diamond circular blades with increasing diameter. The diamond blades are mounted sequentially and in parallel position (the disks can be either in horizontal or in vertical position). The marble strips/billets are loaded on a belt, thus feeding the machine. Pressure units maintain the contact between the strip and the conveyor belt.

#### *3.10.2. Applications*

The machine is used for splitting of marble tiles and other marble shapes and is suitable for a wide production range, including dimensional stones. Because of the fragility of the material, it is not advisable to process marble directly to the desired thickness on the block cutter: the splitting machine processes the thick strips and obtains two or more thinner strips. A splitting machine having a construction suitable for this use is represented in Figure 33.

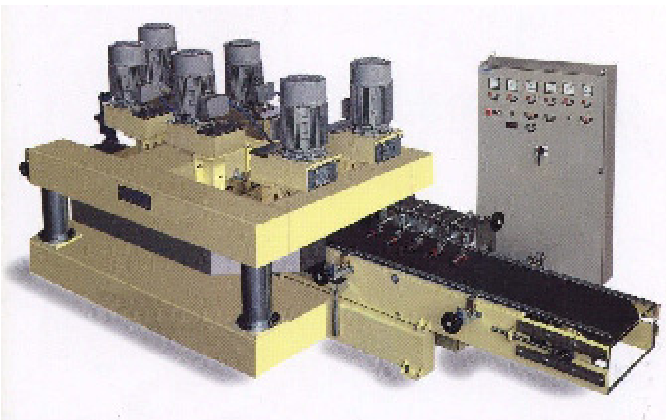


**Figure 33.** View of a splitting machine for marble

#### *3.10.3. Characteristics*

The following features (Table 23) are an indication of the possible characteristics of this kind of machines.

**Table 23.** Characteristics of marble splitting machines

| **Number of Disks** | 2 | 4 | 4 | 6 |
|---|---|---|---|---|
| **Diameter disks (mm)** | 350 | 350 | 600-650 | 600-850 |
| **Cutting width (mm)** | 50-200 | 50-200 | 200-460 | 250-620 |
| **Thickness (mm)** | 15-53 | 15-53 | 20-80 | 20-110 |
| **Belt speed (m/min)** | 0-5.2 | 0-5.2 | 0-5 | 0-5 |
| **Machine length (mm)** | 4000 | 5000 | 5000 | 5500 |
| **Machine width (mm)** | 2400 | 2400 | 2400 | 2400 |
| **Machine height (mm)** | 2200 | 2200 | 2200 | 2300 |
| **Disk motor power (kW)** | 11 | 11 | 18.5 | 18.5-22 |
| **Installed electrical power (kW)** | 18.5 | 36.5 | 76.5 | 120.5 |

#### *3.10.4. Advantages/Disadvantages*

The main advantage of this machine is that, when is properly working in a marble plant for tiles the productivity of the cutting centre is almost doubled. Another advantage is the increase of the plant yield (less broken strips). The disadvantages lay in the extra space and extra investment necessary to install the machine.

### 3.11. Sectioning (splitting) machine for Granite

Material: Granite
Inlet: Strips
Outlet: Strips
Location: Finishing line
Cycles: Tiles

#### *3.11.1. Description*

This machine is located in the finishing line for granite tiles. The granite strips are sawn by a series of diamond circular blades with increasing diameter. The diamond blades are mounted sequentially. The granite strips are loaded on a belt, thus feeding the machine. Pressure units maintain the contact between the strip and the conveyor belt. Since granite is much harder than marble, a greater number of discs is needed, each one working in “deep cutting” conditions (each cut is many centimeters deep).

#### *3.11.2. Applications*

The machine is used for splitting of granite strips (or tiles) in two thinner strips (or tiles).

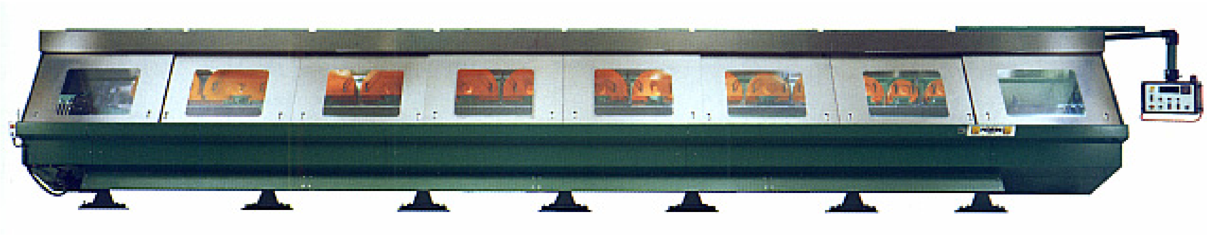


**Figure 34.** View of a sectioning machine for granite

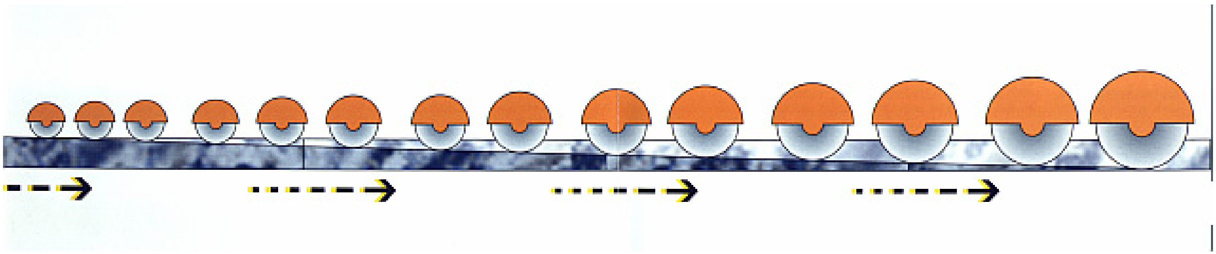


**Figure 35.** The sectioning system (granite)

*3.11.3. Characteristics*

The features of Table 24 are an indication of the possible characteristics of this kind of machines.

**Table 24.** Characteristics of a granite splitting machine

| | |
|---|---|
| **Number of Disks** | 14 |
| **Diameter disks (mm)** | 350 to 900 |
| **Cutting width (mm)** | 300 - 610 |
| **Thickness, at the inlet (mm)** | 15-85 |
| **Thickness, at the output (mm)** | > 6 |
| **Belt speed (m/min)** | 0.5 - 5 |
| **Machine length (m)** | 14 |
| **Machine width (m)** | 2.8 |
| **Machine height (m)** | 2.4 |
| **Machine weight (kg)** | 24 000 |
| **Disk motor power (kW)** | 11 to 15 |

*3.11.4. Advantages/Disadvantages*

According to the purpose for which it was installed, the machine shows the advantage of increasing almost doubling the productivity of the cutting centre. Another advantage is the increase of the yield of the plant (less wasted granite in the cut). When it is employed for manufacturing of “superthin” tiles, it creates additional sales opportunities. The disadvantage is mainly the high cost the machine

### 3.12. CALIBRATING MACHINES

Material: Granite, Marble
Inlet: Strips
Outlet: Strips

Location: Finishing line
Cycles: Tiles

### *3.12.1. Description*

Calibration is an operation performed on stone strips before their surface treatment. In these machines, the slab is placed on a belt that moves under the calibrating heads, which themselves are positioned on fixed supports. The rotating heads remove the excess material of the stone surfaces, grinding the stone with diamond tools, until a harmonised thickness is obtained. The regulation of the head height is decimal and performed by electric motors, or a manual adjusting device. Moreover, as calibrating machines are in line with the other machines (of the finishing line), the speed of the feeding conveyor belt can be adjusted in order to adapt to other machines working time. Such regulation can be performed automatically in modern machines, inside a given range of line speed. The achievable tolerances are in the range of 0.1-0.2 millimeter.

Figure 36 shows a marble calibrating machine. Since marble is a soft stone, its (comparatively) light structure is sufficient enough to assure that the heads position is kept during grinding, which is necessary to assure the uniformity of the thickness. The grinding tools are made of a circular plate on which a crown of diamond segments is brased. Each tool has a preset inclination (a slight tilt angle) that varies from the first to the last head, needed to assure the required cutting pressure on the stone.

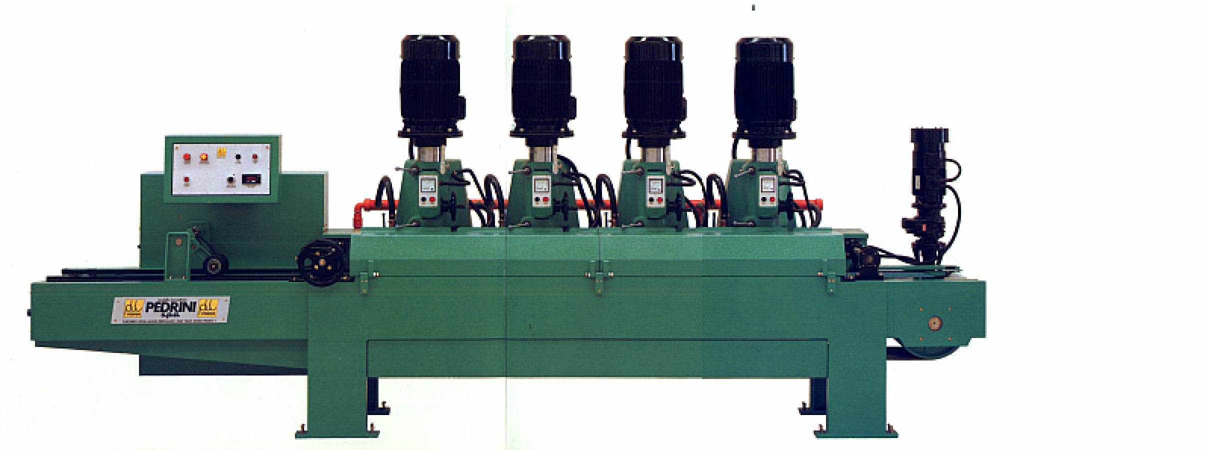



**Figure 36.** Calibrating machine for marble

Figure 37 shows a granite calibrating machine. Since granite is a hard stone, the structure is very sturdy, in order to assure that the heads position is kept stable during grinding, which is necessary to assure the uniformity of the thickness. The construction of the head is very different if compared to a marble machine. The machine in Figure 37b has calibrating rollers, on which the diamond segments are brased in the shape of a multiple helix.

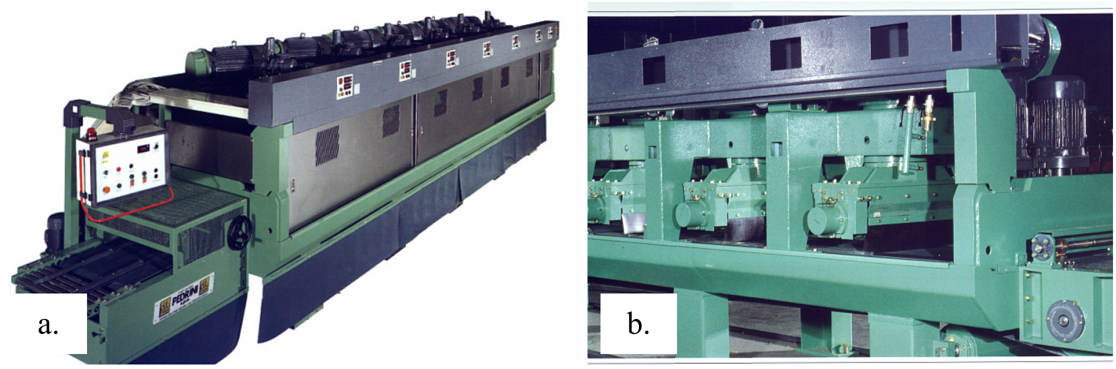



**Figure 37.** Calibrating machine for granite

Each roller is supported by a heavy "bridge" structure, where it is locked by multiple hydraulic brakes during the grinding operation. When the rotation stops, the hydraulic pressure on the brakes is relived in order to allow the rollers positioning.

In the most effective calibrating machines, not only the vertical position is adjustable. Figure 38 shows a machine where each roller can be adjusted in order to change the input section of the machine. This system is particularly effective when the width of the product changes quite frequently, in order to have always the machine promptly set with great precision for any specific width of the stone strips.

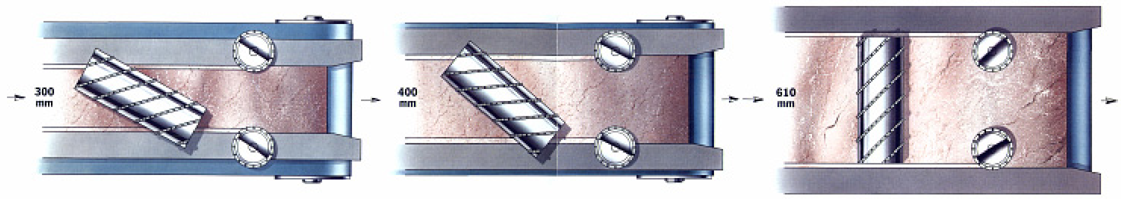



**Figure 38.** The working principle of the "rollers with adjustable inlet section".

### *3.12.2. Applications*

Generally marble and granite strips are submitted to this operation before polishing in order to regularize the strip thickness. Versions of this machine combined with the polishers are available.

### *3.12.3. Characteristics*

In Table 25 and 26 an indication of the possible characteristics of this kind of machines, is given.

**Table 25.** Characteristics of calibrating machine (Marble)

| | |
|---|---|
| **Number of heads** | 2-4 |
| **Head diameter (mm)** | 400-600 |
| **Strip width (mm)** | 300-650 |
| **Strip thickness (mm)** | < 80 |
| **Head motor each (kW)** | 15-20 |

| | |
|---|---|
| **Belt feed speed (m/min)** | 0 - 10 |
| **Water consumption (l/min) per head** | 40 |
| **Machine width (m)** | 1.2 - 1.6 |
| **Machine height (m)** | 3.5 - 5 |
| **Machine weight (kg)** | 3000- 6000 |

**Table 26.** Characteristics of calibrating machine (Granite)

| | |
|---|---|
| **Number of heads** | 2-6 |
| **Roller diameter (mm)** | 200-400 |
| **Strip width (mm)** | 300-1200 |
| **Strip thickness (mm)** | < 80 |
| **Head motor each (kW)** | 35 - 50 |
| **Belt feed speed (m/min)** | 0 - 10 |
| **Water consumption (l/min) per head** | 40 |
| **Machine width (m)** | 1.2 - 1.6 |
| **Machine height (m)** | 3.5 - 5 |
| **Machine weight (kg)** | 8000- 20 000 |

#### *3.12.4. Advantages/Disadvantages*

A calibrating machine is required in modern finishing lines for tiles. Given the kind of material, the machine typology is quite well defined. There are advantages when the calibrating and polishing machine (or at least the first polishing heads) are installed together in a combined machine, provided that the very different requirements for polishing and for calibrating are independently satisfied by the polishing and calibrating sections of the machine. Such advantages lay in the common conveyor belt and supporting bed, which provide a better alignment of the surfaces to be processed. However, if the construction is not accurate and sturdy, vibrations from the calibrating section may interfere with the polishing steps. Even the water coming from the calibrating section can damage the polishing process, if not dumped immediately downstream the calibrating heads. The last polishing heads are often alone on a separate structure.

### 3.13. POLISHING MACHINE FOR STRIPS

Material: Granite, Marble
Inlet: Strips
Outlet: Strips
Location: Finishing line
Cycles: Tiles

Polishing machines for marble and granite strips are very similar to those used for polishing large slabs, apart from the useful maximum width of the stone. The working philosophy is exactly the same: the strip is positioned on a conveyor belt moving under a series of abrasive heads of increasingly finer grains with an adjustable speed. The heads are supported in such a way that can move independently with low friction in vertical direction. The rotating movement of the polishing heads is combined with the electronic reading of the surface and the possibility to maintain the pressure constant all along the operation. Versions incorporating both the functions of calibration and polishing are available. The rotating head could be mounted on fixed support, or, as the modern tendency is, they are mounted on one (or more) mobile beam, which swaps the full width of the strip, to and front, continuously. When the width of the strip increases, the stroke of the beam must be adjusted as well.

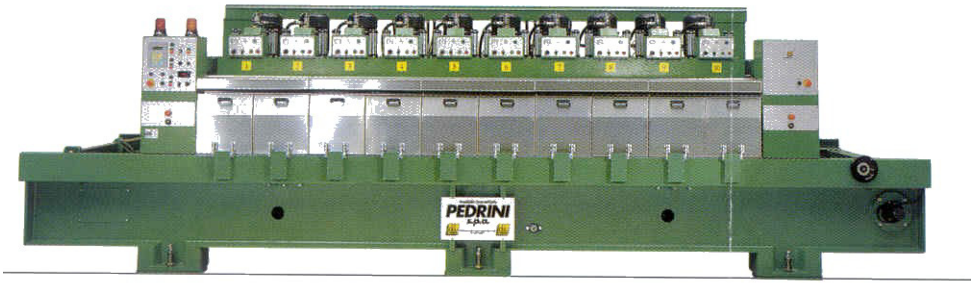


**Figure 39.** Polishing machine for strips

Apart from the sturdiness of the structure and mechanical parts, there is a basic difference between Marble and Granite polishing machines concerning the polishing heads and the tools. The tools for marble are abrasive pads with a flat lower surface, mounted on a supporting disc (see next figure). These are known as “Frankfurt” tools (the name refers actually to the way the pads are attached to their holding plate). The pads contain a resin bond (usually) with abrasive grit. The pads thickness decreases with the use, by wear, until they are replaced. The working pressure, acting locally on the stone surface is given by the force exerted by the head divided by the surface of the pad. Quite low pressure values are sufficient to carry out the polishing operation for marble.

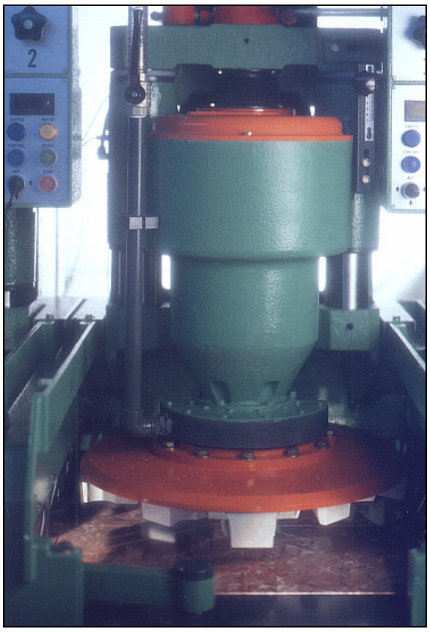


**Figure 40.** Polishing head for Marble

The pressure needed to polish a granite is higher, and the force required to produce that pressure could easily break the stone strip. Hence, the tools are curve-shaped in order to reduce the contact surface with the stone and to increase the contact pressure, given the same vertical force. Unfortunately, when the wear proceeds, the tools would flatten, and the contact pressure would decrease again. For this reason the polishing tools for granite can be mounted on oscillating arms, swinging slowly to and front while the head is rapidly spinning; in this way the curved shape of the polishing pads is always preserved while the wear proceeds. These are known as "Fickert" tools (the name refers actually to the way the pads are attached to their holding arms).

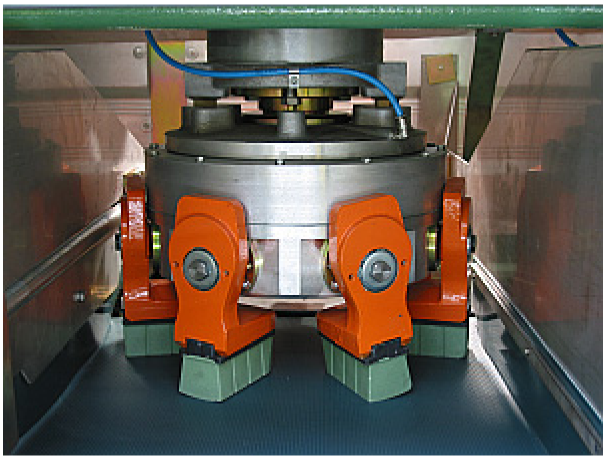


**Figure 41.** Polishing head for granite, with oscillating pads

There are also other effective solutions to the problem of polishing granite stones. There are satellite heads, where the tools are circular discs (flat or conical), or rolls, rotating at a speed, which is different from the head speed. The satellites can also be inclined to accomplish the same purpose as the oscillating arms mentioned above.

**Figure 42.** Satellite Polishing head for granite, with flat polishing discs

Special attention should be given to the diamond polishing tools, subject of studies in the recent years; their use is increasing more and more, and they are now quite common among the advanced processing units, at least in first polishing heads. Their external shape is similar to the normal abrasive pads for granite, but they are made of a synthetic bond with diamond grit.

### *3.13.1. Characteristics*

An indication of the possible characteristics of this kind of machines is given in Table 27 and 28.

**Table 27.** Characteristics of polisher for granite strips

| **Marble** | | | | | |
|---|---|---|---|---|---|
| **Number of polishing heads** | 4 | 6 | 8 | 10 | 12 |
| **Polishing heads diameter (mm)** | 300-750 | 300-750 | 300-420 | 300-420 | 300-420 |
| **Max working width (mm)** | 700-1000 | 700-1000 | 700-1000 | 700-1000 | 700-1000 |
| **Max working thickness (mm)** | 60 | 60 | 60 | 60 | 60 |
| **Polishing head motor (kW)** | 4.5-11 | 4.5-11 | 4.5-9 | 4.5-9 | 4.5-9 |
| **Beam motor (kW)** | | | | | |
| **Total power (kW)** | 21-40 | 30-60 | 40-77 | 50-95 | 58-115 |
| **Beam speed (m/min)** | | | | | |
| **Belt feed speed (m/min)** | 0-40 | 0-40 | 0-40 | 0-40 | 0-40 |
| **Water consumption (l/min)** | | | | | |
| **Machine length (mm)** | 5100-5300 | 6100-6200 | 6900-7300 | 7700-9400 | 8500-9500 |
| **Machine width (mm)** | 1500-2000 | 1500-2000 | 1500-2000 | 1500-2000 | 1500-2000 |
| **Machine height (mm)** | 2000-2300 | 2000-2300 | 2000-2300 | 2000-2300 | 2000-2300 |
| **Machine weight (kg)** | 10 000 | 12000 | 14000 | 16 000 | 18 000 |

**Table 28.** Characteristics for polisher for granite strip

| **Granite** | | | | |
|---|---|---|---|---|
| **Number of polishing heads** | 8-10 | 12-14 | 16-18 | 20 |
| **Polishing heads diameter (mm)** | 470 | 470 | 470 | 470 |
| **Max working width (mm)** | 300-700 | 300-700 | 300-700 | 300-620 |
| **Max working thickness (mm)** | 70-120 | 70-120 | 70-120 | 70 |
| **Polishing head motor (kW)** | 11 | 11 | 11 | 11 |
| **Beam motor (kW)** | | | | |
| **Total power (kW)** | 95-116 | 140-180 | 200-230 | 230 |
| **Beam speed (m/min)** | | | | |
| **Belt feed speed (m/min)** | 0-80 | 0-80 | 0-80 | 0-60 |
| **Water consumption (l/min)** | 200-340 | 300-470 | 450-600 | 680 |
| **Machine length (mm)** | 7500-8100 | 9600-12000 | 13000-14000 | 15000 |
| **Machine width (mm)** | 2400 | 2400 | 2400 | 2400 |
| **Machine height (mm)** | 2600 | 2600 | 2600 | 2600 |
| **Machine weight (tn)** | 14-17 | 21-23 | 25-27 | 32 |

### *3.13.2. Advantages/Disadvantages*

A polishing machine is usually required in any finishing line for tiles. Given the kind of material, however, there is a wide range of machine types available on the market. Each one may have advantages and disadvantages, but the most important task is to define the machine that is more suitable for the set requirements, such as a sufficient number of heads to comply with the productivity required. The advantages of one choice compared to another possible one rely often on the sturdiness of the polishing heads and the other mobile parts.

## 3.14. TRIMMING MACHINES

| | |
|---|---|
| Material: | Granite, Marble |
| Inlet: | Slabs |
| Outlet: | Strips |
| Location: | Finishing line |
| Cycles: | Tiles (from slabs), dimensional stones |

### *3.14.1. Description*

They are basically composed of a plurality of spindle supports and a bed where the piece to be processed is placed. The spindle supports may move vertically and/or horizontally with respect to the stone piece. The diamond disks, used in variable quantities and at a proper distance one from the other, are placed on a single disk-holding shaft.

### *3.14.2. Applications*

These machines are used for both marble and granite to perform a variety of operations on strips or slabs. These versatile machines are ideally used for the complete cut of pieces and for the production of small slabs, doorsteps, steps, tiles and dimensional products.

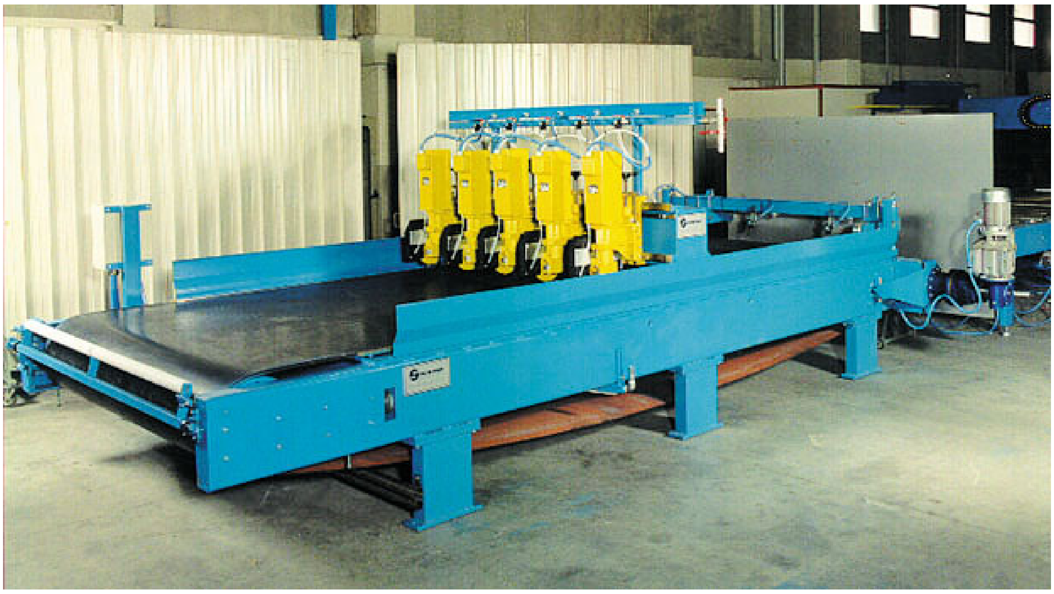


**Figure 43.** View of a trimming machine

### *3.14.3. Characteristics*

The features of Table 29 are an indication of the possible characteristics of this kind of machines.

**Table 29.** Characteristics of trimming machine

| | |
|---|---|
| **Machinable width (mm)** | 200÷1850 |
| **Maximum thickness (mm)** | 35 - 60 |
| **Number of disk-holder heads** | 3 -25 |
| **Disk-holder head motor (kW)** | 4 - 15 |
| **Conveyor system motor (kW)** | 2,2 |
| **Disk-holder head movement motor (kW)** | 0,5 |
| **Conveyor system forward speed (m/min)** | 2 -10 |
| **Disk diameter (mm)** | 300-400 |
| **Discs speed (rpm)** | 1200-3500 |
| **Installed electrical power (kW)** | 15 - 35 |
| **Cooling water (l/min per disc)** | 10- 20 |
| **Machine length (L) (m)** | 2 - 7 |
| **Machine width (W) (m)** | 1.8 - 5 |
| **Machine height (H) (m)** | 1.5 - 2 |
| **Approximate weight (kg)** | 1.8 - 8 |

#### *3.14.4. Advantages/Disadvantages*

A trimming machine is useful when cutting of strips (or other linear elements) from slabs is needed. It can give a certain flexibility to a plant for slabs, allowing the production of tiles, for instance, in order to complete orders including both slabs and tiles. It should be noticed, however, that the production of slabs in a dedicated plant with block cutters can be by far economically more convenient.

### 3.15. CROSS CUTTING MACHINES

Material: Granite, Marble
Inlet: Strips
Outlet: Tiles
Location: Finishing line
Cycles: Tiles

#### *3.15.1. Description*

Cross cutting machines perform multiple cuts across a strip, in order to manufacture tiles. In these machines, the strip, placed on a conveyor, moves at a fixed speed towards the disks, mounted on a steel beam. There are two main versions of these machines:

1. Fixed bridge machines: the disks are disposed to perform the cut in the direction of the movement of the conveyor, more or less in the same way as a trimming machine cuts a slab. The strips must be positioned perpendicularly to their direction of feeding into the machine, (Figures 44, 45).
2. Mobile bridge machines: in this version the disks are disposed in a crossway direction with respect to conveyor movement. When the slab is in the work area, the conveyor stops and the bridge moves, performing the cuts. (Figures 46-49).

Both machines types are suitable for mass production of tiles.

### *3.15.2. Applications*

These machines are used to further process the strips coming from the block cutters. The two models described above are particularly indicated when high productivity of elements having repetitive dimensions is required. By changing the distance among the disks, a variety of formats is available. Such regulation is motorized and computer controlled in the automatic machines, which may be equipped also with a position transducer to read the position of each head automatically. The automatic program gives a great flexibility together with a high speed. Some versions with independent heads have the possibility to exclude some disks for a more versatile production.

Some versions having a rotary bed exist: once the first cross cut has been performed, it is possible to rotate the bed and perform a second cross cut, thus obtaining, for example, elements with right-angle cuts. In the case of a single disk, this machine allows the heading of the strips to provide a regular shape for further processing. This kind of machine is more suitable for small batches or laboratory, more than for mass production.

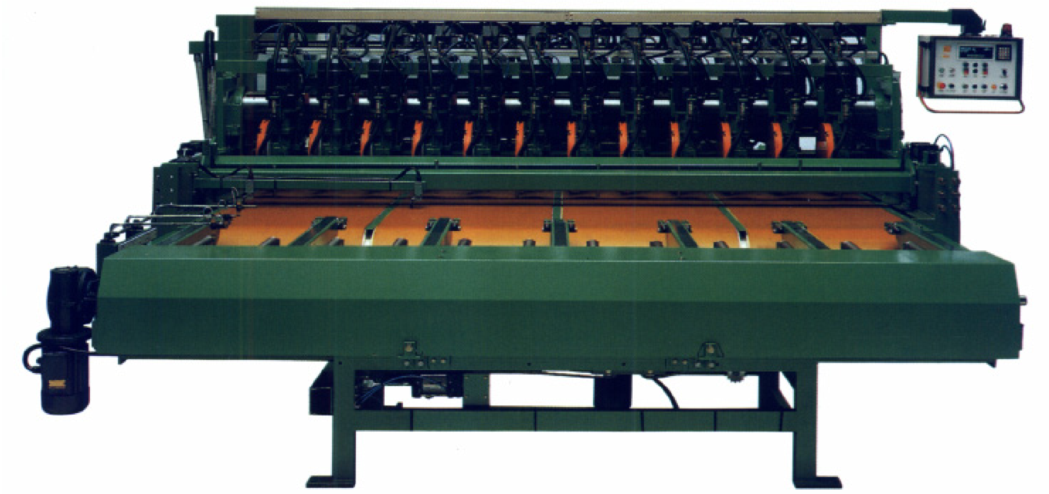


**Figure 44.** Fixed bridge Cross cutting machine

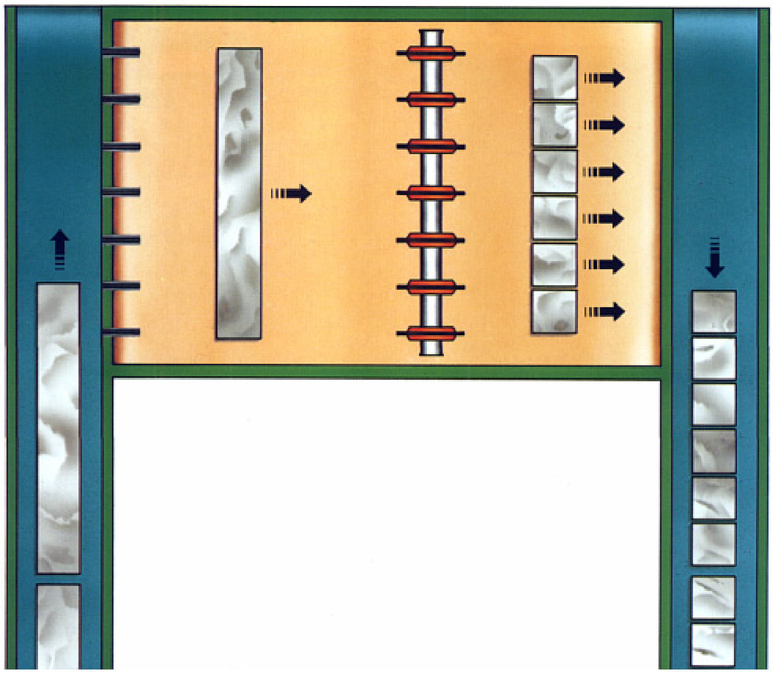


**Figure 45.** The way a Fixed bridge machine works (Schematic diagram)

**Figure 46.** Mobile bridge Cross cutting machine (automatic)

**Figure 47.** The way a mobile bridge machine works

**Figure 48.** Single head automatic cross cutter (for pre-sizing, tile finishing lines)

**Figure 49.** Three heads mobile bridge cross cutting machine (small manual machine)

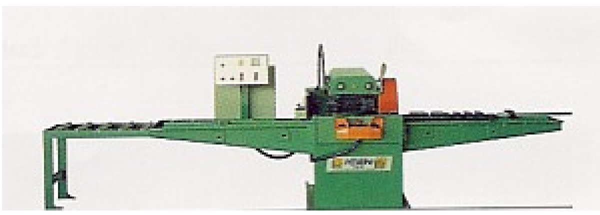


**Figure 50.** Single head cross cutting machine (small manual machine)

### *3.15.3. Characteristics*

The following features are an indication of the possible characteristics of this kind of machines.

**Table 30.** Characteristics of cross cutting machine

| | |
|---|---|
| **Number of disk** | 1 -12 |
| **Discs diameter (mm)** | 300-600 |
| **Min distance between disks (mm)** | 150 |
| **Cutting length (mm)** | 2500 - 3500 |
| **Max Cutting width (mm)** | 300 - 650 |
| **Cutting thickness with max disk (mm)** | 50-100 |
| **Disk motor (kW)** | 4 - 15 |
| **Discs speed (rpm)** | 1200-3500 |
| **Cutting speed (m/min)** | 0.4 - 12 |
| **Water consumption (l/min per disc)** | 10 - 20 |
| **Machine length (mm)** | 2900-3700 |
| **Machine width (mm)** | 2000 |
| **Machine height (mm)** | 1300 |
| **Machine weight (kg)** | 1500 - 10 000 |

#### *3.15.4. Advantages/Disadvantages*

Both the above mentioned versions (Mobile bridge and Fixed bridge) are automatic machines suitable for mass production of tiles, but the first is more modern and considerably faster, because it works continuously instead of by stop-and-go; therefore the average production speed is higher. However, the investment cost may be higher if the quantity to be produced is relevant.

A small 2-3 heads manual machine may be the best choice for a small plant working in small batches. A single head manual machine is good as a pre-sizing machine in a marble ancillary line, following the block cutter. The same function in a modern line for granite should be achieved better by a single disc (or double disc) fully automatic machine, PLC controlled.

### 3.16. CHAMFERING MACHINE

Material: Granite, Marble
Inlet: Tiles
Outlet: Tiles
Location: Finishing line
Cycles: Tiles

#### *3.16.1. Description*

These machines consist of two identical sections, linked by a powered roller table. The chamfering operations are performed on the four sides of the processed tile by two opposing spindles, set at 45° on each section. Initially, two sides are processed, the tile is then 90° rotated on the automated roller table and the other two sides are chamfered. The chamfering units work with pneumatic pressure and each spindle is independently operated. Variation in the depth of the chamfer is obtained by varying the working pressure. The pieces are positioned on a double conveyor belt and are kept aligned against a reference guide by horizontal pressure rollers, while vertical rollers maintain the contact between the tile and the rubber belts. Chamfering machines are generally combined with calibrating units to rectify the lateral edges of the pieces by means of diamond milling tools.

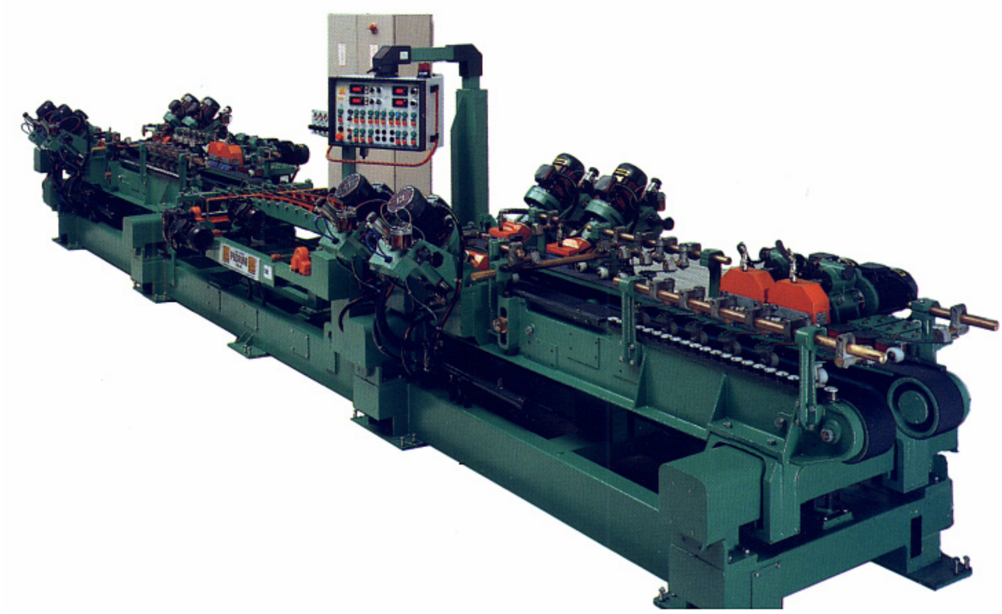


**Figure 51.** Chamfering machine for tile processing line

*3.16.2. Applications*

Chamfering machines are suitable for processing of marble, granite and similar materials. Their application is addressed to tiles of all sizes. Chamfering machines for granite, considering the major hardness, are generally equipped with 4+4 chamfering units (the first two for a rough operation, the others for finishing).

*3.16.3. Characteristics*

The features of Table 31 are an indication of the possible characteristics of this kind of machines.

**Table 31.** Characteristics of chamfering machine

| | | | |
|---|---|---|---|
| **Chamfering units** | 2+2 | 2+2 | 4+4 |
| **Calibrating units** | 1+1 | 2+2 | 2+2 |
| **Max working width (mm)** | 610-920 | 610-920 | 610 |
| **Min working width (mm)** | 150 | 150 | 150 |
| **Max working thickness (mm)** | 30 | 30 | 30 |
| **Chamfering unit electrical power (kW)** | 1.1 | 1.1 | 1.1 |
| **Calibrating unit electrical power (kW)** | 3 | 3 | 3 |
| **Installed electrical power (kW)** | 16 | 21 | 26 |
| **Water consumption (l/min)** | 60 | 70 | 80 |

| | | | |
|---|---|---|---|
| **Machine length (mm)** | 6500-10000 | 6500-10000 | 6500-10000 |
| **Machine width (mm)** | 1200-2200 | 1200-2200 | 1200-2200 |
| **Machine height (mm)** | 1300-1800 | 1300-1800 | 1300-1800 |
| **Machine weight (tn)** | 8000 | 8000 | 8500 |

### *3.16.4. Advantages/Disadvantages*

The chamfering machine is designed for tiles finishing, to provide the tiles with chamfered edges and to give them their final prescribed size (length and width). This machine is required in mass production lines for tiles, however it is not used in laboratories where very small batches or unique pieces are manufactured.

## 3.17. BELT POLISHERS FOR SLABS

Material: Granite, Marble
Inlet: Strips
Outlet: Strips
Location: Finishing line
Cycles: Tiles

### *3.17.1. Description*

The machine consists of a steel frame and one or more moving beams, where a series of polishing heads are installed. The slab is placed on a belt, which moves under the polishing heads. These rotating heads can be generally operated by two pneumatic cylinders with totally independent and individual controls, which provide different pressures and therefore a better abrasive efficiency. Furthermore, working pressures can be maintained uniform, independent of their wear, of any possible slab defect and of the belt speed. The polishing heads are installed in the centre of the beam, and in order to completely cover the slab surface, the beam has a transversal movement driven by electrical motors. The sequence of movements, performed in turns by the heads, is optimised to achieve the desired degree of finishing quality. Electronic CNC performs reading of the surface quality, allowing eventually exclusion from processing of any defective portion of the slab. Many models incorporate, together with the polishing function, the calibrating function, used to remove the excess material from the treated surface in order to have the same thickness all along the slab. The slabs are continuously fed on the belt, thus allowing a big productivity. Polishing machine structure for the treatment of marble or granite is very similar: substantial differences are in the properties of the abrasive heads, as described in paragraph 3.13 relevant to the polishing machine for tiles.

### *3.17.2. Applications*

Belt polishers are suitable for both marble and granite slabs. As modern lines are CNC equipped, these machines are ideal for a mass production with repeated operations.

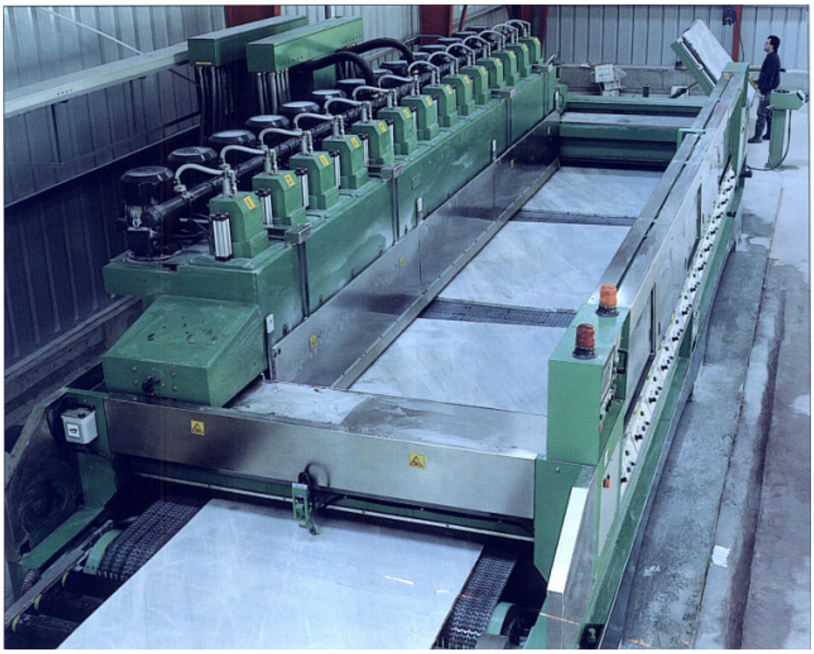


**Figure 52.** View of belt polisher with single beam

**Figure 53.** View of belt polisher with two beams

### *3.17.3. Characteristics of belt polisher*

The features of Table 32 and 33 are an indication of the possible characteristics of this kind of machines.

**Table 32.** Characteristics of belt polisher for marble

| **Marble** | | | | |
|---|---|---|---|---|
| **Number of polishing heads** | 4-6 | 8-10 | 12-14 | 16-18 |
| **Polishing heads diameter (mm)** | 470-520 | 470-520 | 470-520 | 470-520 |
| **Max working width (mm)** | 2100 | 2100 | 2100 | 2100 |
| **Max working thickness (mm)** | 100 | 100 | 100 | 100 |
| **Polishing head motor (kW)** | 11 | 11 | 11-15 | 11-15 |
| **Beam motor (kW)** | 2.2-3 | 2.2-3 | 2.2-3 | 2.2-3 |
| **Total power (kW)** | 50-71 | 92-114 | 136-158 | 180-200 |
| **Beam speed (m/min)** | 0-50 | 0-50 | 0-50 | 0-50 |
| **Belt feed speed (m/min)** | 0-3.5 | 0-3.5 | 0-3.5 | 0-3.5 |
| **Water consumption (l/min)** | 80-120 | 160-200 | 240-280 | 320-360 |
| **Machine length (mm)** | 5600-6900 | 8000-9100 | 10200-11300 | 12400-13500 |
| **Machine width (mm)** | 3000 | 3000 | 3000 | 3000 |
| **Machine height (mm)** | 2300-2850 | 2300-2850 | 2300-2850 | 2300-2850 |
| **Machine weight (tn)** | 10-12 | 14-16 | 18-20 | 22-24 |

**Table 33.** Characteristics of belt polisher for granite

| **Granite** | | | | |
|---|---|---|---|---|
| **Number of polishing heads** | 8-10 | 12-14 | 16-18 | 20-22 |
| **Polishing heads diameter (mm)** | 470 | 470 | 470 | 470 |
| **Working width (mm)** | 2100 | 2100 | 2100 | 1200 |
| **Working thickness (mm)** | 120 | 120 | 120 | 100 |
| **Polishing head motor (kW)** | 15 | 15 | 15 | 15 |
| **Beam motor (kW)** | 2.2 | 2.2 | 2.2 | 2.2 |
| **Total power (kW)** | 130-160 | 190-220 | 250-280 | 310-340 |
| **Beam speed (m/min)** | 0-50 | 0-50 | 0-50 | 0-50 |
| **Belt feed speed (m/min)** | 0-2.3 | 0-2.3 | 0-2.3 | 0-8 |
| **Water consumption (l/min)** | 200-340 | 300-470 | 400-600 | 500-550 |
| **Machine length (mm)** | 7000-8000 | 9000-10000 | 11000-12000 | 14000-15300 |
| **Machine width (mm)** | 3200 | 3200 | 3200 | 2300 |
| **Machine height (mm)** | 2800 | 2800 | 2800 | 2200 |
| **Machine weight (tn)** | 22-26 | 24-30 | 26-34 | 28-38 |

### *3.17.4. Advantages/Disadvantages*

This kind of machines have a conveyor belt. Therefore they are suitable for mass production of slabs, trimmed or not trimmed, giving an excellent productivity and a constant high quality. On the other hand, there are limitations as far as the height and the mass of the slab is concerned. In order to polish very thick and heavy slabs, billets, or small blocks, it may be better to choose a machine without a conveyor belt, having one or more polishing heads installed on a mobile arm or bridge. However, the productivity of such machines may not reach the same level of a conveyor belt machine.

## 3.18. RESIN APPLICATION MACHINES, FILLING MACHINES, PLASTERING MACHINES

| | |
|---|---|
| Material: | Marble |
| Inlet: | Slabs, strips, tiles |
| Outlet: | Slabs, strips, tiles |
| Location: | Finishing line for tiles, finishing line for slabs |
| Cycles: | Dimensional stones, tiles, slabs |

### *3.18.1. Description*

High quality coloured marbles are sometimes fragile and/or fractured. In order to give them enough sturdiness to be polished without breaking, the slabs are generally impregnated with epoxy resin. Automatic machines have been developed specifically for the purpose. Before the treatment, water and humidity are eliminated from the fractures and cavities by driers working with hot air systems, infrared or microwave systems. The presence of water would not permit the complete resin filling and would make difficult for the resin to adhere. Spreading of resin is generally performed on one side of the slab; sometimes it is performed also on the back side, and in this case it is accompanied by the application of reinforcement meshing to increase the slab rigidity. When this procedure is terminated, the tables with the resin reinforced slabs, still in-line, enter into the hot air polymerisation oven where the process is completed.

Filling machines are used to seal cavities, voids and craters with mastics and plasters of appropriate colour (compatible with the treated stone). The slab is positioned on a conveyor belt, moving under the working head. An electric fan removes the water from the holes before the filling and then the slab passes under the filling heads. At the end of the line, shaving devices are installed to clean both sides of the filled slab.

### *3.18.2. Applications*

The resin application process is usually carried out on coloured marbles, which are characterised by a high degree of natural defectiveness and fragility. The process has to be applied before the slab is treated with fine grain polishing. The process is sometimes performed on granite slabs, generally to close small and visible surface holes.

Travertine is the typical material processed with filling-plastering machines; other stones can be treated with filling devices.

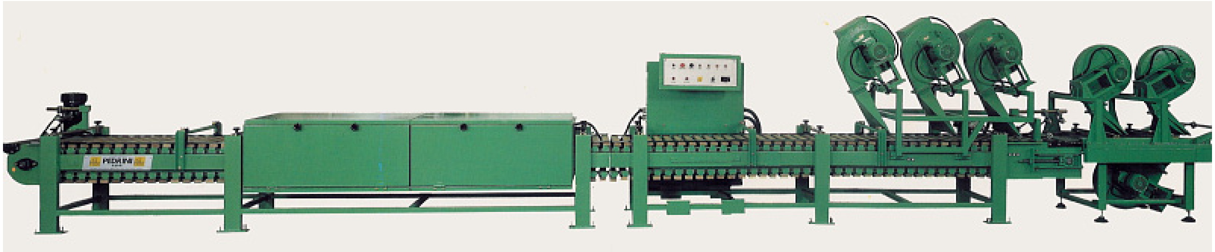


**Figure 54.** Filling-Plastering unit (model for tiles line)

### *3.18.3. Characteristics*

**Table 34.** characteristics of filling-plastering machines

| | Tiles | Slabs |
|---|---|---|
| **Max width (mm)** | 650 | 2000-2500 |
| **Max working thickness (mm)** | 100 | 100 |
| **Max belt speed (m/min)** | 3 - 10 | 2- 8 |
| **Belt feeding speed (m/min)** | 0-3.5 | 0-3.5 |
| **Plastering units** | Manual station, automatic stations | |
| **Number of plastering units** | 1 - 3 | |
| **Kind of heating elements for pre-plastering and post-plastering drying** | UV lamps, IR lamps, IR resistors, natural gas burners, liquid gas burners, hot air blowers | |
| **Drying power (kW)** | 20 - 50 | 30- 200 |
| **Total power (kW)** | 50-71 | 92-114 |
| **Machine length (m)** | 5 - 10 | 5 -10 |
| **Machine width (m)** | 3 - 5 | 3 - 5 |
| **Machine height (m)** | 2 - 3 | 2 -3 |
| **Machine weight (kg)** | 1500 - 9 000 | 3000 - 13 000 |

### *3.18.4. Advantages/Disadvantages*

The advantage of these systems lays in the value added to the product, that can be very important: a material can be improved from a very scarce marketability to a medium-high price class.

The problems are in the high level of know-how required to choose the most suitable process, that may vary from stone to stone. This is due to the very wide range:

- of stone qualities to be treated: limestones, marble and even granites;
- of defect to be recovered: micro and macro fractures, micro and macro pores, pure aesthetical recovery, mechanical recovery;
- of materials to be used as filling compounds: mono-component resins, bi-component resins, inorganic compounds;

- of post-drying systems: UV ovens when induction of reticulation is required, IR ovens, gas heaters.

### 3.19. BRIDGE POLISHERS FOR LARGE SLABS

| | |
|---|---|
| Material: | Granite, Marble |
| Inlet: | Small blocks |
| Outlet: | Small blocks |
| Location: | Finishing line for slabs |
| Cycles: | Small blocks, dimensional stones |

#### *3.19.1. Description*

Unlikely belt polishers, bridge polishers are characterized by longitudinal and transversal movements of the polishing heads, while the slab remains fixed. The structure is very similar to bridge cutters, with a different working tool. Like belt polishers, pressure and other working parameters are continuously controlled electronically. Their use is suitable for mass production.

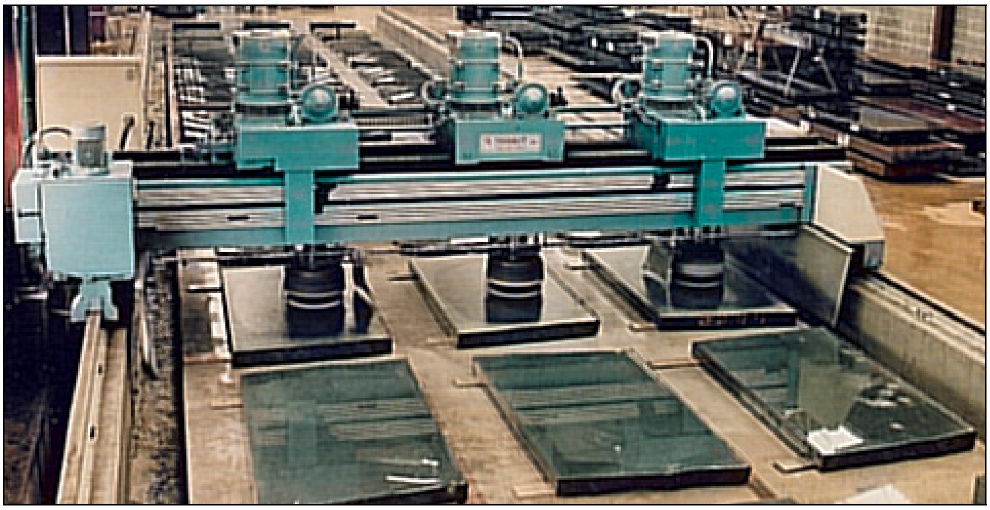


**Figure 55.** View of a 3-heads bridge polisher

#### *3.19.2. Applications*

These kind of machines are applied to polish small blocks (for dimensional stones), too thick and too heavy to be processed by polishing machines with conveyor belt.

#### *3.19.3. Characteristics*

The features of Table 35 are an indication of the possible characteristics of this kind of machines.

**Table 35.** Characteristics of bridge polisher

| Granite / Marble | |
|---|---|
| **Number of polishing heads** | 1, 2, 3 |
| **Polishing heads diameter (mm)** | 340 mm - 460 mm |
| **Working width (mm)** | 1.5 - 4.6 m |
| **Working thickness (mm)** | any |
| **Polishing head motor (kW)** | 9.5 - 30 kW |
| **Machine length (mm)** | up to 12 m rails |
| **Machine width (mm)** | up to 5 m bridge |
| **Machine weight (kg)** | 5000 - 9000 kg |

#### *3.19.4. Advantages/Disadvantages*

Handling the stones without a conveyor belt requires cranes or similar devices. This kind of operations are by far slower than those performed by belt slab polishing machines. The productivity, if expressed in square meters, will therefore be very low in comparison.

### 3.20. BUSH HAMMERING AND ROLLING (RIBBING, CHISELING)

Material: Granite, marble
Inlet: Dimensional stone, slabs, strips, tiles
Outlet: Dimensional stone, slabs, strips, tiles
Location: Stone laboratory, finishing line for tiles, finishing line for slabs
Cycles: Dimensional stones, tiles, slabs

#### *3.20.1. Description*

In comparison with Flaming, these machines can be more easily applied to narrow lines on the side of the tiles/strips (for instance), with different aesthetical results. There is a wide range of machining heads (Rotary, oscillatory) and tools available, in order to hit or scratch the surface in different ways.

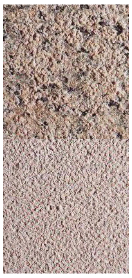
This operation gives a rough surface to the tiles or to part of the tiles, (as in flaming process and with the same purposes). The rough finishing is achieved here by means of a mechanical machining tool head (a bush-hammer or a roll).

According to the desired visual aspect of the surface the shape of the chosen tool will be different. It is possible to achieve different variations of the process, which may go under the names of Ribbing ("rigatura") and Chiseling ("spuntatura"). Ribbing is applied by tradition especially to some kinds of colored limestone when employed for external flooring.The Bush-hammering Machine is also present as a lone standing laboratory machine, instead of being part of a mass production line.

In these machines one or more hammers are installed on a head moving along a bridge. The hammer heads strike the stone slab surface using different tools, depending on the desired finishing quality. The stone is placed on a feeding bed, similarly to other machines, which displaces once the hammer heads have completed their transversal movement. The final result is a series of markings the surface with a regular distribution and form. Dimensions of the markings depend on the type of tool used and on the hammering force. Some models, combining the strike and a rotary movement, exist. There are also special models with a vertical and a horizontal head for treating two stone surfaces simultaneously (i.e. in the kerbstones).

### *3.20.2. Applications*

Bush hammers can be used to process both marble and granite, when a rustic effect is desired. The final product is characterised by a carved, rough and relief surface. The process concerns mainly the texture of the stone rather than its colour, and is adopted on materials destined to external use (stairs, kerbstones, paving elements).



Bush hammered granite

Bush hammered marble

**Figure 56.** Different materials after the hammering process

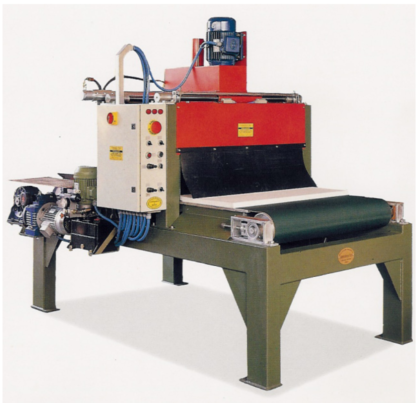


**Figure 57.** Bush hammering machine for a tiles processing line

**Figure 58.** Different applications of bush hammering

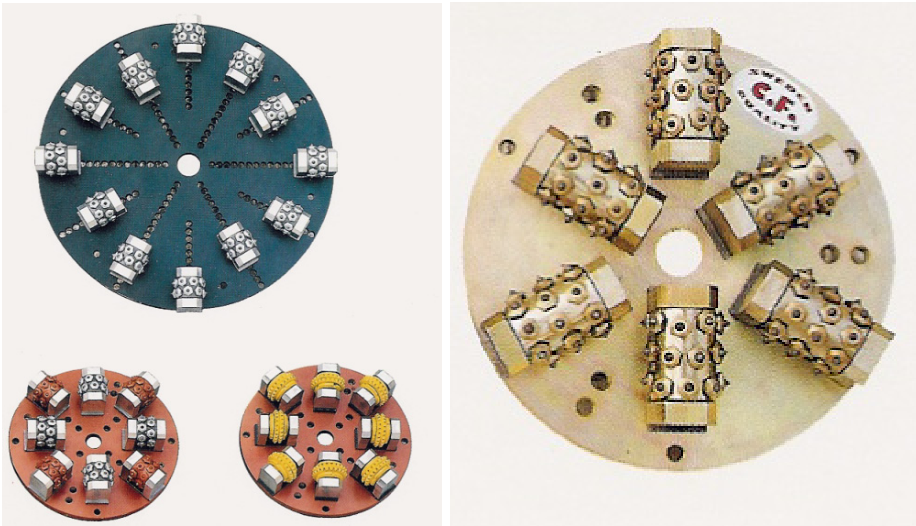


**Figure 59.** Bush hammering tools

### *3.20.3. Characteristics*

An indication of the possible characteristics of this kind of machines is presented in Table 36.

**Table 36.** Characteristics of bush-hammering machine

| | |
|---|---|
| **Diameter of the bush-hammer** | 300 - 500 |
| **Number of tools per heads** | 6 - 20 |
| **Width (mm)** | 600 - 2000 |
| **Examples of commercial definitions of the grade of finishing** | Fine rolled<br>Fine scratched<br>Medium rolled<br>Coarse grain |

### *3.20.4. Advantages/Disadvantages*

Bush-hammering (in comparison to flaming) can be applied to granite (or other stones containing quartz), hard stones with low content in quartz and even to marble with good results, giving products with more precise geometry. On the other hand if the working parameters are not well suited to the stone quality there is the risk of the creation of heavy fractures. There is generally a greater noise emission with bush-hammers in comparison to flaming machines, but the risks related to gas burners are not present.

NOTE: bush-hammering, flaming, sandblasting can be sometimes combined in a single multifunctional machine with interchangeable heads.

### 3.21. Flaming machines

| | |
|---|---|
| Material: | Granite |
| Inlet: | Dimensional stone, slabs, strips, tiles |
| Outlet: | Dimensional stone, slabs, strips, tiles |
| Location: | Stone laboratory, finishing line for tiles, finishing line for slabs |
| Cycles: | Dimensional stones, tiles, slabs |

#### *3.21.1. Description*

The machine is very similar to bush hammers, with the flaming tools installed on a head moving along a bridge, the slab is positioned on a conveyor belt. Due to the similarity between these two machines, it is often possible to use the same plant to perform both operations by simply changing the working tool. In the case of the flaming machine, the tool is a welding torch (or a multiple torch) fed with oxygen and propane and trethene. The flame produced allows to treat the slab surface at high temperature (2500 °C), the thermal shock causes characteristic roughness and a chromatic effect.

#### *3.21.2. Applications*

This operation applies to granite-like stones: the high temperature and the different thermal dilatation coefficient of the constituent minerals (mainly *Quartz* even or Anphiboles with regards to *Feldspar,* generates the cracks that make the surface uneven. The results usually change with the kind of stone.

Flaming can be also applied to marble, limestone and other stones including relevant amount of carbonates (*Calcite*, *Magnesite*), but usually without so satisfactory results. The process acts in a different way: Calcite ($CaCO_3$) is decomposed to CaO and then removed from the surface by means, for instance, of an air jet.

Typically the flaming process is used for exterior applications, where the treatment can provide significant resistance to atmospheric agents or where a high level of pedestrian usage is envisaged.

Flamed granite

Flamed marble

**Figure 60.** Different materials after flaming

**Figure 61.** Flaming machine for slabs

**Figure 62.** Flaming machine for tiles processing line

*3.21.3. Characteristics*

The features of Table 37 are an indication of the possible characteristics of this kind of machines.

**Table 37.** Characteristics of flaming machine

| | |
|---|---|
| **Working width (mm)** | 600 - 2200 |
| **Working thickness (mm)** | 80 |
| **Water consumption (l/min)** | - |
| **Air consumption (l/min)** | - |
| **Other gases consumption** | 100 |
| **Electrical power (kW)** | 15 |
| **Machine length (mm)** | 2000 |
| **Machine width (mm)** | 4000 |
| **Machine height (mm)** | 2400 |
| **Machine weight (tn)** | 1600 |

### *3.21.4. Advantages/Disadvantages*

Flaming in comparison to Bush-hammering can be better applied to granite (or other stones containing quartz). The result may vary when applied to stones having low content in quartz and may become unacceptable when applied to marble. Flaming can be geometrically imprecise. On the other hand, the risk of the development of heavy fractures due to the process is less. There is generally less noise emission with flaming machines in comparison to bush-hammers, but the risks related to gas burners should be taken into consideration.
NOTE: bush-hammering, flaming and sandblasting can be sometimes combined in a single multifunctional machine with interchangeable heads.

## 3.22. SAND BLASTERS

| | |
|---|---|
| Material: | Granite |
| Inlet: | Dimensional stone, slabs, strips, tiles |
| Outlet: | Dimensional stone, slabs, strips, tiles |
| Location: | Stone laboratory, finishing line for tiles, finishing line for slabs |
| Cycles: | Dimensional stones, tiles, slabs |

### *3.22.1. Description*

These machines are used to inject a mixture of water and sand (or other abrasive materials) at high velocity against the stone surface. The structure of the machine is very similar to the bush hammer, with the tools (nozzles) aligned on a moving beam. The movement of the beam along the surface length in combination with the abrasive mixture action perform the work.

### *3.22.2. Applications*

Sand blasting is used both for large slabs and for tiles. The final result varies from the simple treatment, for obtaining a rough and optically soft surface, to the cleaning of materials damaged by atmospheric agents for artistic purposes.

### *3.22.3. Characteristics*

The features of Table 38 are an indication of the possible characteristics of this kind of machines.

**Table 38.** Characteristics of sandblasting machine

| | |
|---|---|
| **Working width (mm)** | 600 - 2200 |
| **Working thickness (mm)** | 80 |
| **Electrical power (kW)** | 15 |
| **Machine length (mm)** | 2000 |
| **Machine width (mm)** | 4000 |
| **Machine height (mm)** | 2400 |
| **Machine weight (tn)** | 1600 |

### *3.22.4. Advantages/Disadvantages*

The smooth but not polished surface obtained by means of sandblasting may give an attractive look at the stone surface, increasing its market value. Nevertheless, a quite similar finishing result may be achieved by “honing”, that is a rough polishing of the surface using only the fist few heads of a polishing machine. In the processing line for mass production of tiles or slabs this can be achieved in a more convenient way on the full surface of the stone. Sandblaster on the other hand is a viable system that can provide good finishing results both in a mass production line or in small parts of the stone surface.
NOTE: bush-hammering, flaming and sandblasting can be sometimes combined in a single multifunctional machine with interchangeable heads.

### 3.23. BRIDGE MILLING MACHINES - CN MILLING CENTRES

| | |
|---|---|
| Material: | Granite, Marble |
| Inlet: | Slabs, Small Blocks |
| Outlet: | Dimensional stone, strips, tiles |
| Location: | Stone laboratory |
| Cycles: | Dimensional stones |

#### *3.23.1. Description*

The bridge milling machine is composed of a cutting disk, which moves along a beam that itself can move forward and backward along two fixed parallel guideways (the entire structure looks like a bridge). The large slab is placed on a bed underneath. The possibility to create special products is given by the rotating movement of the bed and by the inclination movement of the disk.

Modern bridge saws are equipped and controlled by a CNC, permitting the realisation of various cutting programs. CNC allows the control of the horizontal and vertical cutting axis, the bridge translation, the table rotation, the disk inclination and the axis speed.

Machining centres are systems assisted by CNC, which allow to perform complex processing on many types of curved surfaces thanks to co-ordinated interpolation of the work axes. They are mainly constituted of a steel structure and a mobile bridge on which the working unit is installed. The working unit can move along the beam, horizontally and vertically. The beam can move longitudinally, thus obtaining a 3-axis combined movement. Typical machine centres are equipped with 3 to 5 CNC controlled axes, while more complete centres can be available in the versions with up to 12 controlled axes. Moreover, a tool changing system is generally present to perform a huge quantity of different operations (sawing, scooping, lettering, carving, contouring, profiling, shaping, drilling).

#### *3.23.2. Applications*

Bridge saws are extremely versatile machines used to cut the large marble or granite slabs obtained from gangsaws into standard and modular mass products, as well as into customised elements for special applications.

Machines centres are extremely versatile units and can be applied to marble, granite and similar materials. They are used to carry out complex architectural shapes on natural stones.

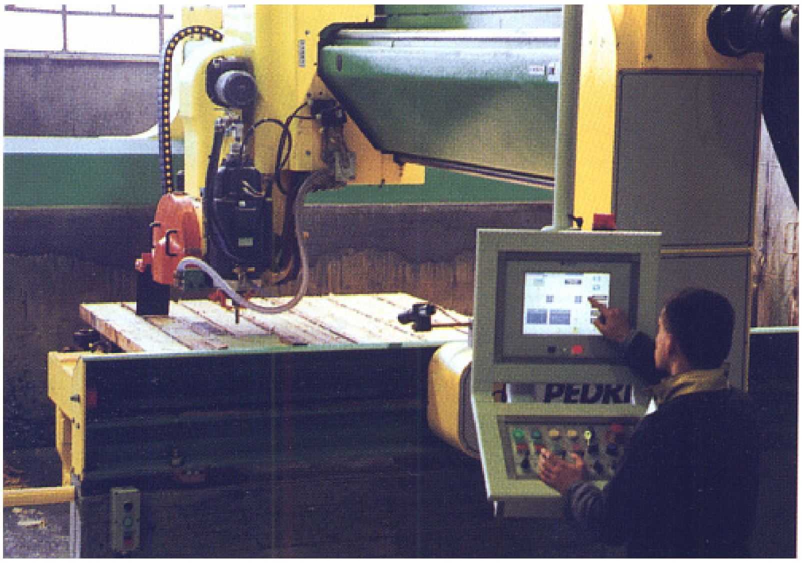



**Figure 63.** A modern CN bridge milling machine in operation

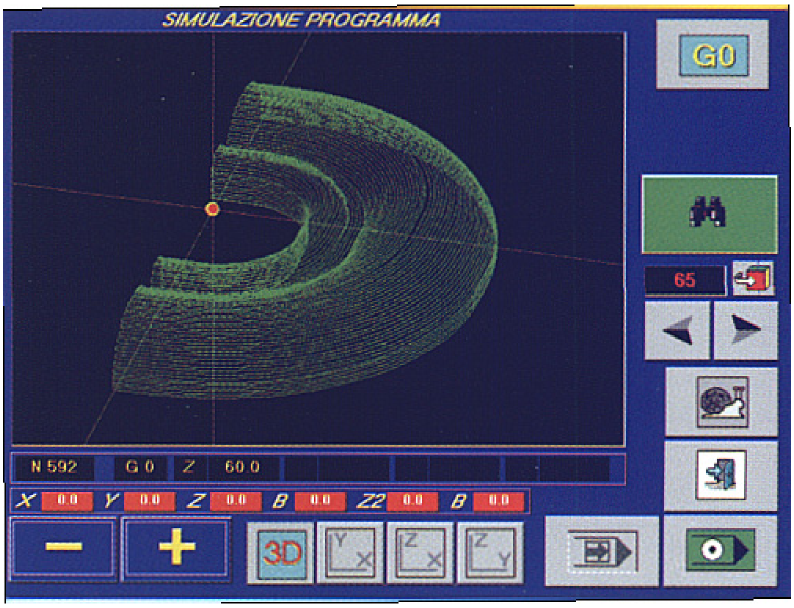



**Figure 64.** CN bridge milling machine - Detail of the Touch Screen

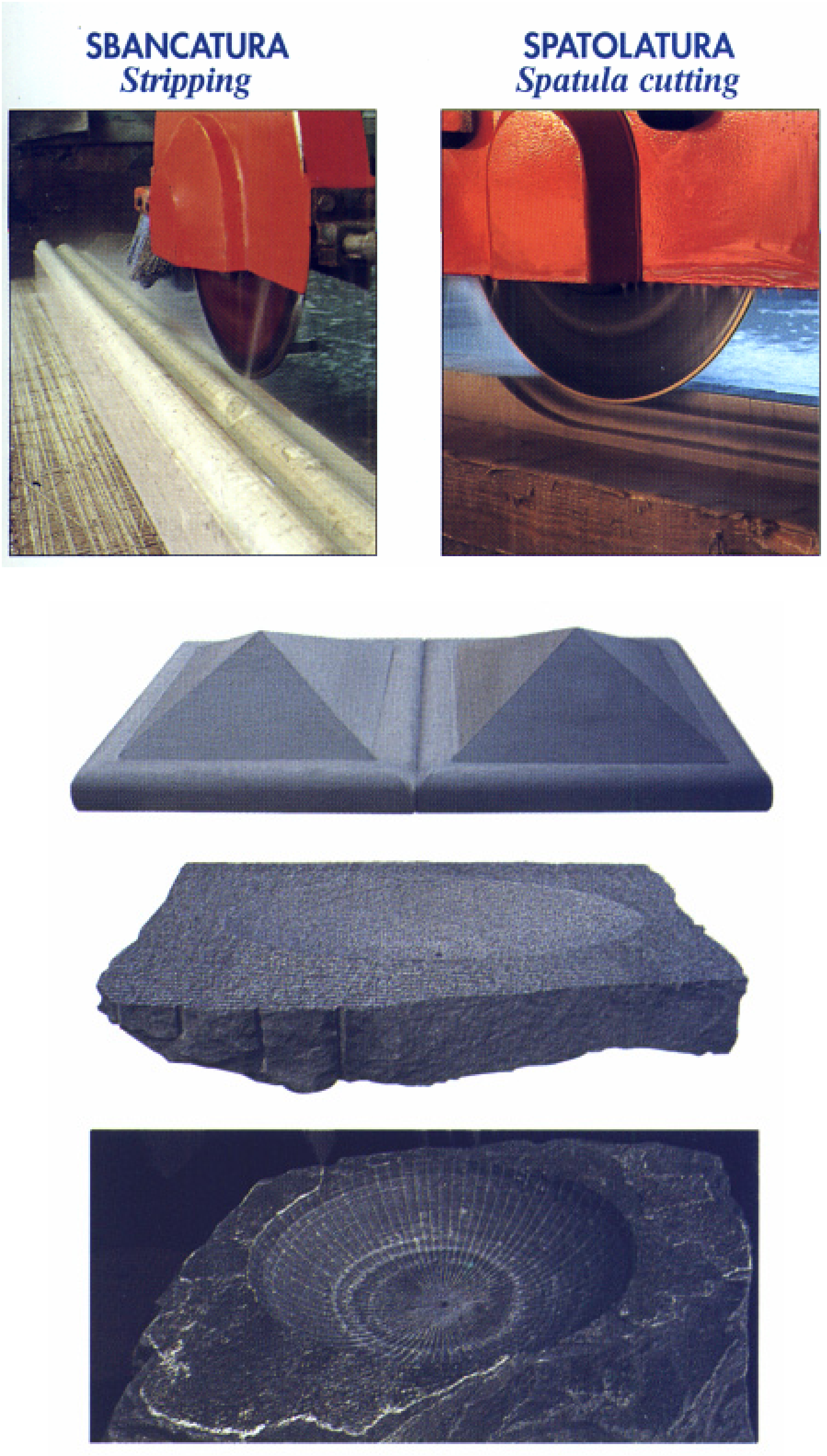



**Figure 65.** Samples of operations and shapes

### *3.23.3. Characteristics*

The features shown in Table 39 are an indication of the possible characteristics of this kind of machines.

**Table 39.** Characteristics of bridge saw

| **Number of disks** | 1 | 1 | 1 | 2 |
|---|---|---|---|---|
| **Max disk diameter (mm)** | 450 (granite)-625 | 725 | 900 | 450-1000 |
| **Disk inclination** | 0-90° | 0-90° | 0-90° | |
| **Min distance between disks (mm)** | | | | 100-300 |
| **Max distance between disks (mm)** | | | | 1500-2500 |
| **Cutting length (mm)** | 3500-3750 | 3500-3750 | 3500-3750 | 3800-4200 |
| **Cutting width (mm)** | 3500 | 3500 | 3500 | 3600 |
| **Cutting depth with max disk (mm)** | 190 | 255 | 320 | 120-350 |
| **Disks motor (kW)** | 15 | 22 | 26 | 15-45 |
| **Blade speed (rpm)** | 700-2000 | 700-2000 | 700-2000 | 3000 |
| **Cutting speed (m/min)** | 0-18 | 0-18 | 0-18 | 0-20 |
| **Bridge speed (m/min)** | 0-12 | 0-12 | 0-12 | 0-20 |
| **Water consumption (l/min)** | 45-50 | 45-50 | 45-50 | |
| **Head rise-descent stroke (mm)** | 350-450 | 350-450 | 350-450 | 600 |
| **Machine length (mm)** | 5700-6600 | 5700-6600 | 5700-6600 | 4800-6000 |
| **Machine width (mm)** | 4400-5400 | 4400-5400 | 4400-5400 | 6500-7000 |
| **Machine height (mm)** | 2800-3300 | 2800-3300 | 2800-3300 | 2300-4200 |
| **Machine weight (tn)** | 4.2.-6.4 | 4.2.-6.4 | 4.2.-6.4 | 13 |

Machine centres characteristics can vary considerably according to the model and the number of controlled axes. A summary of typical characteristics for machines with 3 to 5 controlled axes is presented in Table 40.

**Table 40.** Characteristics of machine centres

| **Controlled CNC axis** | 3-5 |
|---|---|
| **Axis X travel length (mm)** | 2000-6000 |
| **Axis Y travel length (mm)** | 2000-5000 |
| **Axis Z travel length (mm)** | 500-1050 |
| **Spindle electric power (kW)** | 7.5-22 |
| **Spindle revolution speed (rpm)** | 1000-12000 |
| **Spindle inclination** | -100° ÷ +100° |
| **Axis X speed (m/min)** | 0-36 |
| **Axis Y speed (m/min)** | 0-20 |
| **Axis Z speed (m/min)** | 0-10 |
| **Max tools changer positions** | 24 |
| **Total power (kW)** | 35 |
| **Water consumption (l/min)** | 60-80 |
| **Machine length (mm)** | 4800 |
| **Machine width (mm)** | 5300 |
| **Machine height (mm)** | 2900 |

### *3.23.4. Advantages/Disadvantages*

Bridge milling machines are the core of the Stone Laboratory (or of the Laboratory department in a bigger plant). They often work together with contouring machines. The state of the art is defined by the CN machines provided that they are equipped with a CAD-CAM system or interface. Such systems define the modern laboratories, but in order to be employed they require skilled and trained operators so as to exploit the full capability of the machine. When such conditions are not achieved, the machine tends to remain under-exploited. In such a case, the choice should be redirected to a more traditional light bridge milling machine, being easily used even by personnel not so specifically trained, in order to perform basic operations (shaping slabs for a contouring machine, manufacture of tiles from slabs and manufacture of simple traditional shapes).

### 3.24. CONTOURING MACHINES

| | |
|---|---|
| Material: | Granite, Marble |
| Inlet: | Slabs, Small Blocks |
| Outlet: | Dimensional stone, strips, tiles |
| Location: | Stone laboratory |
| Cycles: | Dimensional stones |

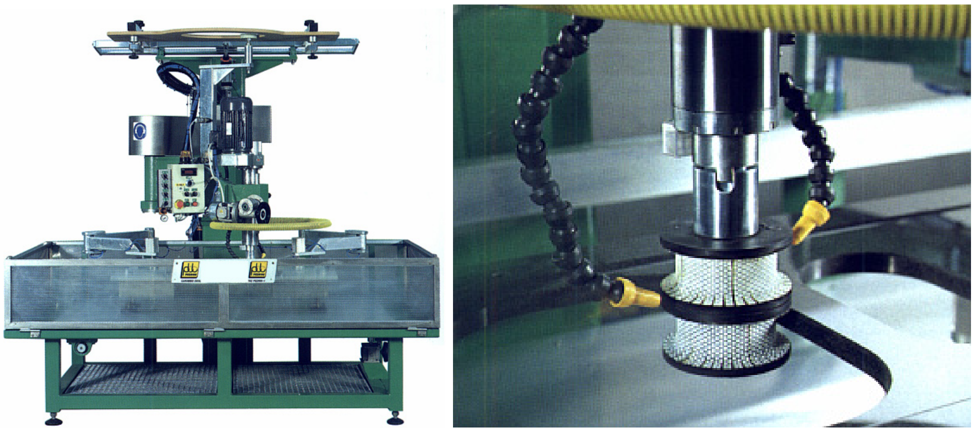


**Figure 66.** Countouring machines

#### *3.24.1. Description*

A contouring machine basically includes a vertical spindle and a workbench. The spindle can be positioned freely on the 3 axes, controlled by a PLC, CN, or by a jig copying device. A wide range of tools can be mounted on the spindle, in order to cut, shape and polish virtually any possible contour.

#### *3.24.2. Applications*

A contouring machine is capable of drilling, shaping and polishing pieces used in interior design (kitchen tops, vanity tops, tables) and constructions (capitals, arches).

#### *3.24.3. Characteristics*

The features of Table 41 are an indication of the possible characteristics of this kind of machines.

**Table 41.** Typical features of a contouring machine

| | | |
|---|---|---|
| **Maximum dimension machinable (m)** | 1.8 x 0.8 | 3.2 x 1.6 |
| **Bench size (m)** | 2 x 1 | 3.2 x 1.6 |
| **Vertical spindle stroke (mm)** | 270 | 270 |
| **Brakes on the arms** | pneumatic | hydraulic |
| **Spindle motor (kW)** | 3.75 | 8 |
| **Installed electrical power** | 4.5 | 10 |
| **Machine height (m)** | 3 | 3 |
| **Machine weight (kg)** | 1500 | 2000 |

#### *3.24.4. Advantages/Disadvantages*

Together with a bridge milling machine, the contouring machine defines the typical Stone Laboratory. The bridge milling machine cut rough shapes from the slabs by its diamond disc, while the contouring machine manufactures the finished product.

### 3.25. PROFILING WIRE SAW MACHINES

Material: Granite, Marble
Inlet: Slabs, Small Blocks
Outlet: Dimensional stone, strips, tiles
Location: Stone laboratory
Cycles: Dimensional stones

#### *3.25.1. Description*

These machines have a structure very similar to the monowire plants used to square the blocks. They are composed of steel frame with tubular uprights housing two flywheels to guide the diamond wire. The block is positioned on a feeding bed. The profiling machines are CNC controlled allowing programming of the work, thus not needing the presence of an operator in the cutting phase. Depending on the model, several movements are available to produce various different shapes: up-down, rotation and translation of the block, flywheel angling and flywheels orbital rotation.

A version with vertical wire exists: the main structure is very similar, but 90° rotated. In this model, the block is positioned on a translating and rotating bed.

#### *3.25.2. Applications*

Profiling machines are used to obtain several and different shapes from marble, granite and stone slabs, such as cylindrical and conical columns, cylindrical and conical coverings for columns, various cornices, profiles, funeral art elements, curved pieces, etc.

#### *3.25.3. Characteristics*

An indication of the possible characteristics of this kind of machines is presented in Table 42.

**Table 42.** Characteristics of profiling wire saw machine

| **CNC controlled axis** | 2 | 2 (Vertical) | 4 |
|---|---|---|---|
| **Max inclination** | | | -30° +30° |
| **Cutting length (mm)** | 3300 | | 2200 |
| **Cutting width (mm)** | 2500-3000 | | 2300 at 0°<br>1500 at 30° |
| **Cutting height (mm)** | 1500-1900 | 450 | 1500 |
| **Flywheel motor power (kW)** | 15 | 12 | 15 |
| **Wire speed (m/s)** | 10-40 | 10-40 | 10-40 |
| **Installed electrical power (kW)** | | | |
| **Water consumption (l/min)** | 40 | 20 | 40 |
| **Machine length (mm)** | 6300 | 5000 | 6200 |
| **Machine width (mm)** | 7400 | 1600 | 6900 |
| **Machine height (mm)** | 4000 | 3000 | 4300 |

#### *3.25.4. Advantages/Disadvantages*

These machines are very suitable for processing stone elements with high added-value but are not suitable for mass production.

### 3.26. MANUAL POLISHERS

Material: Granite, Marble
Inlet: Slabs, Small Blocks
Outlet: Dimensional stone, strips, tiles
Location: Stone laboratory
Cycles: Dimensional stones

#### *3.26.1. Description*

They are composed of an articulated arm, which is manually moved over the stone surface to be treated. The operator can easily check the degree of finishing achieved.

#### *3.26.2. Applications*

Actually this kind of polishers can be used for both large and small slabs and in general for any kind of semi-finished or finished standard or customized product. As it can be easily understood, manual polishers are not ideal for a mass production, but rather for a limited and customised quantity of small products.

#### *3.26.3. Characteristics*

The features of Table 43 are an indication of the possible characteristics of this kind of machines.

**Table 43.** Characteristics of manual polisher

| **Number of polishing heads** | 1 |
|---|---|
| **Max radius (mm)** | 2000-2200 |

| | |
|---|---|
| **Speed (rpm)** | 200-2900 |
| **Motor power (kW)** | 3.5-7.5 |
| **Machine length (mm)** | 3000 |
| **Machine width (mm)** | 3200 |
| **Machine height (mm)** | 2250 |
| **Machine weight (kg)** | 950 |

#### *3.26.4. Advantages/Disadvantages*

These machines are suitable for small batch production or stone laboratory. Because of the very low productivity and the absence of automatic controls it is unfit to be used for mass production or even for remarkable batches.

### 3.27. Edge polishers

Material: Marble, Granite
Inlet: Skirting, strips, tiles
Outlet: Skirting, strips, tiles
Location: Finishing line
Cycles: Dimensional stones, tiles

#### *3.27.1. Description*

The machine is constituted of a steel structure. The stone pieces are positioned on a conveyor belt and then moved under the working heads. Pneumatic pistons lock the piece in the correct position. Several working heads perform different treatments: calibration, straight edges, bevels, sloping cuts, edge polishing and special treatments. The most common units present in an edge polishing machine are:

- horizontal gauging units (adjustable vertically and horizontally) in the form of flat or shaped diamond wheel to obtain different profiles
- vertical polishing units with the possibility to be removed if necessary
- chamfering group (positioned at 45°, lower and upper) for edge shaping
- drip stone cutting unit on the upper surface of the piece

**Figure 67.** Edge polisher

The variety of these machines is rather big, depending on the performance and on the accessories offered. Modern edge polishers are CNC controlled: this means that operations, such as pieces feeding, heads extraction, movement of rollers up and down are managed in an automatic way, once the equipment has been settled. In this way pieces with different width can be worked at the same time.

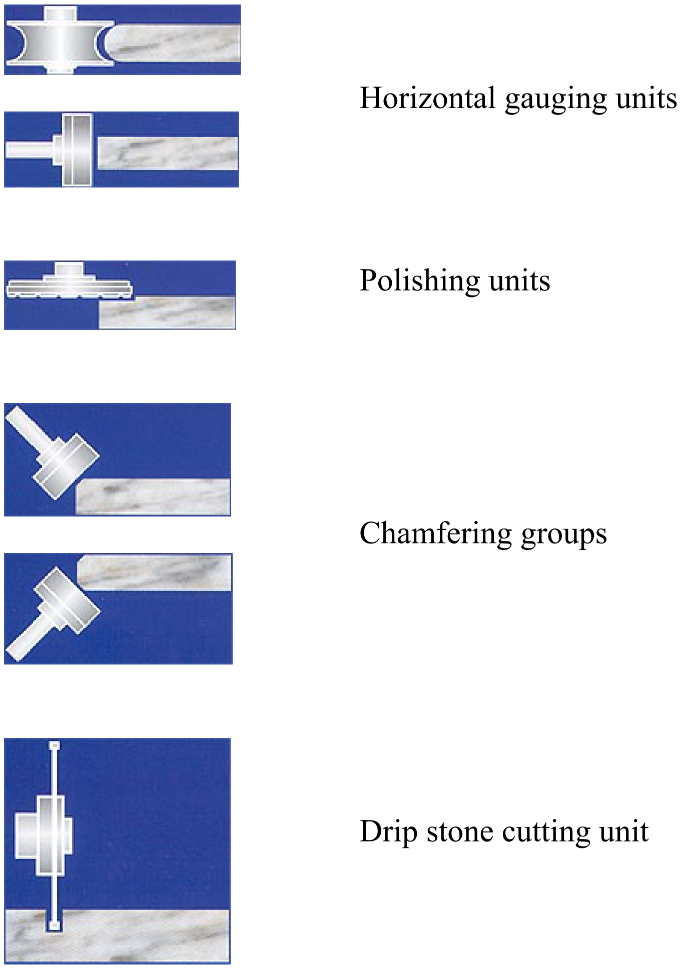



**Figure 68.** Different types of edges

Some versions using a single horizontal tool (thus eliminating the shaped one) for any kind of profile exist.

### *3.27.2. Applications*

Edge polishers are designed to perform several operations on strips, tiles and other elements of granite, marble or similar materials. The use of edge polishers is particularly indicated for manufacturing products for steps, desks and tables, furniture tops, shelves, shop fittings, etc.

### *3.27.3. Characteristics*

The features of Table 44 are an indication of the possible characteristics of this kind of machines. These characteristics are reported for a "standard" machine. Obviously, as many versions of edge polishers exist, some of these properties can not refer to those models.

**Table 44.** Characteristics of an edge polisher

| | |
|---|---|
| **Max working width (mm)** | 600 |
| **Min working width (mm)** | 120 |
| **Max working thickness (mm)** | 100 |
| **Min working thickness (mm)** | 20 |
| **Frontal spindles** | 4-8 |
| **Spindles for bevels** | 2-4 |
| **Gauging wheel diameter (mm)** | 260 |
| **Polishing wheels diameter (mm)** | 130-150 |
| **Installed power (kW)** | 15-21 |
| **Belt feed speed (m/min)** | 0-3 |
| **Machine length (mm)** | 3500-6000 |
| **Machine width (mm)** | 1800-2300 |
| **Machine height (mm)** | 2200 |
| **Machine weight (tn)** | 6.5-7 |

#### *3.27.4. Advantages/Disadvantages*

An edge polisher is a flexible machine, which may fit as an ancillary unit to a line for mass production of tiles (where the manufacture of skirtings also from scraps is useful) such as in a stone laboratory (where it is exploited in all its possibilities). On the other hand the operations which can be performed are quite limited to finishing operation on linear elements, as described before.

### 3.28. LATHES

Material: Granite, Marble
Inlet: Slabs, Small Blocks
Outlet: dimensional stone, strips, tiles
Location: Stone laboratory
Cycles: Dimensional stones

#### *3.28.1. Description*

These machines are composed of a steel structure and are equipped with a blade head unit and a second working head for milling operations. The workpieces are fixed at both ends, brought into rotation and then worked with sharp tools. The processing is divided into two phases:

- the first one, roughing out and turning, is made by a disk;
- the second one, finishing, is made by using milling-cutters for reproducing friezes and relieves.

The two working units can run along the machine length and can move vertically independently. Hydraulic or CNC controlled versions are available. The second one allows a more complete range of operations, due to the availability of up to 5 controlled axes and of a rotating and tilting blade unit.

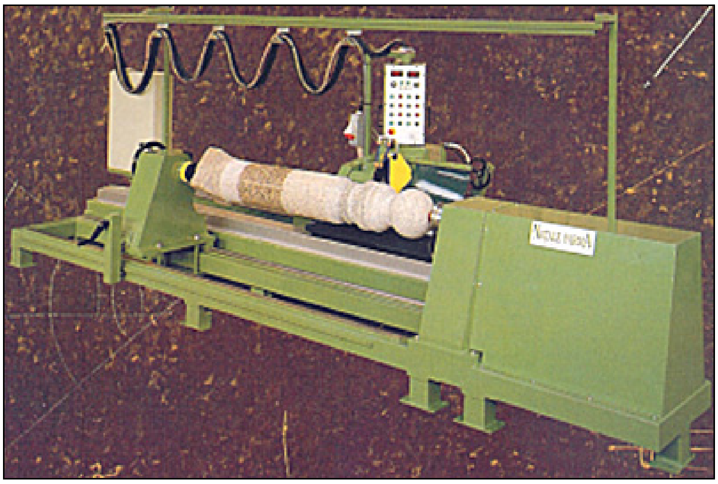


**Figure 69.** View of lathes

*3.28.2. Applications*

Marble, granite and similar materials can be worked with lathes. The typical application is addressed towards columns, balusters, pots, balls and oval shapes, twist, doric, polygonal and ornate columns, statues and capitals. It is possible to perform polishing of cylindrical and tapering columns, realisation of grooves with the rotating sawing head, internal work, sculpting and works on flat surfaces with the milling head.

*3.28.3. Characteristics*

The features shown in Table 45 are an indication of the possible characteristics of this kind of machines.

**Table 45.** Characteristics of lathes

| | **Hydraulic** | **CNC** |
|---|---|---|
| **Controlled CNC axes** | - | Up to 5 |
| **Max working diameter (mm)** | 400-1500 | 400-2000 |
| **Max working length (mm)** | 2000-8000 | 2000-10000 |
| **Max disk diameter (mm)** | 400-700 | 400-1000 |
| **Disk electrical power (kW)** | 9-22 | 9-40 |
| **Installed electrical power (kW)** | 13-26 | 22-70 |

*3.28.4. Advantages/Disadvantages*

In the stone laboratory, a lathe is very effective in the manufacture of pieces having axial symmetry, as described before, but is not suitable for other processes. In the traditional laboratory, it is complementary to a bridge milling machine coupled with contouring machine.

### 3.29. WATER-JET

Material: Granite, Marble
Inlet: Flat element having limited thickness

Outlet: Finished product
Location: Stone laboratory
Cycles: Dimensional stones

*3.29.1. Description*

This machine has been designed for flat cutting operations with a high-pressure CNC controlled water-jet system. It is composed of a fixed table, where the piece is positioned, and of a cutting head installed on a moving bridge, which carries out the cutting operations. The cut is performed by high-pressure water jet ejected through a gauged orifice at three times the sound speed, mixed with abrasive. A feed pump and a water filtering unit complete the machine structure. The working area consists of a tank, where the pieces are immersed under water level for submerged operations, in order to reduce noise at an acceptable level. General options for this machine are:
- the multiple cutting heads system for production series
- the cutting head self-positioning device to ensure that the cutting head is kept at a constant distance from the material surface
- the anticollision system: a sensor preventing the breaking of the nozzle in the event of collision between the tool and the material surface

A slightly different version of the machine allows surface finishing of the treated materials. To obtain this result, it is necessary to dose four elements: the working pressure, the height of the nozzle and the speed of the nozzle and the slab. Nevertheless, the final result depends on the material hardness, chemical composition, density and colour. For this application only water is required.

**Figure 70.** Water jet

*3.29.2. Applications*

The system is used both on marble and granite slabs (and similar materials) and is able to create regular geometric or any required form. It has the capability to perform all kinds of complex shapes (funeral steles, fireplaces, mosaics, lettering,etc.). The drawing is memorised by the CNC and successively performed and eventually repeated indefinitely. It is possible to treat also cylindrical or tapered surfaces with the addition of a horizontal CNC controlled rotating axis.

The application of the water-jet system is suitable for all stones and allows to vary the roughness degree of the material, to stand out its original colour.

### *3.29.3. Characteristics*

**Table 46.** Characteristics of water-jet

| | | | | |
|---|---|---|---|---|
| **CNC controlled axes** | 3 | 3 | 3 | 3 |
| **Working length (mm)** | 2000 | 3000 | 4000 | 6000 |
| **Working width (mm)** | 1200-1600 | 1600-2000 | 2000 | 3000 |
| **Cutting pressure (bar)** | 3750-4130 | 3750-4130 | 3750-4130 | 3750-4130 |
| **Water consumption (l/min)** | 2-9 | 2-9 | 2-9 | 2-9 |
| **Max nozzle diameter (mm)** | 0.33-0.5 | 0.33-0.5 | 0.33-0.5 | 0.33-0.5 |
| **Filtering capacity (μm)** | 1 | 1 | 1 | 1 |
| **Installed electrical power (kW)** | 18.5-90 | 18.5-90 | 18.5-90 | 18.5-90 |
| **Machine length (mm)** | 2700 | 4000 | 5300 | 6700 |
| **Machine width (mm)** | 1800 | 2700 | 2700 | 4500 |
| **Machine height (mm)** | 1500-2000 | 1500-2000 | 1500-2000 | 1500-2000 |
| **Machine weight (tn)** | 2.5 | 3.2 | 4 | 6 |

**Table 47.** Cutting speed in function of material

| Material | Thickness (mm) | Cutting speed (cm/min) |
|---|---|---|
| **Marble** | 10 | 120 |
| | 20 | 70 |
| | 30 | 40 |
| **Granite** | 10 | 90 |
| | 20 | 60 |
| | 30 | 30 |

**Table 48.** Finishing application on Granite

| Granite | Light Roughness ($m^2$/h) | Deep Roughness ($m^2$/h) |
|---|---|---|
| **Sierra Chica** | 62 | 36 |
| **Porrino Pink** | 46 | 30 |
| **Beta Pink** | 46 | 30 |
| **Kashmire White** | 36 | 28 |
| **Yellow Venetian** | 34 | 26 |
| **Gneiss** | 32 | 24 |
| **Balmoral Red** | 28 | 24 |
| **Emerald Pearl** | 28 | 20 |
| **Capao Bonito** | 26 | 16 |
| **African Black** | 22 | 14 |
| **Multicolor Green** | 20 | 12 |
| **Blue Pearl** | 20 | 12 |

| | | |
|---|---|---|
| **Absolute Black** | 18 | 10 |
| **Multicolor Pink** | 16 | 8 |
| **Balmoral Blue** | 16 | 8 |
| **Guiba Brown** | 16 | 8 |

#### *3.29.4. Advantages/Disadvantages*

These machines are very suitable for processing stone elements with high added-value but are not suitable for mass production.

### 3.30. ENGRAVING MACHINES

Material: Granite, Marble
Inlet: Slabs, Small Blocks
Outlet: Dimensional stone, strips, tiles
Location: Stone laboratory
Cycles: Dimensional stones

#### *3.30.1. Description*

Engraving machines or pantographs are constituted of a desk, where the piece is placed, and a milling tool performing the work on the stone surface. A manual an automatic version of this machine, driven by a numeric control is available. In the manual version a mechanical arm is displaced over a rubber or wooden stencil of letters or figures following their outlines. The movement is transmitted to the milling tool, which makes the incision on the stone plate. CNC controlled engraving systems are 3 axes controlled and allow the automatic performance of the incision, starting from a figure acquired from a scanner or from a CAD system.

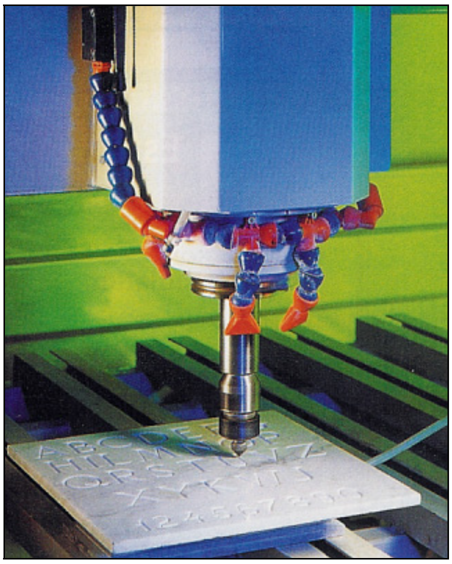


**Figure 71.** Engraving machine

#### *3.30.2. Applications*

Engraving systems have a vast application in all the situations where wording is required (plaques, funeral monuments, grave headstones). The numeric controlled machines can reproduce cyclically forms and letters previously acquired and stored and are able to perform a night-time running.

### *3.30.3. Characteristics*

**Table 49.** Characteristics of engraving machine

| | |
|---|---|
| **Working length (mm)** | 1300 |
| **Working width (mm)** | 1050 |
| **Working height (mm)** | 150-210 |
| **Driller motor speed (rpm)** | 0-12000 |
| **Driller motor power (kW)** | 1.1 |
| **Forward speed (m/min)** | 0-12 |
| **Total weight (tn)** | 0.75 |
| **Machine length (mm)** | 1950 |
| **Machine width (mm)** | 1850 |
| **Machine height (mm)** | 1900 |

### *3.30.4. Advantages/Disadvantages*

These machines are very suitable for processing stone elements with high added-value, but are not suitable for mass production.

## 3.31. ANTIQUING MACHINES (TUMBLING MACHINES, BRUSHING MACHINES)

Material: Granite, Marble
Inlet: Slabs, Small Blocks
Outlet: Dimensional stone, strips, tiles
Location: Stone laboratory
Cycles: Dimensional stones

### *3.31.1. Description and Application*

These machines aim to achieve an “antiqued” surface: a surface with a deliberate “aged” appearance, simulating the wear (and even the stain) normally produced by ageing. This treatment is more frequently applied to limestone (and calcite stones), both for its better machining and the visual aspect generated. The resulting stone products find application in mosaics and generally in flooring and cladding, when “aged” aspect is simulated for architectural reasons and also in furniture decoration.

Antiquing of bricks (having cubical or similar shape, and size ranging from few centimeters up to half meter) is generally achieved by means of Tumbling Machines (Italian terms: “burattatrice” or “buratto”, “tamburlano”). The stone pieces are put into a rotating drum having vertical, horizontal or inclined axis, together with water and compounds, like sand, abrasive mix, etc. As an alternative or in addition to rotation, vibrating drums are also available. The motion of the drum induces wear and smoothes and rounds the stone edges. The stone fragments also contribute to the abrading process. The process may last from a few minutes, up to many tens of minutes.

Antiquing of surfaces can be achieved by means of a brushing process. Special machines may not be needed; instead, metal brushes with standard connection (like “Frankfurt” or “satellite”) can be mounted on the heads of a polishing machine.

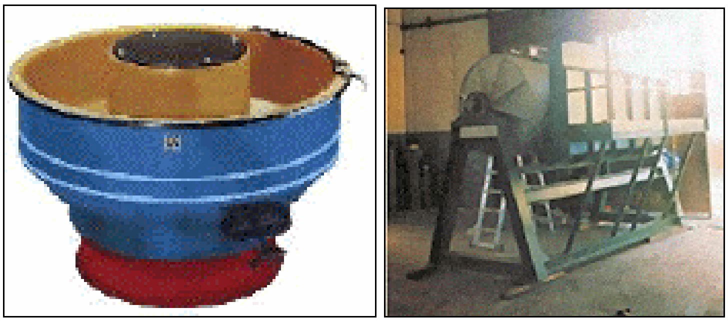


**Figure 72.** Tumbling machines

**Figure 73.** Metal brushes for antiquing

*3.31.2. Characteristics*

**Table 50.** Characteristics of tumbling machine

| | |
|---|---|
| **Working size (mm)** | 20x20 up to 500x500 |
| **Motor power (kW)** | 10 up to 50 |
| **Cycle time (min)** | 10-100 |
| **Total weight (tn)** | 0.5 up to 5 |
| **Machine size (m)** | 1x1x1 up to 6 x 3 x 2 |

*3.31.3. Advantages/Disadvantages*

This kind of machines/processes is focused on a limited range of products. The contribution from technology subject to innovation is low. On the other side, they are very effective for the target to which the process is aimed and for the market to reach.

# 4

# Tools

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## 4.1. TOOLS

In the wider sense, the tools for manufacturing ornamental stone products can be initially divided into tools for quarrying and tools for factory processes. In detail, tools can be classified according to many different approaches. In the following paragraphs tools are classified according to the process in which they are employed and hence according to the kind of machinery where the tools are mounted.

For every kind of machine/process, possible tools arrangements and dispositions are explained. For every kind of tool that can be determined in the above way, more details are given in the appropriate paragraphs.

For more details regarding machines, cycles and processes see the relevant chapters.

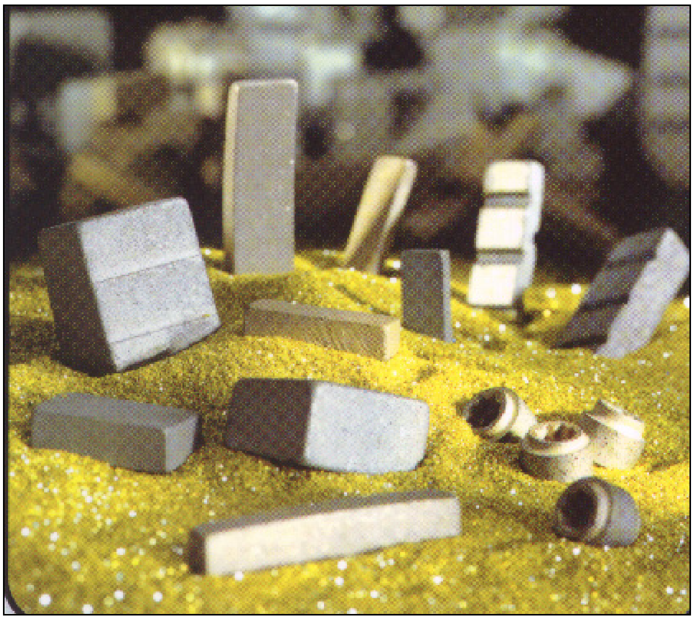


**Figure 74.** Many shapes of Sintered Diamond, widely employed for stone sawing

### *4.1.1. Quarry: Blocks Extraction Technologies*

| Machine | Tools |
|---|---|
| Diamond Wire Cutters | Diamond Wires |
| Chain Saw | Diamond Chains |
| Diamond Belt Saw | Diamond Belt |
| Flame Jet | - |
| Pneumatic Top-Hammer | - |
| Hydraulic Top-Hammer | - |
| Down-The-Hole Hammers. | - |
| Water Jet | - |

### *4.1.2. Processing: Cutting Department*

Process: slab cutting, block squaring (of marble)

| Machines | Tools |
|---|---|
| Single diamond blade frame saw for marble | Linear Diamond blade |
| Multi-blade cutting frame, with diamond blades | Linear Diamond blades |
| Giant disk cutting machine | Diamond disc (big size, >2 m) |

Process: slab cutting, block squaring (of granite)

| Machines | Tools |
|---|---|
| Single diamond wire frame (or cutter) | Linear Diamond blades |

| | |
|---|---|
| Multiple diamond wire frame (or cutter) | Diamond wire |
| Multi-blade gangsaw | Steel blades + abrasive mix |
| Giant disk cutting machine | Diamond disc (big size, >2 m) |

Process: strip cutting for tiles (marble)

| Machines | Tools |
|---|---|
| Single Disc Block cutters | Vertical disc: Diamond disc (average size, 1-1.7 m) |
| | Horizontal: Diamond disc (small size, 300-500 mm) |
| Multi Disc Block cutters | Vertical discs: Diamond discs (average size, 1-1.7 m) |
| | Horizontal: Diamond discs (small size, 300-500 mm) |

Process: strip cutting for tiles (granite)

| Machines | Tools |
|---|---|
| Multi Disc Block cutters | Vertical discs: Diamond discs (average size, 1-2 m) |
| | Horizontal: Diamond disc (small size, 300-500 mm) |

Process: strip splitting (marble)

| Machines | Tools |
|---|---|
| Splitting machine for marble | Diamond discs with reinforced blade |

Process: strip splitting (granite)

| Machines | Tools |
|---|---|
| Splitting machine for granite | Diamond discs (many, increasing in diameters) |

### *4.1.3. Processing: Finishing Department (for Tiles and Slabs)*

Process: strip calibration (granite)

| Machines | Tools |
|---|---|
| Calibrating machine for granite strips | Diamond grinding tools |

Process: strip calibration (marble)

| Machines | Tools |
|---|---|
| Calibrating machine for marble strips | Diamond grinding tools |

Process: strip/tiles polishing (marble/granite)

| Machines | Tools |
|---|---|
| Polishing machine for strips | Polishing abrasive tools |
| | Polishing diamond tools |

Process: slab polishing (marble/granite)

| Machines | Tools |
|---|---|
| Belt polishers for slabs (marble/granite) | Polishing abrasive tools |
| Bridge polishers for large slabs | Polishing diamond tools |

Process: trimming (length-wise) and cross-cutting of slabs, cross cutting of strips (tiles cut-to-size), pre-cut (preliminary strip edges cross cutting before calibration and polishing) for marble/granite.

| Machines | Tools |
|---|---|
| Trimming machines | Diamond discs (small size, 300-500 mm) |
| Single/multi disc Cross cutting machines | Diamond discs (small size, 300-500 mm) |

Process: side calibration of tiles, squaring (marble/granite)

| Machines | Tools |
|---|---|
| Chamfering (squaring) machine | Front diamond cup wheels |

Process: chamfering (marble/granite)

| Machines | Tools |
|---|---|
| Chamfering machine | Front diamond wheels (continuous rim) |
| | Front diamond wheels (segmented) |
| | Polishing cup wheels (abrasive) |
| | Polishing cup wheels (diamond) |

Process: bush-hammering and rolling (Ribbing, Chiseling) (marble/granite)

| Machines | Tools |
|---|---|
| Bush hammering machines | Bush hammers |

Process: flaming, sandblasting (marble/granite)

| Machines | Tools |
|---|---|
| Flaming and sandblasting machines | - (see note below) |

Process: Resin application, filling (marble/granite)

| Machines | Tools |
| --- | --- |
| Resin application machines | - (see note 1 below) |
| Filling machines | - (see note 1 below) |
| Plastering machines | - (see note 1 below) |

Note 1: some machines and processes do not employ any means for mechanical removal of the material from the working place, hence no classic mechanical tool is required for the process; instead other means, such as nozzles and heating plates, are employed.

### *4.1.4. Workshop (Laboratory)*

Note: Some processes (for instance Edge Polishing or Bush-hammering) may take place either in a workshop (with lone-standing machines) or in a finishing department (where machines are series-connected and aimed to mass production). However, in such a case craftwork or mass production does not affect in a relevant way the choice and the characteristics of the tools.

| Machines | Tools |
| --- | --- |
| Edge polishers, slotting machines | Front segmented diamond wheels |
| | Front continuous diamond wheels |
| | Peripheral diamond wheels for dripstone |
| | Grinding diamond plates |
| | Diamond slotting radial wheels |
| | Edge honing abrasives |
| | Half and full torus segmented diamond wheels |
| | Front grooved continuous band diamond wheels |
| | Peripheral diamond wheels for dripstone |
| Bridge milling machines - CN milling centers | Diamond discs for marble |
| | Diamond discs for granite |

CN milling centres equipped with additional vertical (inclinable) spindle

Tools for Bridge milling machines

Tools for Contouring Machines

| Machine | Tools |
|---|---|
| Contouring Machines (automatic, CNC) | |
| | Continuous rim diamond cutting mills |
| | Segmented rim diamond cutting mills |
| | Electroplated diamond cutting mills for marble |
| | Segmented peripheral diamond wheels for concavity |
| | Electroplated diamond wheels |
| | Diamond drills |
| | Torus abrasives wheels |
| Manual contouring mill machine for marble and granite | |
| | Segmented and electroplated diamond wheels |
| Manual machine for curved cutting of marble and granite | |
| | Segmented diamond discs with special protection |
| Profiling wire saw machines | Diamond wire (various kinds of wire) |
| | Diamond sintered wires for granite |
| | Diamond sintered wires for marble |
| | Electroplated wires for marble and sandstone |
| Manual polishers (Articulated manual polishing machine) for marble and granite. | |
| | Frankfurt and segmented magnesiac wheels and plates |
| Water-jet | - (see note 1 above) |
| Engraving machines, Drilling machine, key hole saws | |
| | Diamond drill bits |
| Angle grinders cutting machine | |

dry and wet diamond discs, diamond segmented cups, grinding wheels, convex diamond circular blades, segmented sintered diamond front plates and peripheral wheels for grinding operations, half torus segmented diamond wheels, flexible diamond resin discs

## 4.2. DIAMOND WIRE

### *4.2.1. Machines and processes*

This kind of tools applies to different machines and processes :

- Diamond wire cutters (process: block extraction in the quarry)
- Single stationary diamond wire frame (process: slab cutting, block squaring, granite)
- Multiple diamond wire frame (process: slab cutting)
- Profiling wire saw machines (process: laboratory machines for craftworks)

### *4.2.2. Description*

Diamond wire replaced steel helicoids wire that was used with fine abrasive material (emery or quartz sand) in the primary cutting of blocks of in dimension stone quarries, thus making the wire method flexible and ten times faster. A common diamond wire consists of:

- A stainless steel 7X7 cable, 5 mm diameter, on which the effective cutting parts and all other elements of the diamond wire are mounted. The cable absorbs static and dynamic stresses;
- Diamond pearls (beads), 10 mm diameter, which are the effective cutting parts. The diamond grains are **electroplated** or **sintered** on an annular (ring shaped) steel frame;
- Spacer springs, which are flexible elements aiming to keep the proper distances between the pearls on the wire;
- Spacers, which are steel rings that ensure correct arrangement of the pearls;
- Joint clamps, which link sections of wire; the stops are metal rings, solidly pressure-fitted to the wire.

There are two types of diamond pearls:

*Electroplated Diamonds Pearls*

The electroplated diamond pearls wire is the first diamond wire introduced in the market. The pearls consist of a ring-shaped steel frame, on which the diamond grains are deposited by electrolysis. A layer of metal bonding agent holds the grains of diamond deposited on them until they are worn out during rock cutting process. The electroplated diamond wire has a remarkable coherence of the diamond grains and a high rock-cutting capacity. It is more effectively used for sawing soft stones, or for small cuts and for squaring small blocks. It has higher initial cutting speed compared to the sintered diamond wire, requires power not more than 25 hp and needs a relatively small amount of cooling water that varies from 10 l/min minimum to 20 l/min maximum.

*Sintered Diamonds Pearls (impregnated diamond pearls*)

The diamond grains are mixed with the bonding material according to a special method. This mixture is placed in matrix, heated and compressed under predetermined and carefully controlled and recorded conditions. After sintering, the diamond pearls are removed from the matrix for brazing. At each stage of the manufacture process there is a detailed inspection of the quality and dimensions. The technical features and mostly the abrasion resistance of the alloy that hosts the diamonds grains are of high importance. If the alloy is of a very high abrasion resistance, new diamond cutting surfaces do not effectively appear and the cutting speed decreases. On the contrary, if the hosting material is very soft and easily abraded, the diamond grains are taken off, even before they are used, and the productivity of the wire is minimised.

The sintered or impregnated diamond pearls wire can be effectively used in all types of stone, even the most hard and abrasive ones. The life time of the impregnated diamond wire is usually double of the electroplated diamond wire one. The cutting speed of the sintered diamond wire is practically high and constant during the entire life of the tool, while the speed of the electroplated wire, although starts from higher values, decreases rapidly. The sintered diamond wire requires a minimum power of 40 hp and a normal amount of cooling water, from 20 l/min up to 50 l/min depending mainly upon the cut area. Apart from the above, some other advantages of the sintered diamond wire are the ability of large dimension cuts, rapid starting of the cut, clear cut surface, smooth surface and easily inspected for cracks, flaws or other defects, very small percentage of rock loss, little supervision, low investment costs and good working conditions.

**Figure 75.** View of diamond wire: with springs, plasticated, electrodeposited

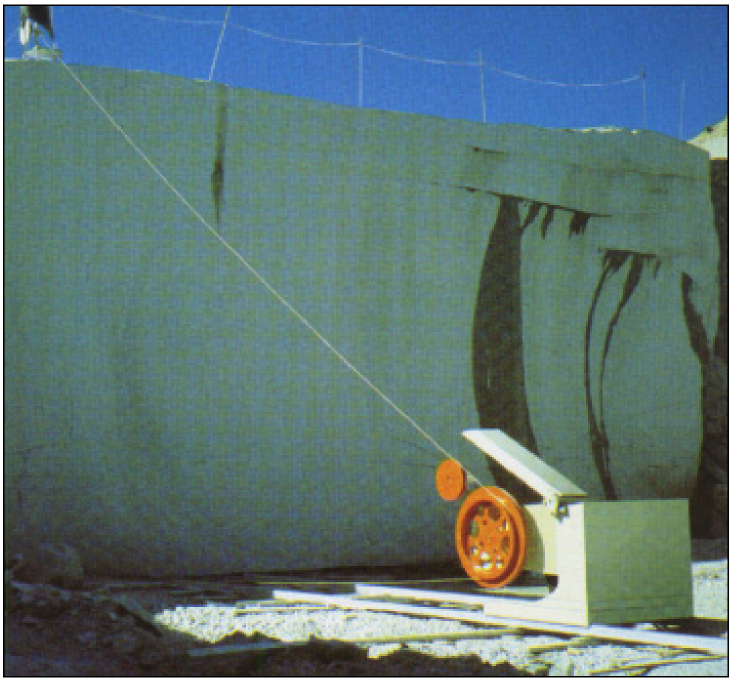


**Figure 76.** Diamond wire in the quarry

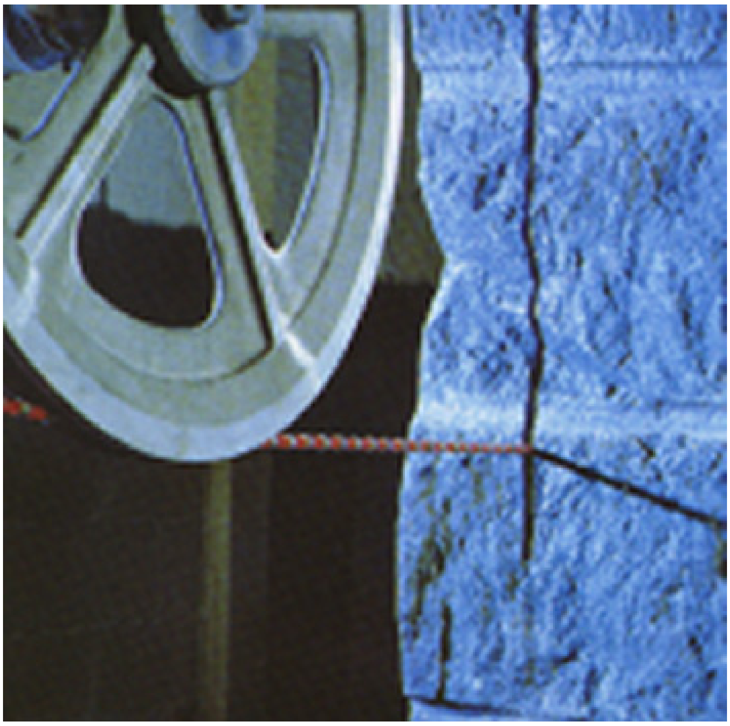


**Figure 77.** Diamond wire for block squaring or cutting

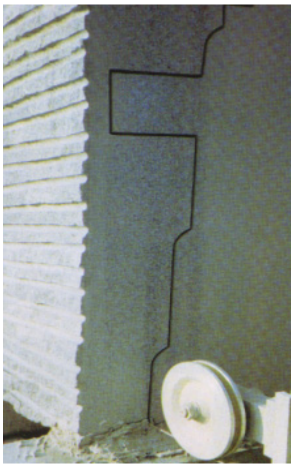


**Figure 78.** Diamond wire for cutting special shapes

### *4.2.3. Types of diamond wire*

In the most common type of diamond wire the springs, the spacers and the other elements the wire consists of, stay uncovered and the internal space between those elements and the cable remains unfilled. Some other types of diamond wire are also available in the market. In the case of ***plasticated wire***, the springs and spacers are replaced by a sheath of thermo-plastic resins injected at high pressure. In another type, ***rubber*** replaces the plastic resins. Lately, a new type of diamond wire has been used in ornamental stones quarries. In this type, the rubber material fills the empty internal spaces joining firmly the cable to the pearls, the spacers and the other parts of the wire, increasing this way the life time of the diamond wire parts and improving safety conditions.

### *4.2.4. Applications*

Diamond wire is used for marble primary cutting and squaring-off. In granite quarries it is used for primary cutting. For hard material in general, plasticated wire can be used as an alternative. To increase the overall strength of the system, plasticated wire can be replaced by rubber wire.

Diamond wire is used for primary cutting, squaring off and profiling in marble and granite quarries and processing plants. It is used in a variety of wire cutting machines. Most reliably constructed wires for hard and intense cutting conditions are plastic and rubber ones.

**Table 51.** Applications of diamond wire (**MR-*Marble***, **GR-*Granite,*** **C-*Concrete)***

| **Diamond wire** | **6 mm** | **8 mm** | **10 mm** | **11 mm** |
|---|---|---|---|---|
| **Plasticated sintered** | GR MR | GR MR | | GR MR C |
| **Plasticated electroplated** | MR | | MR | |
| **Traditional electroplated** | | | MR | |
| **Traditional sintered** | | | | MR C |

### 4.2.5. Characteristics

**Table 52.** Technical characteristics of sintered diamond wire applications

| | **Marble** | **Granite** |
|---|---|---|
| **Beads per meter of wire** | 28-34 | 34-40 |
| **Linear wire speed (m/s)** | 30-40 m/s | 15-30 |
| **Average production ($m^2$/h)** | 6-12 $m^2$/h, with peaks of 13-15 $m^2$/h | 1 to 5 |
| **Average duration of wire ($m^2$/m)** | 20-50 $m^2$/m | 2.5-8 |

**Table 53.** Technical characteristics of electroplated and of sintered diamond wire applications

| | **Electroplated beads** | **Sintered beads** |
|---|---|---|
| **Carat/bead** | 0.4 | 0.36 |
| **Cutting speed** | High initial speed which lessens in time | Low initial speed but constant over time |
| **Consumption** | Fairly quick | Relatively slow |
| **Water consumtion** | Low | High |
| **Cost** | Low | High |
| **Grain size (mesh)** | 40-60 mesh | 40-50 mesh |
| **Attachment** | To the metal bushing with nickel binder | Amalgam of cobalt and bronze |
| **Minimum power** | 25 HP | 40 HP |
| **Use** | Most efficient for small cuts and for squaring-off blocks | All types of stones and for improving the $m^2$ sawing |

**Table 54.** Characteristics of diamond wire

| **Materials** | **Cutting speed ($m^2$/h)** | **Electroplated wire ($m^2$/m)** | **Sintered wire ($m^2$/m)** |
|---|---|---|---|
| **Travertine** | 10-17 | 50-80 | 70-120 |
| **Marble medium-coarse grain sized** | 8-15 | 30-50 | 40-80 |
| **Marble and Limestones** | 5-12 | 15-45 | 35-70 |
| **Hard marbles** | 3-10 | | 15-35 |
| **Granite** | 2-5 | | 4-25 |

### *4.2.6. Advantages/Disadvantages*

The diamond wires present numerous, often essential advantages: high sawing speed, cuts of large dimensions (above 200 $m^2$), rapid starting of the cut, very little supervision necessary, low investments costs, high cutting quality so as to avoid material wastes, low noise level.

They are suitable for various applications (marble, granite, slate, sandstone):

- opening of beds (slabbing of large surfaces)
- extraction of blocks out of the bed rock by vertical, horizontal or oblique cuts
- squaring-off, sizing and slabbing of blocks

When employed for block sawing and when compared to other techniques, diamond wire shows mainly the following disadvantages:

- the cut is not straight (on the horizontal and vertical plane)
- the reliability of the sawing system is lower, mainly due to wire breaking
- the tool cost tends to be higher

## 4.3. CIRCULAR SAW BLADES (DIAMOND DISCS WITH SINTERED SEGMENTS)

### *4.3.1. Machines and processes*

These tools apply to a wide range of machines and processes. The main difference is the disc diameter and, of course, the steel core thickness, which usually increases together with the disc diameter.

- “Giant disc” saws for Marble and Granite (processes: block squaring, slab cutting). Big size, more than 2 meters.

- Single/Multi disc Block Cutters for Marble and Granite. (processes: strip cutting in the tiles plant). Vertical cut (average size1 to 1.7 m). Horizontal cut (small size reinforced discs, 300-500 mm).

- Splitting machines for granite, (process: strip splitting (granite)). Diamond discs (many, with increased diameter, up to about 1 meter).

- Splitting machines for marble, (process: strip splitting (marble)). Diamond discs with reinforced blade, average diameters about 1 meter.

- Cross cutting machines (processes: tiles cut-to-size and pre-cut in the tiles plant). Small sized discs, 300-500 mm.

- Cross cutting machines for slabs (process: slab cutting). Small sized discs, 300-500 mm.

- Trimming machines for slabs (processes: slab cutting, slab sizing and cut into strip). Small sized discs, 300-500 mm.

- Chamfering machines (process: cutting of grooves under the tiles)

- Bridge milling machines (process: laboratory machines, craftworks). Small-average size, 0.6 to 1.2 m).

- Angle grinders cutting machines (process: laboratory machines, craftworks). Small sized discs, 300-500 mm.

Diamond discs are the most widely employed tools in the field of ornamental stones; the most frequent uses are in cutting of blocks, cross cutting and trimming of tiles and slabs, stone cutting by means of hand tools, like angle grinders. Just to mention, there are also two less common uses: cut of grooves in the dripstones and in the lower faces of tiles (see Figure 81) during the chamfering operation in a line for mass production. The latter aims to create grooves useful during cladding and flooring operations.

Diamond discs consist of two elements: the **sawbody** (the core), which carries the **diamond segments**.

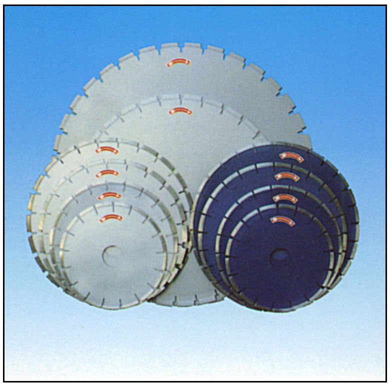


**Figure 79.** Diamond discs of many diameters, for all the stone cutting needs

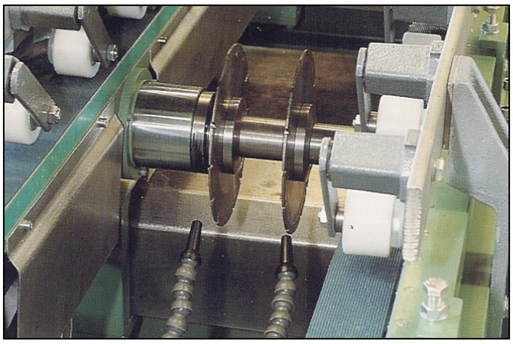


**Figure 80.** Chamfering machines (cutting grooves under the tiles)

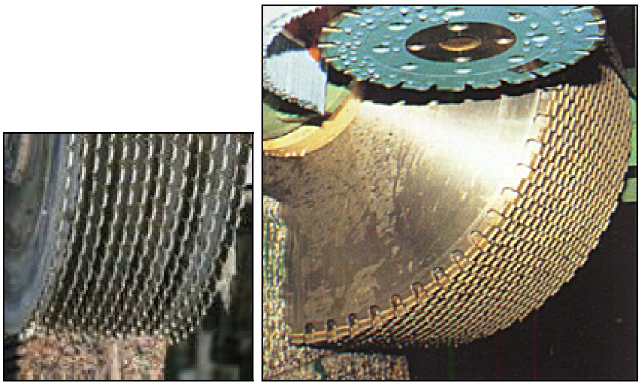


**Figure 81.** Multi disc sawing of granite strips (vertical discs and horizontal disc)


**Figure 82.** Giant discs. Left: manufacturing. Centre and right: block sawing

### *4.3.2. The core*

The core is usually made of a steel alloy, treated in order to increase its mechanical features for the specific application. The core is a disc with a central axial bore, used to fix the disc to the machine structure. The core is commonly made of tool-steel 75 Cr 1 or similar, with varying composition in weight percentage, as presented in Table 55:

**Table 55.** Saw centre material composition in weight (%)

| | C | Si | Mn | Cr |
|---|---|---|---|---|
| min | 0,70 | 0,25 | 0,50 | 0,30 |
| max | 0,80 | 0,50 | 0,70 | 0,40 |

After the heat treatment (hardening at 830°C in oil, tempering at 500°C) the microstructure has a hardness of 46 + 2 HRC and is characterised by a homogeneous fine grain.

Currently, more heavily alloyed steel is also employed, but its use is not widely diffused. Investigations on the possible use of case hardened low-carbon steels for saw cores are performed also nowadays.In current practice, non-steel core is not applied yet, but may be subjected to research in the future: aramidic fibre (kevlar), carbon fibre.

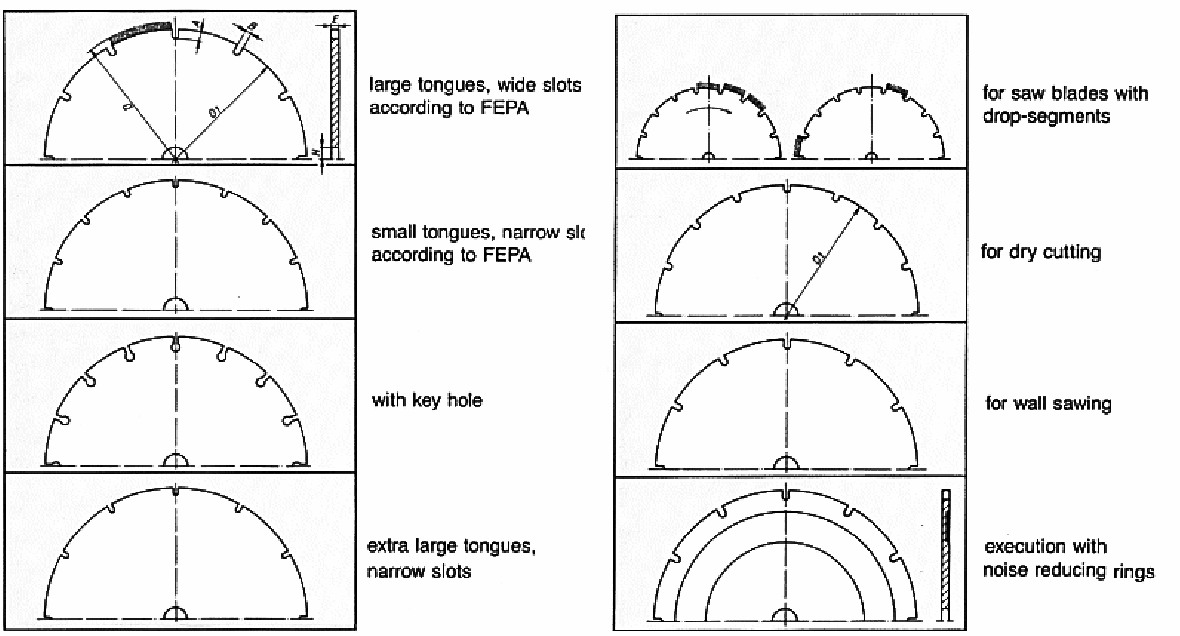



**Figure 83.** Examples of core structures

### *4.3.3. Between the core and the segment: welding*

Core and segments are manufactured in most of the cases by different companies; the segment manufacturer usually attaches the diamond segments on the core. This process is also known in technical jargon as “tipping”.

Welding is of outmost importance in order to obtain a correct behaviour of the tool during the awing operation.

The diamond segment can be attached to the steel centre using two basic methods.

(1) Brazing: The segments are attached to the core by brazing with silver solder. These segments are:

- used on standard blades for wet cutting;
- not suitable for discs for dry cutting, unless their size is small.

Before brazing, de-oxidation of the steel core contact surface is performed. The diamond segments are brazed on sections protruding from the disc core, defined by the slots, which are cut in the steel core. Brazing is achieved by heating a brazing alloy to its melting point. A layer of brazing alloy is left between the steel core tip and the base of each segment; when the alloy cools down, it forms two distinct secondary alloy layers, one with the bond in segment and the other with the steel of the core, in this way fixing the segment steadily.

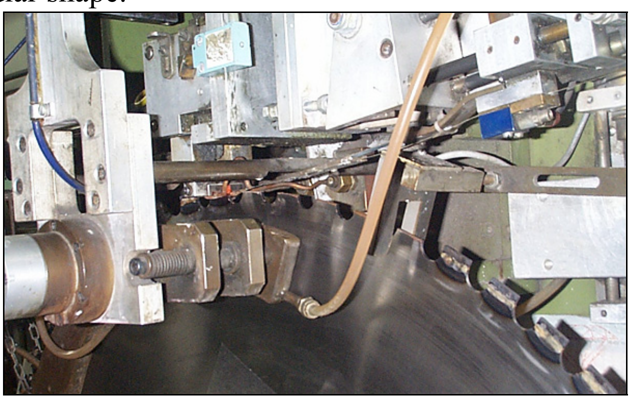
In the modern equipment, such operation is fully automated: the core is held and rotated by a controlled system, the segments are fed and held automatically, while the alloy strip is fed between the disc core and the segment. The welding temperature must be suitable for the employed alloy; if the temperature is too low, the welding time is not sufficient, or if the temperature is too high, the welding will de defective, with a risk of segment detachment during sawing operation. The most common components of the used alloy are: Silver, Copper, Zinc, with small quantities of Nickel, Manganese, Potassium, Tin, Silicon and Cadmium (not used anymore because of its toxicity). The alloy is chosen by the tool manufacturer according to the designed tool working load.

( 2 ) Laser-welding: Segments are welded at the centre using a laser beam. In this way:

- the strongest bond possible is developed between steel centre and segment;
- the segments are suitable for wet and dry cutting applications.

The laser-welding process is the latest method to attach diamond segments to the blade centre. This process assures a maximum degree of safety. Current research will indicate, if glueing of segments is suitable.

After the welding process, the disc is ground in order to remove any defects and assure its perfect circular shape.



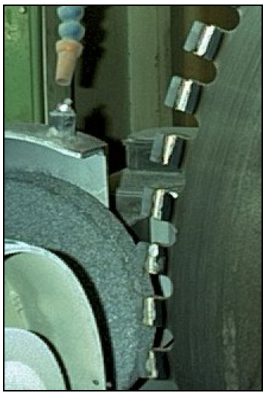


**Figure 84.** Left: Automatic segments brazing - Right: grinding the tipped disc

### *4.3.4. Re-tipping*

When the diamond segments are worn, the core can be re-used. The tool manufacturer can usually remove the worn out segments and braze/weld new ones on it. This process can be carried out a limited number of times on each core (or set of cores), and only if the cores are not damaged. This operation is relevant for tools cost calculation, that is of extreme importance for the process cost calculation. Re-tipping of *silenced cores* can be subjected to further limitations (see relevant paragraph below).

### *4.3.5. The segment*

The diamond segment is the part of the tool that performs the actual sawing. It is a small block, shaped approximately like a parallelepiped. It includes metal grains (the segment bond) aggregated by a thermal process under pressure (sintering), containing a certain variable percentage of industrial diamond grit (which can be natural or synthetic). Any combination of diamond and bond gives different sawing performance.

A soft matrix has normally a higher cutting speed but a shorter life-span; a hard matrix has normally a lower cutting speed but a longer life-span. A good ratio between the thickness of the segment and the thickness of the steel disk allows an ideal discharge of material, an appropriate teeth wear and avoids blockage of the disk inside the material during cutting. A typical surface structure of a diamond impregnated segment is shown in Figure 85, view from above. Thinner disks and teeth can have a higher culling speed but a poorer performance. Thicker disks and teeth can have a lower running speed but a better performance.

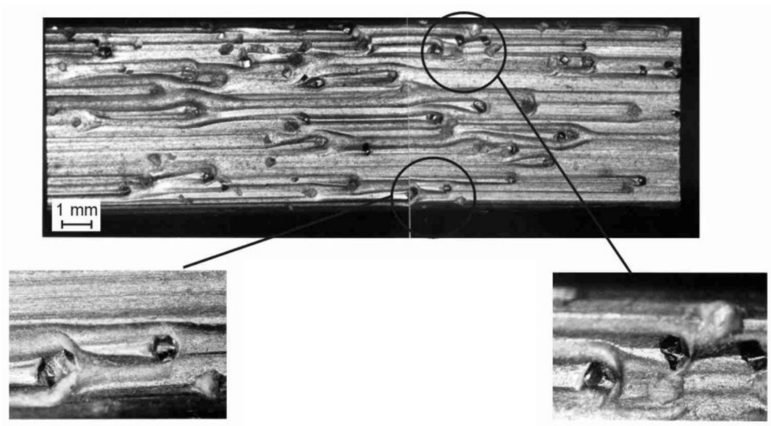



**Figure 85.** View of segment surface and diamonds

Sintering is performed (for standard segments used in granite sawing or grinding) by heating at 760 °C to 830 °C. The components are mixed together, while a strong pressure is exerted on the dies, which contain the mixture and give to the segments its shape. The result is segments having variable hardness according to the bond mixture and the sintering pressure/temperature combination. The segment hardness is measured with a hardness meter and it is expressed in Rockwell degrees; for instance, the hardness of a granite segment can be about 60 - 65 HRC.

The most common bound components are: Cobalt (mixed in various grain sizes), Bronze (very small quantities), Iron Carbide (mixed in various grain sizes), and small amounts of other metals, in order to give to the segments the required characteristics to saw: (with the correct parameters on the designed material) constant progressive wear, a tool life (measured in square meters sawn per disc or per segment) adequate for industrial production.

Diamond concentration is another important parameter; it defines the quantity of diamond grit contained in each segment, or, better in each cubic millimeter of segment. Usually, the higher the diamond concentration, the higher are the tool performances.

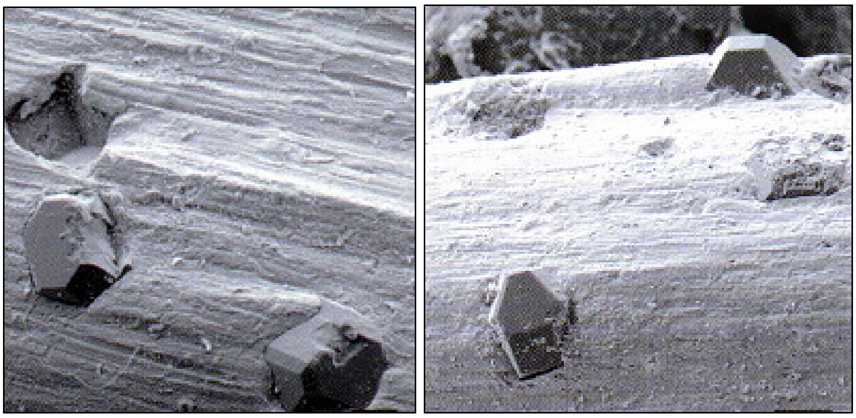


**Figure 86.** Magnified view of a segment

One problem with diamond segments is that while the wear goes on, the side corners tend to get rounded in shape. This change in shape affects the cutting precision, that is improved by the guiding effect of sharp cutting sides. For this reason, the segments are often manufactured by the "sandwich" technique: two side layers made of "hard" bond include a single central layer made of "softer" bond. In this way, the segment wear will proceed starting from the central layer, keeping the initial segment shape. Another way is to increase diamond concentration on both sides of the segments (Figure 87).

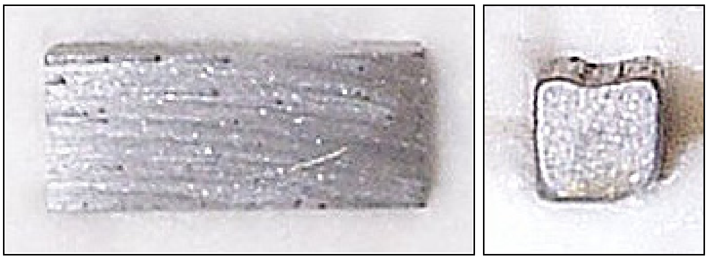


**Figure 87.** Diamond segment. The "sandwich" shape is visible in the picture to the right.

Another element to be considered is the type of diamond, which is included in the diamond segment. Industrial diamonds can be natural or synthetic, and are manufactured by a limited number of companies in the world. Usually, the tool maker buys the diamond and the cores, manufactures the segments, welds the segments on the cores and carries out the treatment on the finished disc (peripheral grinding, tensioning).

The classification of the diamond grit can be done according to a standardised table, internationally accepted, which defines the size and quantity of diamond grains per carat. The unit measures universally accepted are *microns* for the grain size, *Carats, Mesh and J.V.S*, which identify the quantity and the dimensional features of the diamond grit, are fundamental factors determining the tool performance.

The diamond segments employed for granite sawing up to 625 mm are usually in standard sizes of 10 mm, 12 mm, 15 mm and 18 mm, manufactured according to the “sandwich” technology. The diamond segments employed for granite sawing with diameter higher than 650 mm are usually in standard sizes of 10 mm, 12 mm, 15 mm, 18 mm, 20 mm and 30 mm, manufactured also according to the “sandwich” technology. For bigger sizes (to be used in “Giant Disc Sawing machines”) diamond segments manufactured according to a stepping shape defined as “PAGODA” are also available on the market.

**Figure 88.** Section of a “Pagoda” Segment

### *4.3.6. Disc fastening systems*

From a technical point of view, the tool system should include also the system used to connect the disc(s) to the machine, which cannot be designed without taking into consideration the characteristics of the disc(s) and especially of the core(s). On the other hand, the core(s) must be designed in such a way in order to be compatible with the selected connection system. Basically, there are two main systems:

( 1 ) Flanging. Flange and counter flange clamps the disc(s) and are closed by a closing nut. The flange size influences the guiding effect of the disc (useful to perform straight cuts), but limits the size of the stone element that can be cut. In average, flange is the one third of the disc diameter, or slightly less. This system is mainly used for block cutting machines, because it is suitable for multi-disc applications: in this case discs are interlaced with spacer, which reproduces the size and the clamping effect of flange and counter flange on each one of the discs. It is also used as well for bridge milling machines, cross cutting machines, etc. The core thickness tolerance (and surface finishing) must be very accurate in order to obtain proper coupling with the flange surface, at least in the radius in contact with the flange. If not, the clamping effect will be compromised, and so will be the positive guiding effect of the flange.

For saw blade diameters from 725 to 1500 mm the flange diameter is = 0,28 x wheel diameter, while for saw blade diameter of 1600 mm the flange diameter can be progressively reduced in a range of 5 to 30 %. Identical flange diameter and bearing faces have to be used. For severe working conditions, such as higher cutting rates, flange dimensions are theoretically subjected to an increase.

( 2 ) Screws. The disc is fastened to the flange by a circular crown of screws located at a given distance from the centre. This system is not suitable for multi-disc applications, but it is reliable and there are no specific requirements for a special finishing of the core surface in its central area. It is applied, for instance, to the Giant Disc Saws, or to the horizontal discs for Block Cutters.

### *4.3.7. Pre-Tensioning*

Core pre-tensioning (in brief “tensioning”) is of capital importance for the correct cutting behaviour of the discs, in proportion to the disc size and as long as the core is thin. A first tensioning operation is carried out by the core manufacturer on the core alone. After welding the segments, the tool manufacturer applies a given tension to the whole disc, in order to remove any effect due to welding. When a disc is re-tipped, it must be re-tensioned. Tensioning can be applied also at the stone facility, in order to recover partially damaged cores when the diamond segments are far from being completely worn out. This operation requires skilled personnel and usually it is not carried out by the user, but by the tool manufacturers after sales service, when available; in other cases the tools are sent to the manufacturer for tensioning.

Tensioning is the application of heavy local pressure to both disc faces (rolling), in order to carry the steel over its plastic deformation point, at room temperature. In this way, a residual state of stress will remain “imprisoned” in the steel. The tension produced by such stress will result in reducing the static deformation and the instability under static tip compression, which is a critical load applied during the sawing operation. In other words, the tensioned core will be more “rigid”. The effect of tensioning can be adjusted by changing the radial position of the rollers, their radius, their number and of course the load applied. The result of the tensioning operation is checked by specific equipments, where the disc rotates slowly in vertical position, while a force is applied in axial direction at a certain distance from the centre and while a gage sensor is in contact with the core surface, at different angular position (often 90° or 180°, on the same radius). If the disc is not tensioned, the deflection will be in the same direction of the force applied; in a tensioned disc it will go in the opposite direction or it will be null. The result of the measurement can be plotted as a tolerance graph for quality control purposes.

Tensioning also affects the dynamic behaviour of the disc; more specifically it modifies the natural frequencies of vibration, bringing them toward the desired values. A frequency-shift of a discrete vibration mode to higher or lower values can be achieved.

Run-out control. Machines and systems used for checking the disc tensioning state are suitable also for checking the run-out, that is the geometrical error of the axial position of the disc surface when no load is applied. It is usually measured in vertical position, rotating slowly the disc while a gage sensor is in contact with the core surface, at different radial position. The measurement result can be plotted as a tolerance graph for quality control purposes. Of course, tensioning must not override the basic requirements for an accurate geometry of the tool.

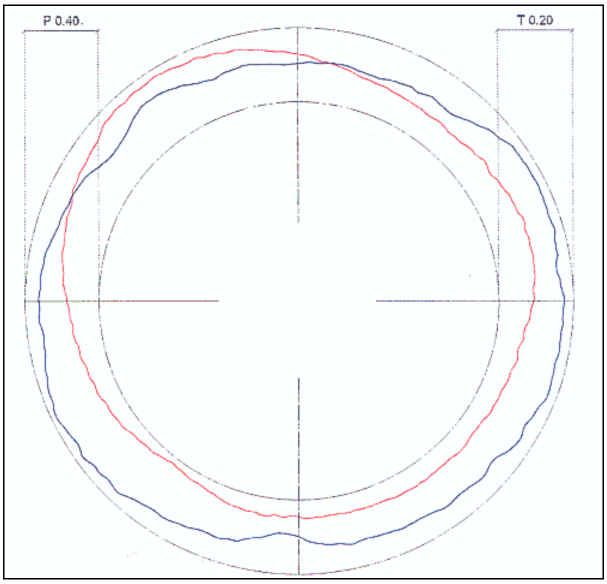



**Figure 89.** Run-out and tensioning effects diagram (diamond disc for block cutter)

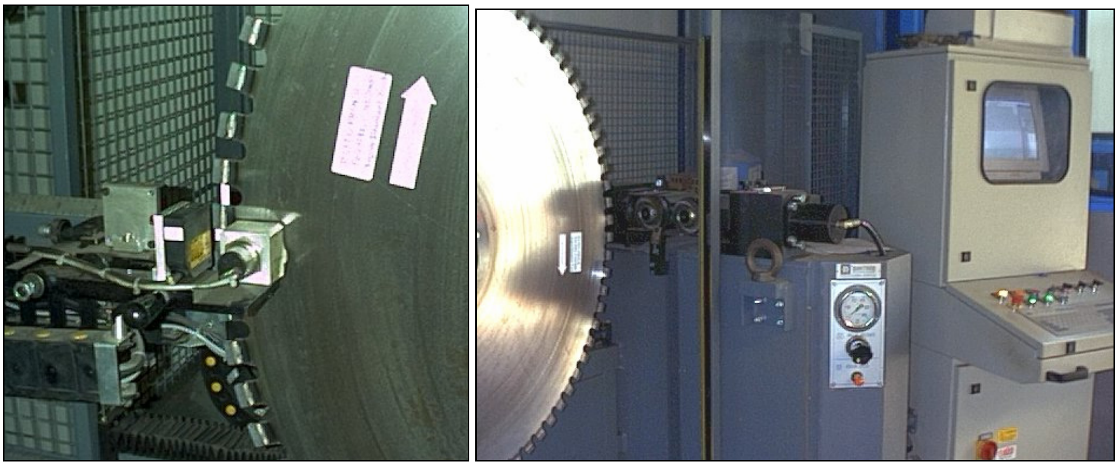


**Figure 90.** Equipment to measure tensioning and run-out

### *4.3.8. Slots or continuous rim*

Diamond discs described in this paragraph, for the processes stated above, are usually slotted instead of having a continuous diamond rim. By one side, slots reduce slightly the mechanical characteristics of the core; by the other side they have two important positive effects:

- slots allow a better water circulation during cutting, improving the cooling of the cutting area, and most of all, improving the efficiency of the waste removal;

- when welding the segments on the core, slots are very useful to limit the distortions of the core during the heating peaks. Slots practically “insulate” each segment from the next ones. This advantage is less needed when welding is carried out by laser.

There are many stots shapes available in order to obtain the desired tool behaviour: semi-circular, very narrow, wide shallow slots and so on.

Continuous rim is another viable option, but its main disadvantage is a certain lack of waste removal possibilities under high production rates, which are typical for stone processing machines included in stoneyard facilities.

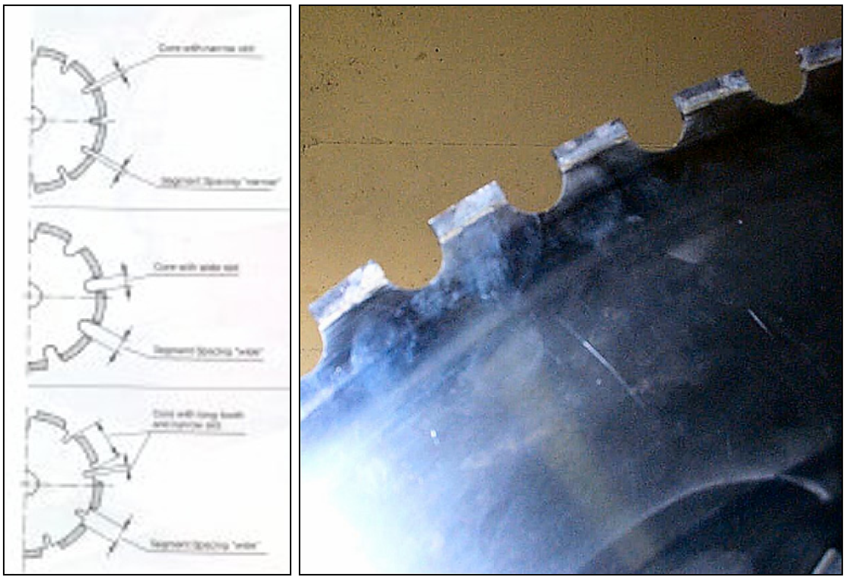


**Figure 91.** Different kinds of slots (left). Shallow slots (right).

*4.3.9. Noise emission (silenced tool, anti-noise cores)*

During sawing operation the steel core acts as a resonant vibrating plate, generating and diffusing in the environment the noise emitted by the sawing process. Figure 92 shows the geometry of the vibrational modes and a Fourier diagram with their possible frequencies. Of course the frequency of the vibrational modes depends on the core constructive features (diameter, thickness, material, etc.).

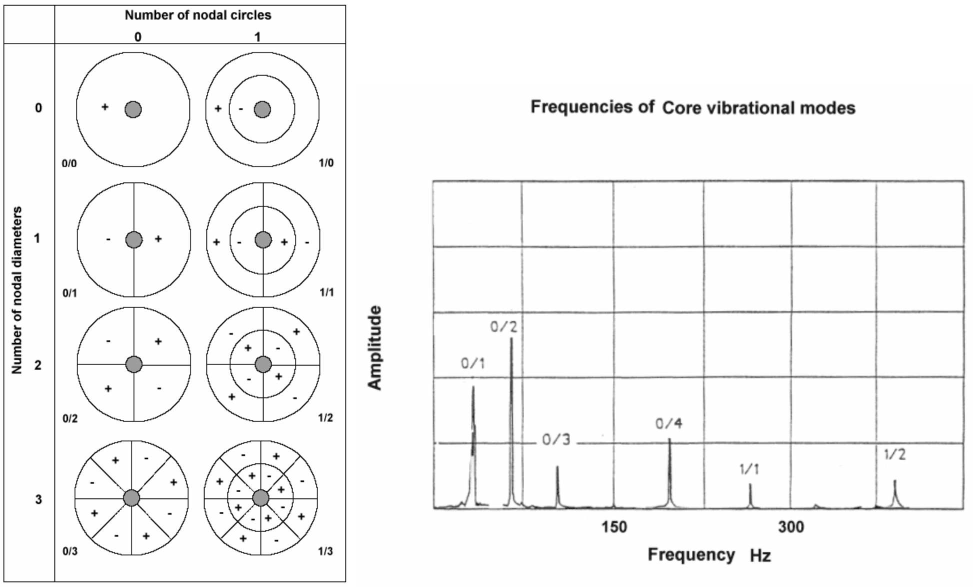



**Figure 92.** Vibrational modes of a core (left) and their frequencies (right).

In order to reduce such noise emission, there are different solutions already available on the market, often protected by patent (“silenced discs”, “silenced cores”). The working principle is to damp the vibrations and/or to shift the resonance frequency of the disc vibrating modes.

In Figure 93 the sound diagrams of two cores hitted by a hammer are presented in order to visualize the damping behaviour of the core. The left picture shows a “normal” core, the right picture shows a “silenced” core, in which the increased damping factor results in smaller vibrational amplitudes.

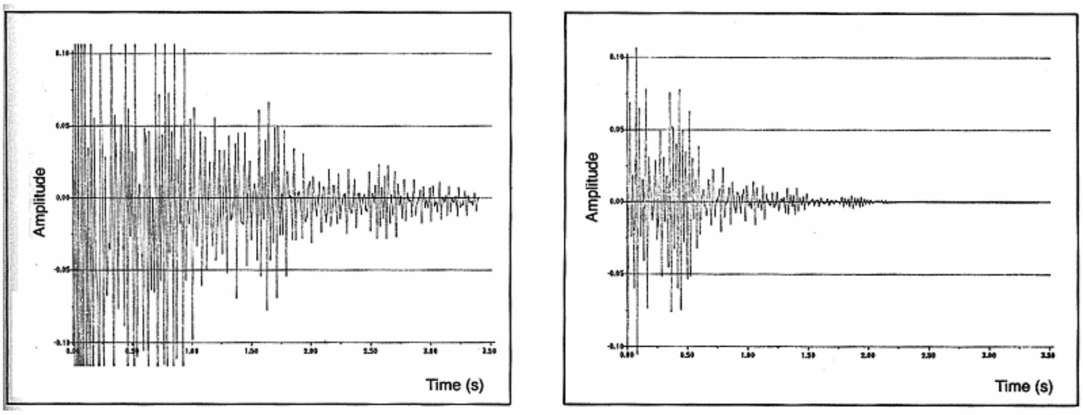



**Figure 93.** Amplitude/Time diagrams of core vibrations

Alternative available constructive techniques for silenced discs are described below. The choice among them must be done considering mainly the disc diameter.

- “Sandwich” core. Effective for small diameters (less than 500 mm). The core includes more than one layer glued, brazed or welded together up to the final thickness. Often, three layers, the outer ones made of steel, the central one of a different metal or alloy (brass for instance), are used. The layers tend to detach more easily when the disc is bigger in size.

- Steel core with ring inserted. A circular slot is grooved into one face of the core (1/2- 1/3 of the core thickness). A ring is riveted or glued into the slot. The surface of the core is then made perfectly flat by grinding and the damping factor increases. This system can work also with average sized discs (say, discs for block cutters). Of course the damping ring tends to detach with the use and this limits the number of times the disc can be re-tipped.

- Steel core with laser cuts. Very thin full depth slots (0.1 - 1 mm, indicative values ) are cut into the core by laser. The shape, size, number and position of such slots are studied in order to increase the damping factor without a significant reduction of the mechanical characteristics of the core, that nevertheless cannot be completely avoided.

- Steel cores with rubber inserts, placed in slots cut into the steel core.

The disadvantages of the silenced disc are: reduction of the number of times that the core can be re-tipped and reduced mechanical characteristics of the disc.

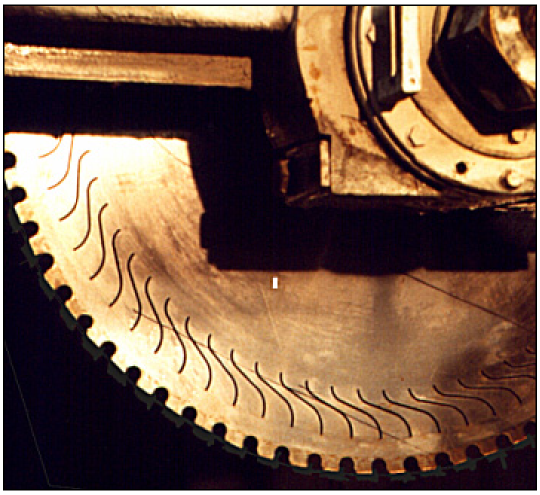


**Figure 94.** Silenced disc (with bending elements acting in elastic range)

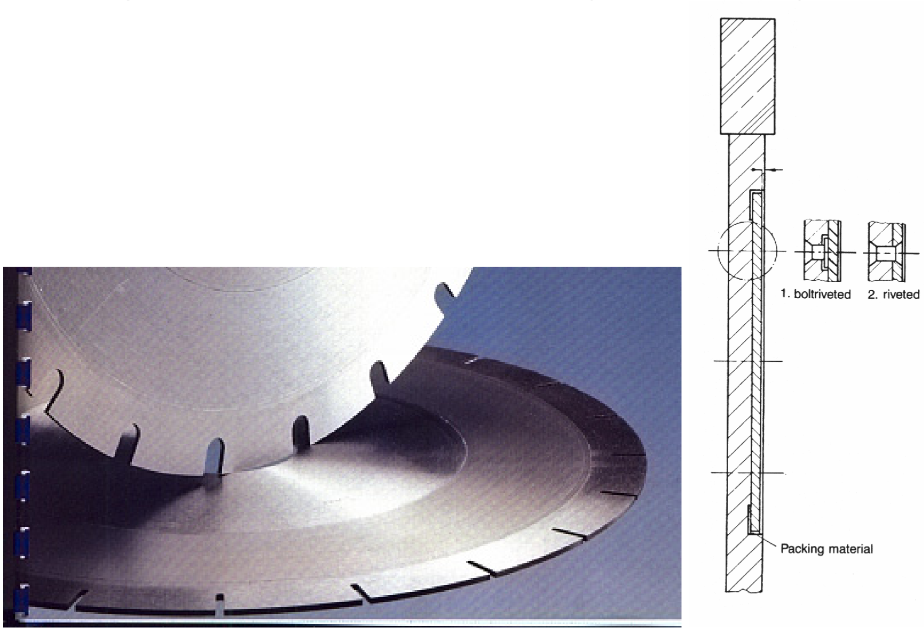



**Figure 95.** Silenced discs (ring/groove system)

### *4.3.10. Multi disc and single disc applications*

Circular diamond discs are well suited for a high production rate with a sufficient surface quality of the products. They are used in single or multi blade machines. When manufactured for multi-disc applications, they are treated as a set of a given number of discs having equally harmonised characteristics. This is extended also to the core, which is specially manufactured for multi-disc application. The final tensioning operation is carried out with the purpose of keeping the same behaviour for the full set of blades.

**Figure 96.** Diamond discs used in a multi-blade-machine

**Figure 97.** Diamond discs for marble

In Figure 98, a system widely used to cut wide strips marble, using two coupled discs having different diameters, is shown. The smaller disc cuts the first half of the groove (1), then the couple of discs is moved sideways, making another similar cut (2). Another side step follows, and the bigger disc cuts the full depth in the first groove, while the small disc continues and cuts another fresh groove (3). After another side step, the big disc completes the second full cut (4). At the completion of each full cut, the horizontal disc (not shown) detaches the strip from the block. This cycle is repeated until the full layer in the block in vertical. This system is sometimes called "False Step" or "Double Step", and the disc assembly is often called "Scaletta System" (from the Italian terminology). The main advantage of this system is the performance of a pre-cut with a smaller disc (less subject to deviations), before performing the cut to full depth with a bigger disc. In this way the deviations are remarkably reduced and the cut is more straight.

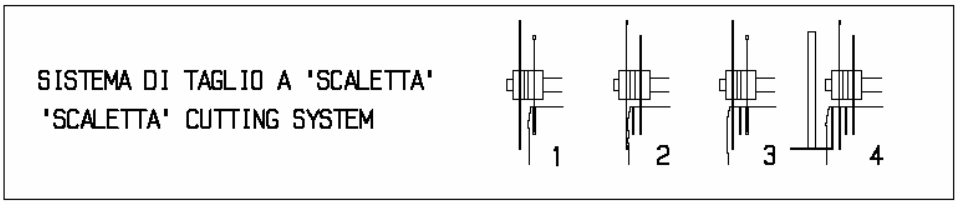



**Figure 98.** Marble cutting with two discs having different diameters

Figure 99 shows two classic disc arrays for granite cutting, usually consisting of 34 to 56 discs, or 80 to 100 discs.

The picture on the left shows a set of discs having the same diameter, useful to cut strips up to 400 mm wide, with discs having a diameter up to 1300 mm. The picture on the right shows a “Scaletta system” for granite, useful to cut wide strips up to 650 mm, with discs having diameter up to 1680 mm, flanges 350 mm, bore 200 mm.

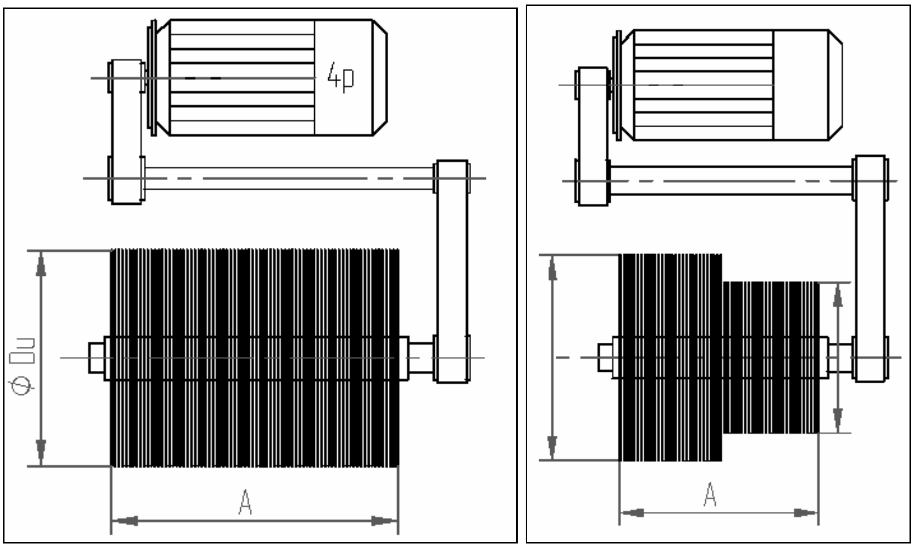



**Figure 99.** Discs arrays for granite cutting

Figure 100 presents an extension of the previous systems, employing an array of discs having increasing diameters. This system is mentioned as “Progressive Scaletta”, and it is used for fast block topping operations on high performance granite block cutters. In this case the aim is to increase the material removal speed, while a high cutting quality is not requested.

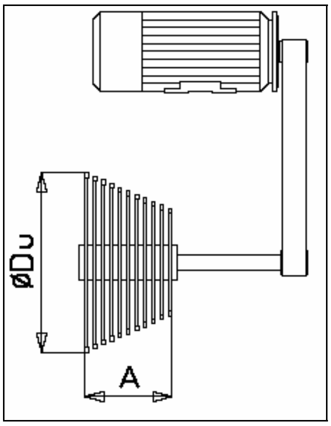



**Figure 100.** “Progressive Scaletta” system

### *4.3.11. Characteristics*

Saw blades for cutting stone are manufactured according to the FEPA (Fédération Européenne des Fabricants de Produits Abrasifs) standard. The main dimensions are body-diameter, tipped saw-diameter, bore, blade thickness and flange-diameter, which are influencing the vibrational behavior beside the state of stress distribution.

A list of operating technical data is given below. They are standard data required when interacting with the toolmakers:

- Core diameter (diameter of the steel core)
- Steel core thickness
- Bore diameter in the steel core
- Flange diameter, to hold the disc in working position
- Nominal disc diameter (including the segments, not worn)
- Segment shape (standard - conical - sandwich)
- Segment length
- Height of the diamond tipped portion of the disc (in some cases only part of the segment height contains diamond)
- Total segment height
- Slot depth and shape
- Spindle power of the target machine
- Target machine category
- Spindle rotational speed (referred to the target machine)
- Material to be sawn
- Available kind and flow of coolant (lubro-refrigeration)
- Required depth of cut

In order to define the performance of this kind of tool, the following parameters can be employed:

-Total square meters sawn per disc

-Feeding speed in m/min in reference to the specific cutting down strokes (on the block cutters the feeding speeds in the two directions are usually different, due to constructive features of the diamond segments).

-Disc cutting down strokes in mm

The main dimensions of the rim shape and saw blades are displayed in the following tables.

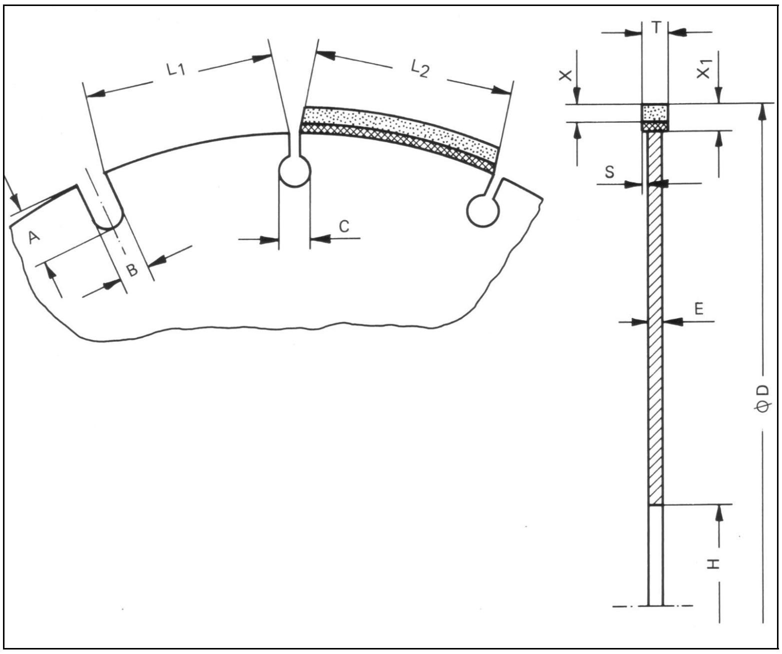



**Figure 101.** Diamond discs size parameters

**Table 56.** Dimensions and rim shape of diamond discs

| | | | | narrow slot | | | wide slot | | | narrow slot elongated tooth | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| D mm | D1 mm | E mm | A mm | B mm | teeth | L1 | B | teeth | L1 | B | teeth | L1 |
| 200 | 190 | 1,3 | 14 | 3 | 13 | 42,9 | 8 | 12 | 41,7 | 3 | 12 | 46,7 |
| 500 | 490 | 3,0 | 14 | 3 | 42 | 41,1 | 10 | 36 | 41,5 | 3 | 36 | 48,5 |
| 1000 | 984 | 5,0 | 18 | 7 | 96 | 25,2 | 20 | 70 | 24,1 | | | |
| 1600 | 1582 | 6,75 | 18 | | | | | | | | | |
| 2000 | 1982 | 7,5 | 18 | | | | | | | | | |
| 2500 | 1482 | 9,0 | 22 | | | | | | | | | |
| 3000 | 2982 | 11,5 | 22 | | | | | | | | | |

**Table 57.** Dimensions of diamond discs (mm)

| | from | to |
|---|---|---|
| for single-blade machines | 200 | 825 |
| for block-cutting machines | 800 | 1.600 |
| for horizontal cut | 350 | 500 |
| giant discs | 2000 | 4000 (5000) |

**Table 58.** Standard sizes for granite diamond discs (milling, cross cutting, trimming m/c).

| Ø mm Disc | 250 | 300 | 350 | 400 | 450 | 500 | 550 | 600 | 625 |
|---|---|---|---|---|---|---|---|---|---|
| Standard number of segments | 15÷17 | 18÷21 | 21÷25 | 24÷28 | 26÷32 | 30÷36 | 32÷40 | 36÷42 | 36÷42 |
| Standard segment sizes (mm) | 40x2,8 | 40x2,8 | 40x3,0 | 40x3,0 | 40x3,6 | 40x3,6 | 40x4,5 | 40x4,5 | 40x4,5 |

For the discs in the above table, the standard segment heights are: 7 – 10 – 12 – 15 – 18 mm, while, the anti-noise (silenced) discs are preferred.

**Table 59.** Diameter of diamond discs for different machines used for Marble and Travertine.

| | Diameter from mm | up to mm |
|---|---|---|
| Milling machine | 200 | 625 |
| Single disc high power block cutter | 700 | 1600 |
| Standard single disc block cutter | 700 | 1200 |
| Multi discs block cutter | 700 | 1600 |
| Cross cutting / trimming machine | 300 | 500 |
| Splitting sectioning machines for marble (horizontal discs) | 500 | 850 |

**Table 60.** Diamond disc sizes for marble/limestone cutting using Milling Machines

| | | | | | | |
|---|---|---|---|---|---|---|
| External diameter (mm) | 200 | 250 | 300 | 350 | 400 | 500 |
| Steel thickness (mm) | 1,8 | 1,8 | 1,8 | 2,2 | 2,5 | 2,8 |
| Number of segments | 12 | 15-17 | 18-21 | 21-25 | 24-28 | 30-36 |

| | | | | | | |
|---|---|---|---|---|---|---|
| External diameter (mm) | 550 | 600 | 625 | 650 | 700 | 725 |
| Steel thickness (mm) | 3,5 | 3,5 | 3,5 | 3,5 - 4 | 4,0 | 4,0 |
| Number of segments | 32-40 | 36-42 | 36-42 | 38-46 | 40-50 | 40-50 |

| | | | | | | |
|---|---|---|---|---|---|---|
| External diameter (mm) | 750 | 800 | 825 | 850 | 900 | 1000 |
| Steel thickness (mm) | 4 – 4,5 | 4,5 | 4,5 | 4,5 - 5 | 5,0 | 5 – 5,5 |
| Number of segments | 42-54 | 46-57 | 48-57 | 50-60 | 62-66 | 68-74 |

**Table 61.** Standard sizes of the more often used vertical discs

(Single disc block cutters, Bridge milling machines)

| Total external diameter (mm) | Steel thickness (mm) | Number of segments |
|---|---|---|
| 500 | 2.8 | 30 |
| 550 | 3.8 – 3.2 | 32 |
| 600 | 3.2 – 3.5 | 36 |
| 625 | 3.5 | 36 |
| 650 | 3.5 – 4.0 | 38 |
| 700 | 4.0 | 40 |
| 725 | 4.0 | 40 |
| 750 | 4.5 | 42 |
| 800 | 4.5 | 46 |
| 825 | 4.5 | 48 |
| 850 | 4.5 – 5 | 50 |
| 900 | 5.00 | 64 |
| 1000 | 5.00 | 70 - 72 |
| 1050 | 5.0 | 72 |
| 1100 | 5.0 - 5.5 | 74 |
| 1200 | 5.5 | 80 |
| 1300 | 6.0 | 88 - 92 |
| 1350 | 6.0 | 88 - 94 |
| 1400 | 6.5 | 92 |

**Table 62.** Standard sizes of the more often used vertical discs (Giant disc saws)

| Total external diameter (mm) | Steel thickness (mm) | Cutting width (mm) | Number of segments |
|---|---|---|---|
| 1500 | 6.5 | 9 | 100 |
| 1600 | 7.0 | 9 | 104 -108 |
| 1800 | 7.0 | 9 | 120 |
| 2000 | 8.0 | 10.5 | 128 - 132 |
| 2500 | 9.0 | 12 | 140 |
| 2700 | 9.0 | 12 | 140 |
| 3000 | 10.0 | 12 | 160 |
| 3500 | 10.5 - 11 | 12 | 180 |
| 4000 | 10.0 | 13.0 | 210 |
| 4200 | 10.0 | 13.0 | 220 |

**Table 63.** Standard sizes of the more often used vertical discs (Multidisc block cutter)

| Total external diameter (mm) | Steel thickness (mm) | Number of segments |
|---|---|---|
| 900 | 5.0 | 64 |
| 1000 | 5.0 | 70 |
| 1050 | 5.0 | 72 |
| 1100 | 5.5 | 74 |
| 1200 | 5.5 | 80 |
| 1300 | 5.5 | 88 |
| 1600 | 5.8 | 108 |

For these kinds of discs the segment thickness is usually related to the thickness of the steel core. The height of the segment depends on its specific use, the manufacturer and the user requirements. Standard heights of the more often used discs are the following:

| | |
|---|---|
| H. 10 mm | Disc diameters from 500 to 850 mm |
| H. 12 mm | Disc diameters 625 to 1300 mm |
| H. 15 mm | Disc diameters 500 to 2000 mm |
| H. 20 mm | Disc diameters 900 to 3500 mm |
| H. 30 mm | Disc diameters 2000 to 3500 mm |

*4.3.12. Horizontal diamond discs*

Horizontal discs are used (on the block cutting machines) to detach the base of each strip from the stone block, after the performance of the vertical cuts by the vertical discs. They have usually small diameters and are fastened to their spindles by screw crowns. A reinforced core is provided for heavier working conditions (such as granite cutting). In spite of their small diameter, these discs work in quite heavy conditions, due to the irregularity of the stresses applied and their remarkable feeding speed; moreover, impacts with detached strips may occur. The standard size of the more often used horizontal discs is given below:

| Total external diameter (mm) | Steel thickness in the holding position (mm) | Steel thickness in the welding position (mm) | Diamond segment thickness (mm) | Number of segments |
|---|---|---|---|---|
| 300 | 8 | 3 | 4.0 - 4.2 | 15 - 18 |
| 350 | 8 | 3 | 4.0 - 4.2 | 21 - 24 |
| 400 | 8 | 3 | 4.0 - 4.2 | 24 - 28 |
| 450 | 8 | 3 | 4.0 - 4.2 | 32 - 36 |

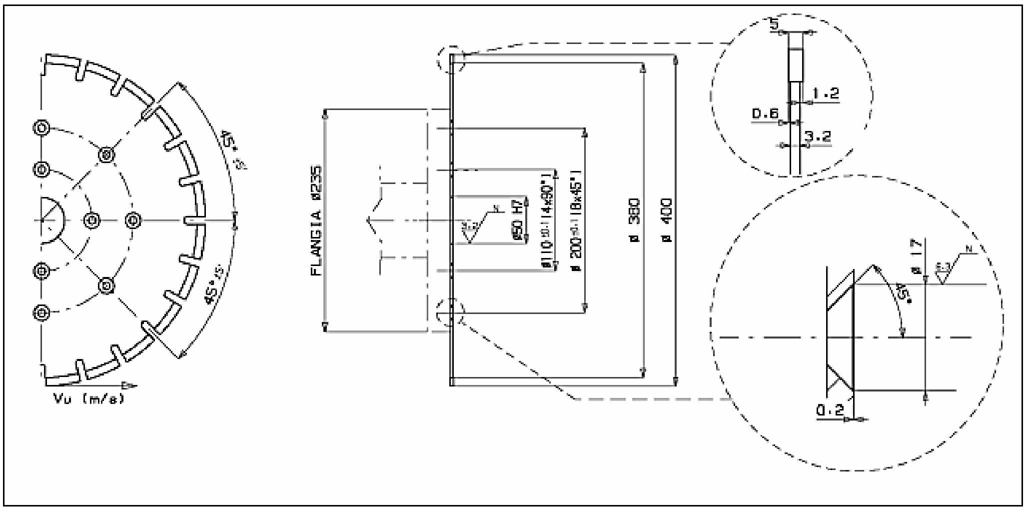



**Figure 102.** Horizontal disc for block cutter (plain, for marble)

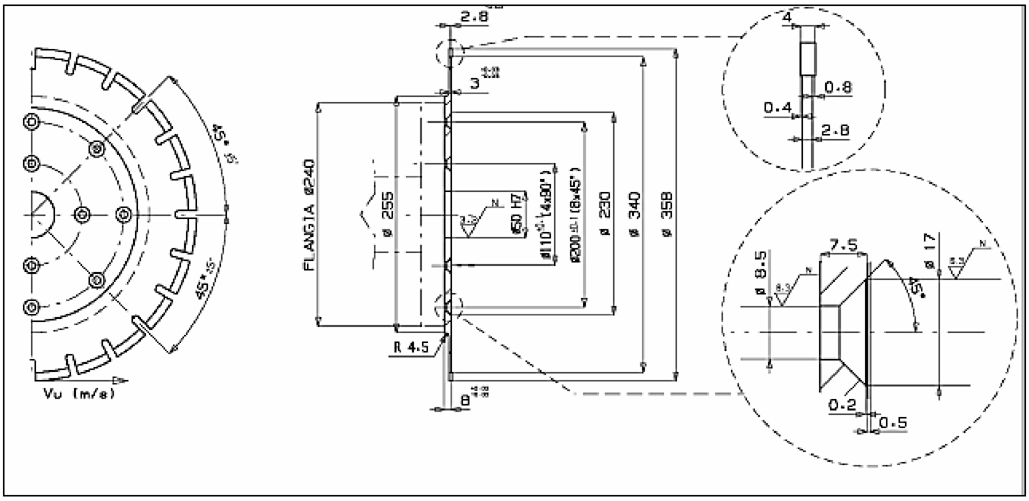



**Figure 103.** Horizontal disc for block cutter (reinforced, for granite)

### *4.3.13. Discs for marble splitting machines (also known as sectioning machines)*

The most common segment height is 6 mm. The most common type of bond is a cobalt/bronze mixture. In the marble/limestone sectioning machines the discs are usually horizontal.

| External diameter (mm) | Number of segments |
|---|---|
| 500 | 50 |
| 550 | 54 |
| 600 | 60 |
| 625 | 62 |
| 650 | 65 |
| 700 | 64 |
| 725 | 68 |
| 750 | 70 |
| 800 | 74 |
| 825 | 76 |
| 850 | 78 |

### *4.3.14. Tools peripheral speed*

This parameter is very important for the correct use of diamond discs. The tool manufacturer always delivers instructions regarding the recommended peripheral speed for each kind of stone to be cut. According to the type of machines available on the market, the speed may vary using different combinations of transmission pulleys, or electronic speed regulators, where installed.

As an approximate indication, the average values for the recommended peripheral speeds are given in Table 64.

Table 64. Recommended peripheral speeds of diamond disks for different stone types

| Kind of stone to be cut | Average peripheral speed (m/s) |
|---|---|
| Soft white marble (coarse grains) | 48 - 62 |
| Medium hardness marbles/limestones (such as “Pearl”, Botticino”, “Trani”) | 42 - 50 |
| Hard marbles (such as “Arabesque”, “Carrara”) | 40 – 50 |
| Very hard marbles (such as “Levanto”, “Red”, “Green”) | 32 - 42 |
| Granites with low percentage of quartz | 30 - 40 |
| Granites with high percentage of quartz | 20 - 30 |

*4.3.15. Lubrication and cooling*

It is absolutely necessary to use the right quantity of water during the cutting phase. The quantity and, in some cases, the quality of the water (too hard, not enough filtered) influence the tool performance. It is important that the water feeding system can assure the effective cooling of the contact area between the stone and the diamond segment during machining. Usually, the tool manufacturers recommend the right water flow to be employed. In the following table the recommended water quantity per disc is given.

| Disc diameter (mm) | Minimum recommended values (l/min) | Maximum recommended values (l/min) |
|---|---|---|
| 200 – 250 | 5 | 10 |
| 300 – 400 | 10 | 15 |
| 450 – 550 | 15 | 22 |
| 600 – 625 | 20 | 30 |
| 700 – 750 | 30 | 40 |
| 800 – 900 | 30 | 45 |
| 1000 – 1100 | 40 | 60 |
| 1200 – 1300 | 50 | 75 |
| 1400 – 1600 | 60 | 90 |
| 2000 | 70 | 120 |
| 2500 | 80 | 140 |

The values of the above table must be considered as an indication, and only for single discs. Such values depend directly on the material to be cut and on the cutting parameters, such as cutting and feeding speed, material removed, condition of the diamond segment, wear of the steel core.

Another important factor affecting the quantity of water required for lubro-refrigeration is the number of discs used at the same time on the machine (for instance: 32 – 50 – 80 – 100). In such cases, the value given per disc must be reduced as the number of discs increases, according to the manufacturer’s instructions.

*4.3.16. Important notes regarding the use of diamond discs*

It is important to follow all the instructions for handling and stocking of diamond disks, delivered by the manufacturers. The diameter of the holding flanges is always a very relevant factor. Appropriate flange of the correct diameter must be employed in order to avoid or reduce instability in the steel cores. The number of discs employed on a block cutter must not exceed the limitations of the machine itself. Before the cut, and while the machine is not in operation, it is important to check the axial and radial run out of the discs, comparing the measures with the data delivered by the manufacturer.

It is absolutely necessary to use the right of water quantity during the cutting phase. The quantity and, in some cases, the quality of the water (too hard, not enough filtered) influence the tool performance. It is important that the water feeding system can assure the effective cooling of the contact area between the stone and the diamond segment during the machining. Usually, the tool manufacturers recommend the right water flow to be employed.

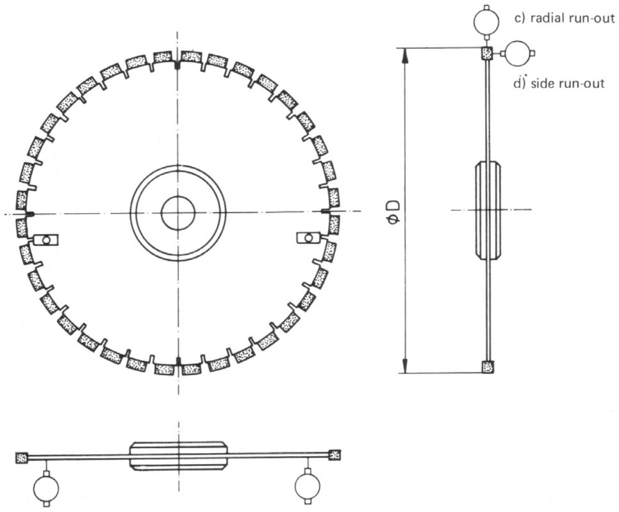



**Figure 104.** Diamond saw blade mounting recommendations

*4.3.17. Advantages/Disadvantages*

The circular saw blades are the most widely used cutting instruments for sawing natural stones. They have a high production rate and in many cases a sufficient cut quality. Straight and even cuts can be performed. If there is a necessity for a higher cut surface quality additional milling, grinding and polishing has to be done.

In relation to their outer diameter, very thin tools tend to vibrate and run out during cutting. Careful mounting and alignment of the blades within the machine and proper preparation of the tools as well as adjustment of tool behavior to machine characteristics has to be considered.

The demand for less waste by a thin cutting kerf and a minimum core thickness to achieve a stable blade performance leads to a true dilemma that has to be solved in the daily struggle between user and manufacturer of the tools. The same can be said about noise emission, which in some cases is very high.

The interaction of tool and stonepiece leads to forces which will act on the blade and induce strain and stresses, which again will influence the working behavior. If a saw blade cannot be designed specifically for a certain machine, the vibration behavior should be defined and the vibration amplitude should be decreased by increasing the damping effects and the dynamic stiffness. The minimisation of the tool area, which is ready for free vibration and therefore able to radiate noise, will additionally result in a more "quiet" tool.

The most important limitation is the relationship between the disc diameter and the maximum sawing height, due to the space took by the flanging system. Generally, the maximum height that can be cut is about one third of the disc diameter; this ratio may reach the value of 0.45 for giant discs and/or when the disc thickness is increased.

The use of circular cutting tools will not be limited in the future because of the high cutting productivity, but newly developed processing techniques will gain in importance.

## 4.4. CIRCULAR SAW BLADES (DIAMOND DISCS WITH ELECTROPLATED RIM)

### *4.4.1. Description*

Diamond discs with electrolytic deposit are manufactured in all required dimensions from a minimum diameter of 40 mm up to about half a meter. They are used with a continuous rim, different profiles and also a segmented rim (Figure 105).

These tools are for hard materials (such as glass or ceramic). They are also employed for stone cutting in specific operations, on fragile hard materials or to cut extremely reduced thickness in order to avoid cracks on the cut edges.

The steel cores employed for this type of tools must be very thin, because in the cutting section the diamond is plated on the core side surfaces.

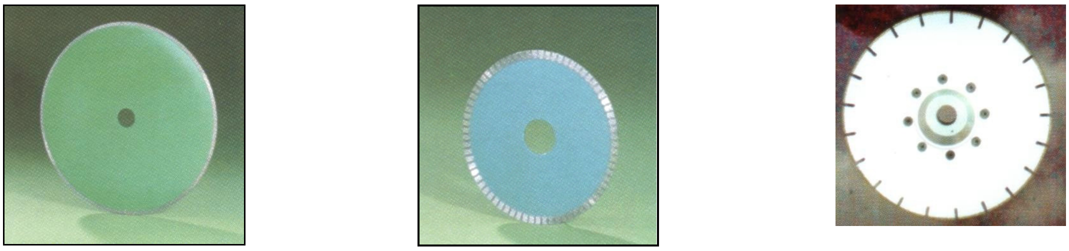


**Figure 105.** Electroplated diamond discs

### *4.4.2. Applications*

These tools are used for the cutting of marble, glasses, plastic, fiberglass, fibers and other similar materials. They may be used in dry and wet cutting conditions on stationary and hand-held machines where precise cuts with a small cutting-kerf are demanded.

In order to achieve cutting precision higher than the usual, recommendations for running truths of continuous rim saw were established. The satisfactory operation of continuous rim saws is dependant upon the close dimensional tolerances of the saws, as produced by the saw manufacturer. However, in order to maintain these close tolerances, while the saw is in operation, the machine itself must be in good condition, free from vibrations and the saw must be properly mounted between flanges. The method used for mounting the saw is of vital importance. The mounting flanges must be of proper design and must themselves be in good running truth. A list of the recommended minimum flange dimensions for given saw diameters and mounting tolerances is shown in Table 65.

**Table 64.** Mounting tolerances of continuous rim saws

| Diameter D mm | flange diameter Df mm | flange bearing width mm | radial run out mm | side run out mm |
|---|---|---|---|---|
| 50 | 20 | 3 to 5 | 0,05 | 0,03 |
| 100 | 35 | 3 to 5 | 0,05 | 0,05 |
| 200 | 70 | 5 to 8 | 0,05 | 0,10 |
| 300 | 100 | 6 to 10 | 0,05 | 0,15 |
| 400 | 130 | 8 to 12 | 0,05 | 0,20 |
| 500 | 170 | 8 to 12 | 0,10 | 0,25 |

Provided that accurate flanges and careful mounting procedures are adopted, the running truths listed in Table 65 could be obtained with saws supplied by reputable saw manufacturers. If closer tolerances are required for very high precision operations, the saw manufacturers should be consulted.

### *4.4.3. Characteristics*

The tools are manufactured with dimensions as stated in Table 65, with additional diameters in between. They are on the market with different fixings to the machines as bores, flanges and shafts. The blades are used for precise cutting of a variety of hard materials to perform slicing, grooving and breaking down of slabs and ceramic tiles.

### *4.4.4. Advantages/Disadvantages*

Because of the narrow cutting width, the saw blades tend to be in contact with the material to be cut. Careful alignment and mounting in the machine has to be performed. The main advantages are the smooth cut surfaces achieved with high precision and the low material wastes produced.

Usually, they are not employed for cross cutting, trimming and block cutting, where segmented discs are employed (see previous paragraph). Due to their manufacturing process, the electroplated discs do not allow the easy removal of the cutting swarf from the sawing area. The electroplated tools are thin, with parallel sides and the diamonded area is very thin; during cutting water can not reach easily the cutting area. For instance, sawing a limestone or marble can result in a “muddy” cutting tool because cleaning is not easy.

Cutting granite may result in deviations due to lack of the “softer bond” central layer (typical of a diamond sandwich segment) that defines the segment shape in order to achieve a great “guiding effect”. While the steel cores of the segmented diamond discs can be re-tipped a certain number of times, this is not a standard process for electroplated discs.

## 4.5. LINEAR DIAMOND SAW BLADES

### *4.5.1. Machines and processes*

These tools are to be employed on single or multiblade cutting frames for marble machines, for slab cutting and block squaring processes.

### *4.5.2. Tool manufacturing features*

The tool is made of a linear blade of special steel, equipped at each one of its ends with a device to couple it with the steel holder mounted on the frame. The blade is tipped with diamond segment brazed on the cutting line.

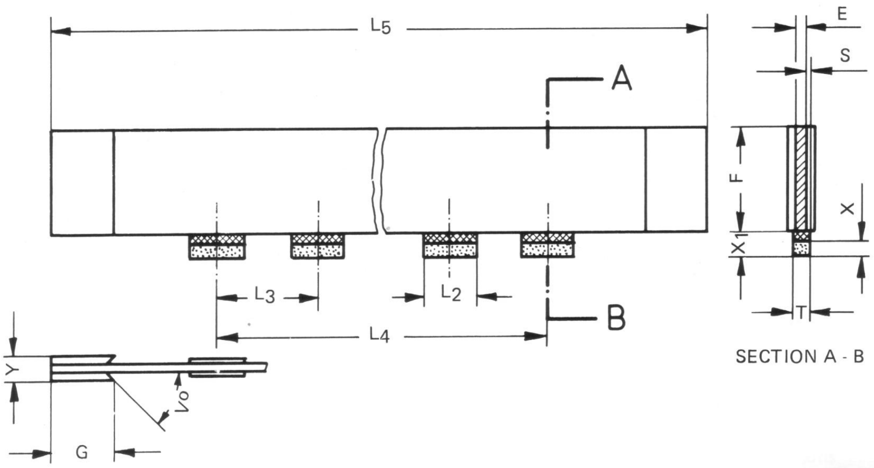



**Figure 106.** Frame saw blade dimensions

The diamond segment is the blade part that performs actual sawing. It is a small block, shaped approximately like a parallelepiped. It includes metal grains (the segment bond) aggregated by a thermal process under pressure (sintering), containing a certain variable, percentage of industrial diamond grit (which can be natural or synthetic). Different combinations of diamond and bond give different sawing performance.

### *4.5.3. Applications*

Diamond blades for single and multi blade machines for cutting marble and soft materials are sized for each machine type. The blades have a long service life and guarantee effective cutting until the cutting edge is completely worn.

The tool must be solidly fixed to the structure of the cutting frame blade holder, that delivers both the longitudinal cutting motion and the feeding motion, by means of an alternating motion and a vertical displacement. Both motions must be considered as relative to the stone block to be cut; the stone block is usually firmly resting on its supporting trolley, while the blade moves alternately to and fro; the feeding motion is obtained either by moving the blade(s) downward or by lifting the supporting trolley. In order to perform a correct cut free from deviations, the blade(s) must be put under tension by a hydraulic, mechanic or pneumatic tensioning device. The value of such tension is a parameter depending on the blade manufacturing.

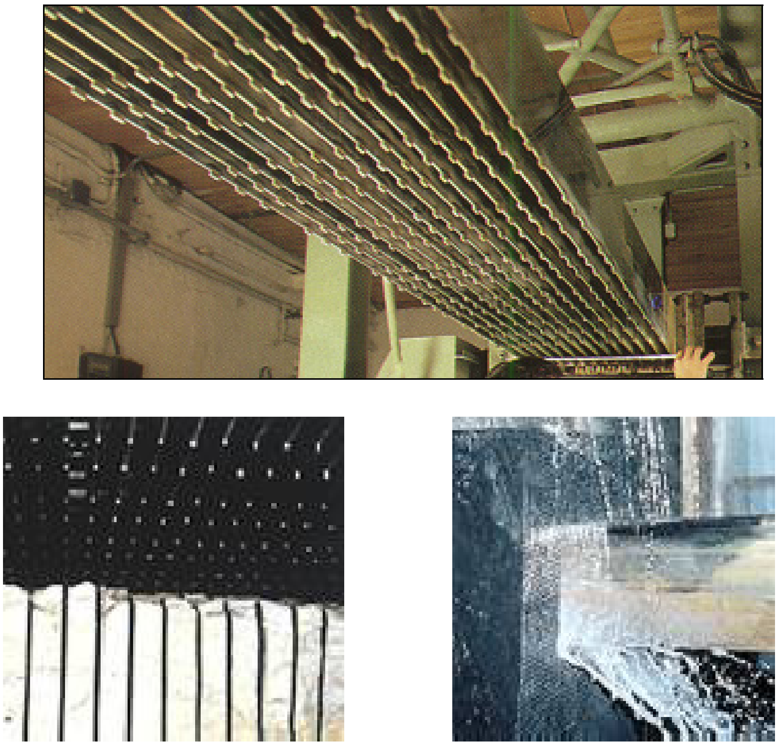


**Figure 107.** View of diamond blades

*4.5.4. Characteristics*

For sawing stone blocks of various sizes, the dimensions shown in Table 66 are suggested.

**Table 65.** Frame saw blade dimensions

| block length<br>mm | segmented<br>lenghth L4<br>mm | total saw length<br>L5<br>mm | cross section<br>F x E<br>mm² | recommended<br>tension<br>kN |
|---|---|---|---|---|
| 2000 | 2000 | 2900 | 180 x 3,0 | 80 to 110 |
| 2500 | 2500 | 3400 | 180 x 3,0<br>180 x 3,5 | 80 to 110 |
| 3000 | 3000 | 3900 | 180 x 3,0<br>180 x 3,5 | 80 to 110 |
| 3250 | 3250 | 4150 | 180 x 3,5 | 80 to 110 |
| 3500 | 3500 | 4400 | 180 x 3,5 | 80 to 110 |
| 3750 | 3750 | 4650 | 180 x 3,5 | 80 to 110 |
| 4000 | 4000 | 4900 | 180 x 3,5 | 80 to 110 |

The bladed length varies according to the use. The size of the standard segments available on the market can be summarised as follows:

| Size of the diamond segment | Thickness (mm) | Length of the segment (mm) | Total height of the segment (mm) | Height of the diamond tipped section (mm) |
|---|---|---|---|---|
| Blades for vertical frames | 4.0, 4.5, 4.8,5.0 ,5.5,6.0 | 20 | 7 | 5.5, 6, 7 |

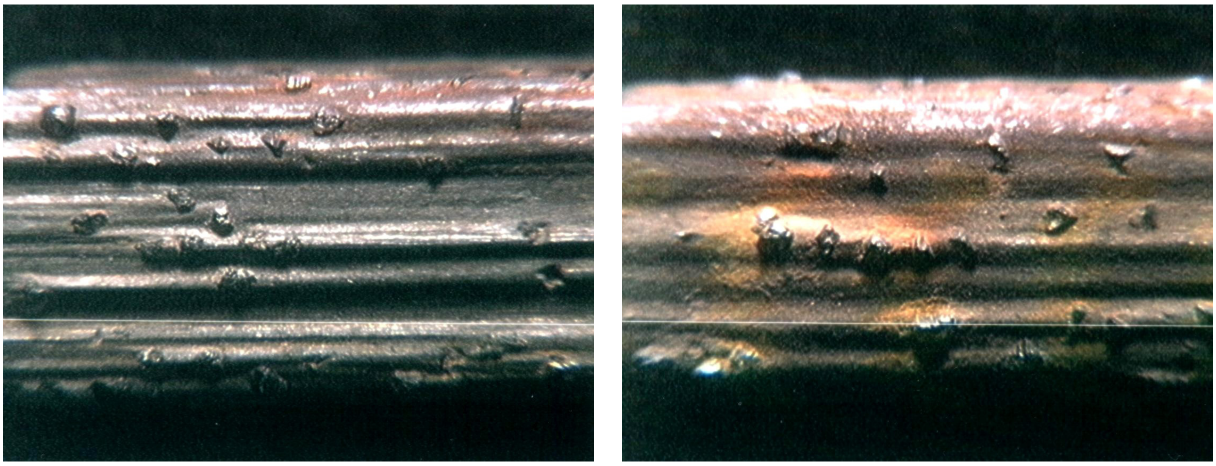


**Figure 108.** View of frame saw segment

The diamond blades are also manufactured according to the material to be sawn: coloured marbles, white marble, Travertine, abrasive marbles. The segment surface during cutting, formed by the longitudinal movement of the tool, is characterised by grooves and hill-ranges, which were formed by the queueing of diamonds.

Terminology and technical abbreviations for tool identification:

-Number of blades (in case of multiblade frame).

-Number of segments per blade.

-Segment size.

-Length and thickness of the blade.

Operating technical data:

-Useful cutting length-

-Strokes per minute

-Power available on the motor

-Type of stone to be cut

-Type of lubro-refrigerating agent (water or else)

The following parameters are useful for defining the performance of these tools:

- Total square meters cut (for the whole tool life)
- Blade feeding speed (cm/h)

Such parameters depend on the manufacturing features of the tool, in relation to the material to be sawn, the conditions of the machine where the tool is installed and the skill and experience of the personnel in the factory.

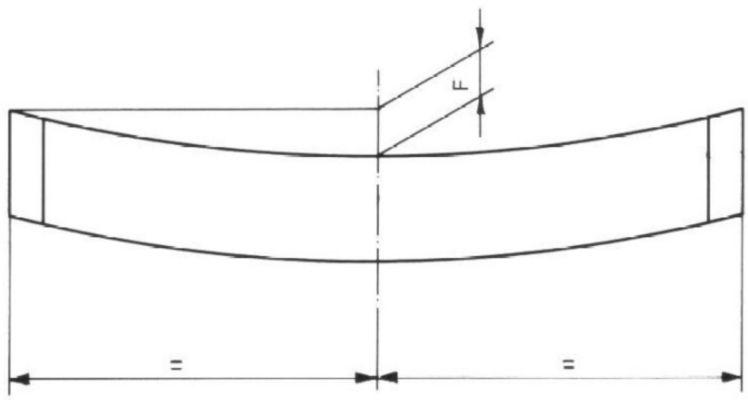
### *4.5.5. Blade tension*

Because of the great length of the frame saw blades, a proper tension has to be applied to the tools by the sawing machine. After correct tensioning (see Figure 109), the diamond frame saw blades must show a concave deflection, which can be measured at the top of the blade. This deflection is:

1,5 to 3,5 mm for soft stones

2,0 to 4,0 mm for hard stones

This deflection can be maintained by shifting the blades out of the cleats (high tensile stress on the tooth side).




positive deflection

**Figure 109.** Mounting tolerances for vertical and horizontal frame saws

It is particularly important to check the deflection under load. For this purpose, the frame saw is stopped after the blades are approximately in a downfeed position of 3 quarters of the blade depth (This is a very practical method that can only be applied to certain gang saw machines, where the downfeed continues while the gang saw machine is stopping).

The deflection should be measured at the top side of the blade with the aid of a nylon cord. It is acceptable when the top side is straight, or alternatively, has a positive deflection. If necessary a gauge blade approximately 1,5m in length can be used for this check. The check must always be carried out at the centre of the saw blade. If the top of the saw blade has been forced upward and the blade has, thus, taken a convex deflection, the blade will have to be repositioned and retensioned.

One good method for checking the concave deflection is a visual inspection, while the frame saw machine is operating, specifically at the point where the blades emerge from the block.

### 4.5.6. Sawing technique

In order to employ correctly such kind of tool, it is necessary to proceed with the appropriate operating techniques. Some measures to improve the quality of the cut are, as follows:

-Fixing the block. Sound securing of the block is essential because in practice this leads to reduced sawing vibrations, lower wear on the segments and higher down-feed speed. The stone blocks must be firmly fixed on the carrying trolley and the carrying trolley must be firmly secured on the machine structure.

-Block size and blades length. As far as this is possible, use of blocks of consistent length corresponding to the effective segmented length of the diamond blades. In this way there will be a regular wear of the diamond segments. If the length is too short, the diamond blade wear will be irregular at the edges, if it is too long the central section of the blade will be irregularly worn.

-Blades mounting. The blades must be mounted in the correct position (horizontality or verticality, according to the kind of machine), respecting the mounting tolerance. The blade must be parallel. The tension of the blades must have the correct value and must be constant; the blade(s) camber must be well inside the tolerance range, defined by the manufacturer.

-The cutting parameters must be correct.

-Cooling. The quantity, quality and good distribution of cooling water are important factors affecting the blade life and the cut quality. Soft, well-decanted water should therefore be used, especially when working with materials producing sticky or abrasive mud.

-Down-feed speed. The down-feed speed is an essential parameter in frame-sawing. lt affects not only the production per hour, but also the quality of the cut and the pressure exerted on the segments to avoid glazing of the diamond impregnation. In any case the down-feed speed should be sufficient to ensure the self-sharpening process of the diamond segments.

-Sawing approach. Sawing should start using a low down-feed speed. As soon as the blade's segments bite into the material the down-feed speed should be gradually increased till normal working speed is reached. This should be maintained until the whole block is cut.

-Sawing plan. When dealing with the same stone quality - and this is the case for quarries - it is possible to decide on and maintain an optimal speed. However, this cannot be done when sawing various material types. In this case, not only feed speeds should be modified according to the nature of the stone, but different types of stones should be alternated. Sawing, therefore, should be carefully planned both to ensure a maximum blade life and to avoid frequent mounting and dismounting of blades.

-Alternating materials. In sawing various types of marble on the same machine nearly always the same blades are used, whereas the ideal solution would be to employ two, or sometimes three, sets of blades of different types. However, it is logical to use a single set of blades, and in fact this will be effective, provided that the materials are classified beforehand according to their hardness and their abrasiveness. Moreover, the down-feed speed should be appropriate to each material and alternate sawing of hard or compact materials and soft or crystalline ones should be performed.

### 4.5.7. Advantages/Disadvantages

Diamond frame sawing is an efficient method by which a great number of stone pieces with same dimensions can be cut out of blocks. The production of stone pieces of large dimensions is possible. It can not be used for a quick change in slab thickness as the whole block has to be finished first. With the current technology, only soft stones (like marble and limestone) can be sawn with diamond blades.

Wide cutting kerfs and large waste amounts characterise the frame sawing process. Noise emission is lower than in most of the other stone machining processes.

## 4.6. LINEAR STEEL SAW BLADES

### *4.6.1. Machine and process*

These tools are to be employed on multiblade cutting gangsaws for granite and for slab cutting.

### *4.6.2. Tool manufacturing features*

The tool is made of a linear steel blade, equipped at each one of its ends with a device to couple it with the steel holder mounted on the holding frame.

### *4.6.3. Applications*

This tool is used in Multi blade machines (Gangsaws) with alternate motion, for cutting granite and hard stones.

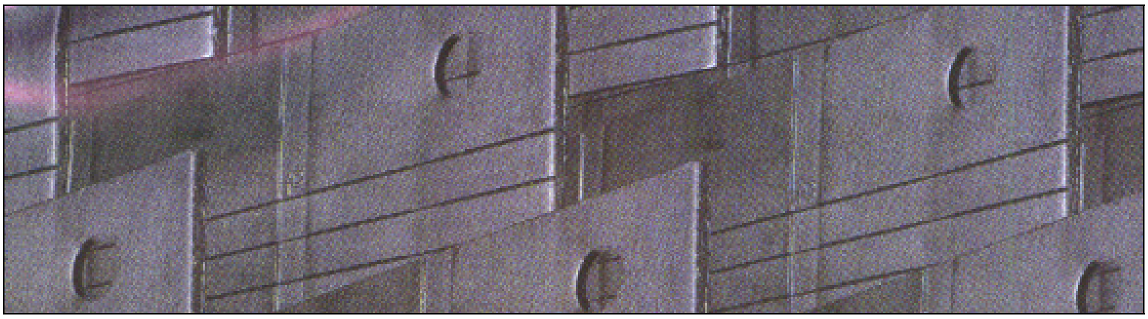


**Figure 110.** Linear steel blades for granite, horizontally grooved

### *4.6.4. Characteristics*

For sawing stone blocks of various sizes the overall dimensions are similar to those given for the diamond tipped blades for marble. The blades tensioning system is also similar (usually hydraulic).

Unlike the marble sawing technique (by diamond blades), in a granite gangsaw the blade is not tipped with diamond segments: sawing is performed by friction between the stone and iron shots, slurry and/or a mixture of abrasive components. The steel blade performs the action of pushing the sawing medium against the stone.

There is also another difference in comparison to the marble sawing technique (by means of diamond blades): in a granite gangsaw, the sawing action is usually not only an alternate motion, there is also a periodical vertical component that translates into “hits” or “bumps” between the blades and the stone. Such vertical oscillations are given by the machine mechanics (usually a pendulum-like system). The motion of the abrasive mixture is also an important factor in determining the sawing action. This should be taken into consideration during the blade manufacture and application (size, shape, alloy, tensioning) should take this into consideration.

In the current practice the sawing mixture is made of water, 1.2 % lime (CaOH), 3% steel grit, and 30% mineral. This is an indicative average composition, given in volume mixture, since there is a great difference in density among the components. The viscosity of the mix is a critical factor and its value is (as an approximate indication only) around 1000 Centipoise (1 Centipoise=0.001 Pa x S).

### *4.6.5. Evolution of the Characteristics*

In the last decades, sawing of granite slabs was dramatically improved in terms of productivity. The descent rate of the blades (feeding motion) can be used as a reference in order to evaluate the productivity because (when multiplied by the number of blades) it is proportional to the square meters of slabs cut in the unit of time. Around year 1975, the descent rates were in the range 2 to 5 mm/h; around 1985 they were between 10 to 30 mm/h, while after 1995 they reached a range from 20 to 70 mm/h. This means a ten times increase of the productivity in 20 years.

During the sixties, the technology included sawing by means of an abrasive mixture made of water, cast iron grit, and lime (CaOH). Cast iron was hardened during the grit manufacturing process. The lime was found to be a good system to prevent or limit the cast iron oxidation, which alters the granite colour. Lime plays also another important role: it increases the viscosity of the mixture; low viscosity means that the grit falls too fast by gravity and the abrasive effect of the mix is reduced. At this stage, the mix was supplied/recycled by means of mine pumps. The grit tended to separate from the mixture and the finer grit separated from the coarse grit; since the sawing action of the coarse and fine grit is different, separation, recycling and mixing are critical factors. Separation was performed by gravity in tanks or similar.

Blades were made of C60 carbon steel, mechanically tensioned.

The alternate sawing action was improved by cranks having adjustable length, to be regulated during the cutting. At that time, such adjusting operation was manually performed.

In the seventies, the grit was turned into steel and the blades into C70 carbon steel, pretensioned and grooved. In the grit separation, special centrifugal pumps were introduced.

In the eighties, hydraulic tensioning was introduced for blade tensioning. The crank length adjustment became automatic, applied by means of a system with hydraulic cams.

In the nineties, the fully automated abrasive mixture management was introduced. A computer controls the composition of the mixtures, while sensors and actuators measure the mixture condition and control the supplying devices. Motors with electronic speed regulation and power recovery were introduced on the frames during the alternate motion (for reduced power consumption).

### *4.6.6. Advantages/Disadvantages*

This sawing technique is not very efficient and the productivity is quite low. Moreover, the cutting mixture can not always assure the predictable behaviour and constant performance offered by the diamond tools.

Nevertheless, in the current practice, it is still the best way to cut a big number of full sized (i.e. hard stone) slabs, having the same dimensions, out of granite blocks. The production of large sizes slabs is possible. It cannot be used for a quick change in slab thickness as the whole block has to be finished first. The productivity (square meters per unit of time) is very low, if compared to diamond sawing.

## 4.7. DIAMOND TOOLS FOR SURFACE CALIBRATION ("GRINDING")

### *4.7.1. Machines and processes*

This kind of tools applies to different machines and processes:

- Calibrating machine for granite strips (Process: granite strip calibration)
- Calibrating machine for marble strips (Process: marble strip calibration granite)

In the current practice, true calibration of slabs is not available.

Note: the tools for side calibration of tiles are discussed in the paragraph related to chamfering. Side calibration and chamfering operations are usually performed together on the same machine in the line for tiles (marble and granite).

### *4.7.2. Description*

Surface calibration is the process that gives to a cut strip the desired thickness, which is constant in the whole length of the strip, and a surface adequate to support the subsequent processes (such as polishing).

The calibrating machines must provide an effective and reliable system to maintain and control the vertical position of the tool, without which succesful calibration cannot be performed. The machines must also provide systems to adjust the vertical position of the tools, in order to obtain the desired thickness and recover their progressive wear.

Calibrating tools (also "grinding tools") are produced in many different shapes and sizes, according to the machine where they areintroduced, to the stone, the process and the calibrating system employed. In any case, all the calibrating systems must deal with the problem of grinding the wide flat surface of hard, thin and fragile materials, at a high removal rate, without inducing fractures. The solutions employed tend to reduce the contact area between tools and stone, that is, keeping the actual grinding area to the minimum. In this way, a vertical force can be applied without breaking the stone but producing a very high local pressure on the stone crystals, allowing the material removal at an acceptable rate.

Finally, the flexibility of the process is taken into consideration in the recent machines for granite. This flexibility means two things. The first one is obvious: it should be possible to switch to another stone width without halting the process for tool replacement for a long time. The second thing is less obvious and refers to the problem of the tool wear: if a tool wears more in the area corresponding to the width under process, when changing to another strip width the thickness will not be uniform anymore (for instance, "steps" are generated on the strips in the direction of the tool feeding motion).

Granite calibration requires carefully-weighed solutions, if compared to marble. In the case of the granite there are actually many solutions, where the tool construction meets the machine design specifications at a quite good level.

A summary of the requirements for calibration, particularly relevant for hard stones follows. These requirements must be met by the right combination of machine/ tools.

- tool vertical position always steadily assured
- high material removal rate, high productivity
- techniques to avoid fractures on thin stone, about 10 mm
- uniform tool wear
- fast change of the working width ("small batches")
- if possible, the resulting surface should be smooth enough to facilitate polishing

For this process **diamond tools** are employed. They can be classified in two groups:

( 1 ) Tools made of supports with many diamond segments attached. The segments are similar to those described for the diamond disc (rectangular in shape and having more or less similar sizes). The supports are usually plates or rolls; the support determines the overall shape and size of the tool.

( 2 ) Tools made of solid sintered blocks of bonded diamond grit, of desired shape and size. They are mounted directly on the calibrating head. They are employed mainly when calibration is performed by means of heads rotating around their vertical axes.

Sizes, shapes and mounting systems show a remarkable wide range of solutions, according to the material to be processed (marble or granite), but also to the choices and "philosophy" of the machine and tools manufacturers. As often happens in the industrial field, many solutions are protected by valid international patents, and therefore, can only be employed under the permission of the owners.

### *4.7.3. Marble strip calibration with diamond plates*

Soft stones (marble, limestone) require quite simple means for an effective calibration. Usually, the tool includes a circular plate, on which **diamond segments** are attached (by brazing). Alternatively, each segment is welded on a support and each support is fastened on the plate by means of screws. In order to reduce the load on the strip, while increasing the specific pressure on the grinding area, the tool spindle is provided with a certain tilt angle (machine lengthwise), variable from the first head to the last one. Therefore, the contact between the stone and the tool is reduced to a narrow line. For soft stones this is sufficient.

In the calibration of marble and limestone, the water flow for cooling and waste removal is of outstanding importance. Overheating (usually due to a momentary lack of water or to an insufficient flow in the grinding area) causes the chemical transformation of the main mineral (Calcite) into Calcium Oxide (CaO). Such alteration is visible, it degrades the aesthetical value of the stone, and may reach a relevant depth into the stone, to the point that the material cannot be recovered by any further machining operation.

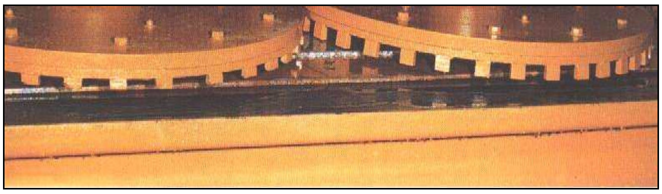



**Figure 111.** Tools for marble calibration, with diamond segments

### *4.7.4. Fixed diamond rolls (granite calibration)*

This system employs rolls equipped with **diamond segments** arranged in the shape of an helix (having one or more threads). In this way, the contact between the stone and the tool is reduced to a few small “points” continuously shifting their position on the stone surface. This is a very effective solution for hard stones, in order to reduce the load on the strip while increasing the specific pressure on the grinding area.

The segments can be attached directly to the roll by brazing/welding, or to special coverings mounted on the roll. The segments can also be brazed/welded on small supports, which are then fastened on the rolls by means of screws, as shown in the Figure 112. The rolls rotation axes are arranged perpendicularly to the motion of the conveyor belt. During calibration, the rolls are not subjected to any other motion; they are kept firmly in their position by mechanical systems, hence assuring the precision of the calibrating gap. The vertical adjustment is carried out while the machine is not calibrating.

Usually, more than one rolls are employed (2 to 6) to progressively reduce thickness. Each roll removes usually few tenths of mm, depending on the material hardness and the feeding speed (and, consequently on productivity). This system allows a very limited number of breaks in the strips, high productivity, easy operation, reduced power consumption and reduced tool wear. Moreover, the stone strips are continuously fed by a conveyor belt at a constant speed.

This system must be fed with stone strips having similar width to that of the rolls diamond helixes. Changing the strip width, the width of the rolls diamond helixes should be changed also by replacing the rolls, or by adding/removing diamond tips (when removable).

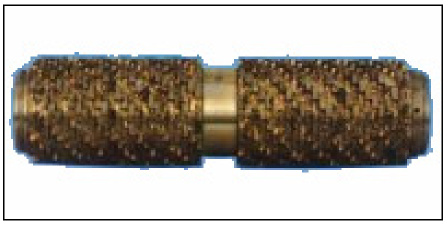



**Figure 112.** Granite calibration by means of fixed diamond rollers

### *4.7.5. Mobile diamond rolls (granite calibration)*

In this process the rolls are arranged with their longitudinal axes parallel to the conveyor belt carrying the stone strips, that means lengthwise the machine. While the rolls rotate, they also move to and fro across the strip, as they are mounted on mobile bridge(s). In this way, their wear is uniform and in order to change the strip width, it is sufficient to change the stroke of the transversal motion.

These rolls are not much different from fixed diamond rolls; in most cases the diamond segments are arranged along inclined lines. Usually, the strips stop while the calibrating rolls feeding motion is active, then the calibration stops and another section of the stone strip is carried into the calibration area. This “stop an go” system limits productivity, since it limits the average speed of the conveyor belt.

Moreover, the need for a transversal alternate motion during calibration means that the vertical position of the tools can hardly be assured: additional mobile mechanical means (like guides or bushes) may result in vibrations or backlash. This is another limitation of the system.

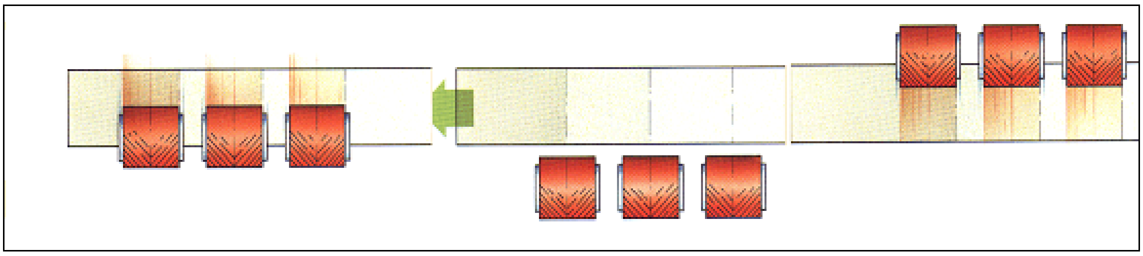


**Figure 113.** Calibration with mobile diamond rolls (“stop and go”)

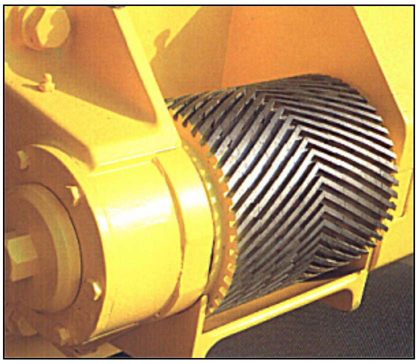


**Figure 114.** Calibrating roll used especially for this kind of operation

### 4.7.6. *Arrays of diamond discs (granite calibration)*

Calibration is performed by two or more arrays of diamond discs (that means disc tipped with **diamond segments**, as described in the relevant paragraph). Each array may include 12 discs (for instance), firmly packed together by flange and counter flange, in order to form a solid cylinder. The arrays rotate on spindles, which are parallel to the feeding motion given by the conveyor speed. While the belt moves and the stone strips advance, the set of discs may move slowly in a transversal direction. Therefore, this system works in a quite similar way to the one equipped with mobile diamond rolls.

The first array is used for the coarse grinding of the strips, while the following do the finishing work. The resulting strips (or tiles) are well calibrated in thickness, but their surface is quite rough, mainly due to the discontinuity among one disc and the other. Moreover, the need for a transversal alternate motion, while the calibration is performed, means that the vertical position of the tool can hardly be assured: additional mobile mechanical means (like guides or bushes) may result in vibrations or backlash. This is a limitation of the system.

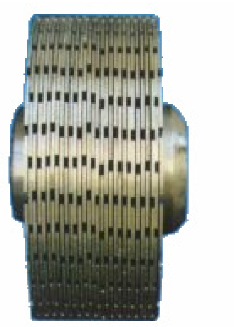


**Figure 115.** Granite calibration by means of a diamond disc

### 4.7.7. *Fixed diamond rolls in combination with plates (granite calibration)*

This solution combines the system “fixed diamond rolls” with the “strip calibration with diamond plates” system, as seen before. The latter should only be used for marble calibration, but here it is only employed to calibrate a very reduced amount of material, and in this case, it actually works very well.

In short, the rolls do not calibrate the full width of the strip; instead, about 5-10 mm are left not calibrated on each side. At the end, two diamond plates (one on each side) remove the material left on the two sides. This system assures a very uniform tool wear, because the whole rolls width is always grinding, even if there are small variations in the strips width (and this is quite likely). The rolls are firmly locked vertically during the calibration, and so, their vertical position is steady. The strips flow on the conveyor belt continuously, without interruption, and their speed can be kept high enough to assure high productivity.

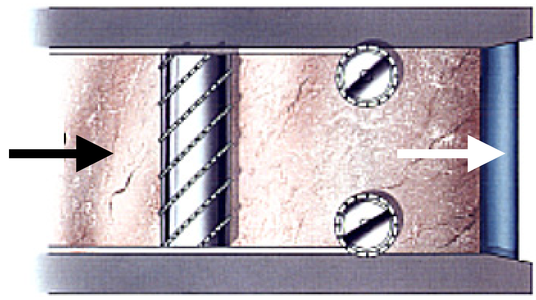


**Figure 116.** Fixed diamond roll and plates (roll not inclined shown)

*4.7.8. "Variable Inclination" rolls in combination with plates (granite calibration)*

Among the most well studied solutions available, this system is quite similar to the previous one, with the difference that each diamond roll can be adjusted (when the machine is not calibrating) by rotating it around its vertical axis by a motorized system. During the process (while the machine is calibrating), the roll is kept firmly anchored by means of mechanical systems.

This system has all the benefits of the system explained in the previous paragraph, and some new ones:

- the stone surface is even smoother, facilitating the subsequent polishing process. The reason for this is that, as the roll is not perpendicular to the strip flow, each diamond crystal grinds (statistically) different positions along the width of the strip and the defects are not enhanced by hitting always the same line along the strip flow.

- the change of the processed strip is very fast; no tool replacement is needed, no segment removal; it is only necessary to adjust the inclination of the rolls, which can be electronically controlled. This is the ideal situation for "small batches". For such uses, special rolls having smoothed ends (slightly conical) are also employed.

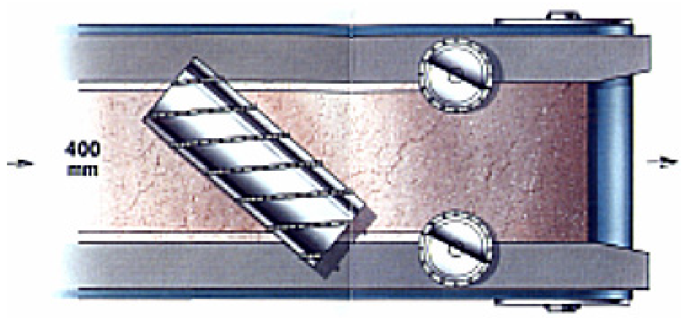



**Figure 117.** "Inclined" diamond roll and plates

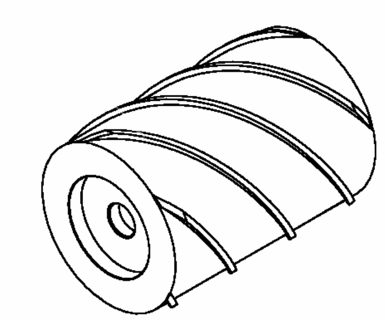


**Figure 118.** Schematic drawing of a diamond roll with smoothed ends

### *4.7.9. Calibration with rotary heads (granite calibration)*

This type of calibrating heads can be considered as an evolution of the rotary polishing heads, because their resemblance is remarkable. Diamond tools are always employed in calibration, as **diamond segments** applied to supports, or as **solid sintered blocks** of bonded diamond grit, usually having cylindrical or conical shape.

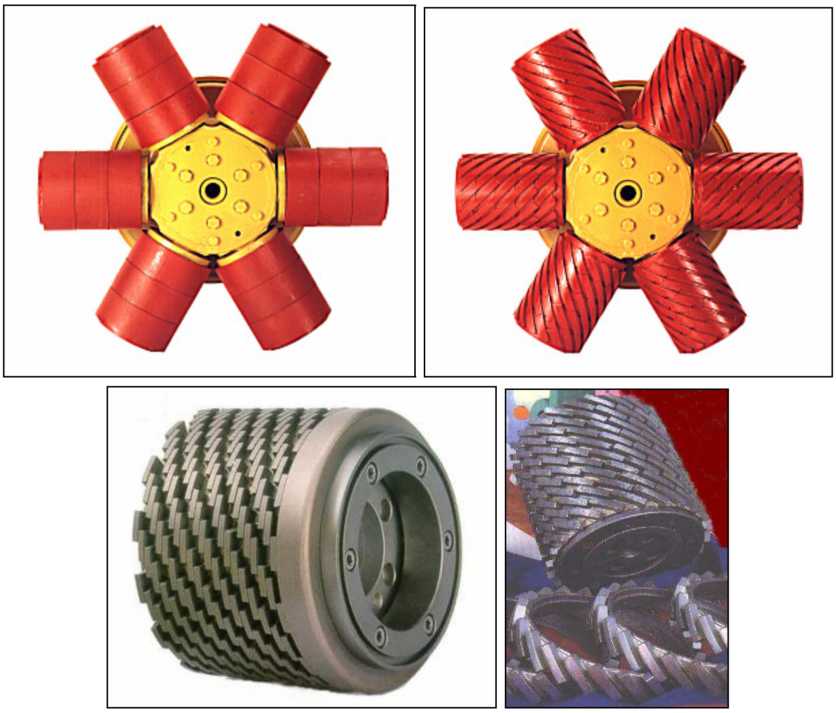


**Figure 119.** Different diamond arrangements on rotary calibrating heads

One limitation is that the peripheral speed of the diamond tool must be within a range compatible with that of the diamond grit in granite grinding conditions (i.e. 20-30 m/s). The cutting speed is determined by a combination of head rotation and tool rotation and hence varies across each diamond tool. Since the diameter of the tools is quite small (if compared to the rolls seen before) a high number of tool rotations per minute may be required. The mechanics included in the head should meet these requirements and also assure the mechanical rigidity needed for calibration.

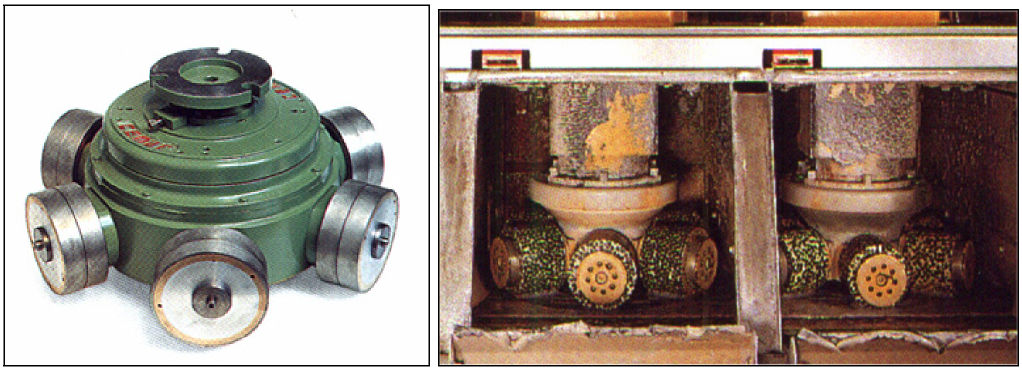


**Figure 120.** Rotary calibrating heads (with cylindrical tools)

Tools made of solid sintered blocks of bonded diamond grit have also been manufactured in a conical shape, in order to keep the peripheral speed (i.e. the diamond cutting speed) as constant as possible going from the inner side to the outer side of the head. This may allow higher head rotation speed and simplify the kinematics, but the mechanical rigidity may be more critical.

**Figure 121.** Rotary calibrating heads (with conical tools)

Another kind of diamond head, which can be employed for calibration, mounts only slightly conical tools, and each tool is slightly inclined on the vertical axis; in this way the contact area with the stone is kept to a line, as required. This head is very rigid; the grinding speed is given by the combination of the rotational speed of each tool and the whole head.

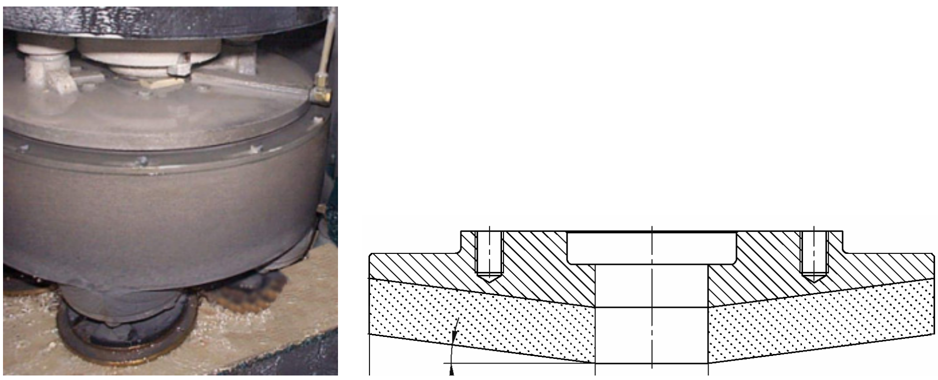


**Figure 122.** Rotary calibrating head (with conical inclined satellite tools)

*4.7.10. Characteristics of the calibrating tools.*

Calibrating rolls with helix of diamond segments

| | | | | | | |
|---|---|---|---|---|---|---|
| diam. width (mm) | 550 | 600 | 600 | 650 | 840 | 1240 |
| diameter (mm) | 200 | 200 | 200 | 200 | 290 | 290 |
| number of threads | 5 | 5 | 7 | 5 | 7 | 7 |
| number of segments | 5x22=110 | 5x27=135 | 5x27=189 | 5x29=145 | 7x34=238 | 7x50=350 |
| segment size (mm) | 40x10x10 | 40x10x10 | 40x10x10 | 40x10x10 | 40x10x10 | 40x10x10 |

The diamond segments of a calibrating roll can be arranged as follows:

- one segment welded per support, each support fixed to the roll by means of screws
- two or more segments welded per support, each support fixed to the roll with screws
- all the segments are welded directly on the roll
- segments are welded in helical grooves of steel jackets, then mounted on the roll.

The composition of the segments for calibrating tools is similar to that of the segments for diamond discs.

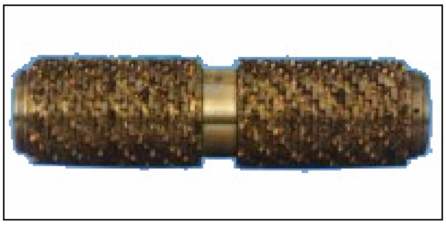


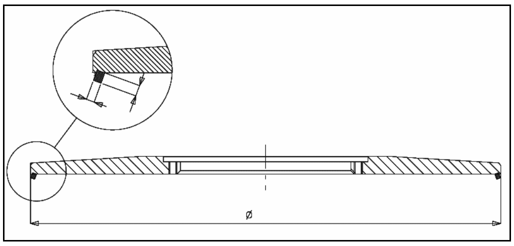
**Figure 123.** “Cassani” diamond rolls

These rolls can be employed to calibrate one or two rows at the same time. Due to their construction, they must be used on strips having the same width of that of the diamond belt.

| Strip width (mm) | Number of diamond segments |
|---|---|
| 250 + 250 (double diamond band) | +/- 420 |
| 300 + 300 (double diamond band) | +/- 580 |
| 400 | +/- 370 |

**Table 66.** Calibrating plates with diamond segments (for marble)

| | | | |
|---|---|---|---|
| diameter (mm) | 650 | 690 | 840 |
| number of segments | 70 | 77 | 94 |
| segment size (mm) | 20 x 8 x 6 | 20 x 8 x 6 | 20 x 8 x 6 |



Calibrating plates with diamond segments (for granite, combined with rolls)

- continuous ring, thickness 10 mm, diameter inner/outer (approx.): 160/180 mm
- continuous ring, thickness 10 mm, diameter inner/outer (approx.): 210/230 mm

#### *4.7.11. Advantages/Disadvantages*

In tiles manufacturing, the calibrating process as a whole is useful and necessary (1) when a uniform thickness of the finished product is required, and/or (2) in order to perform more effectively the following operations, mainly polishing. Non-calibrated products can be required by the market and polishing machines have been manufactured for non-calibrated stone strips; nevertheless, calibration is nowadays a “must” in lines for mass production of tiles.

In the current practice, thickness calibration is not usually performed on slabs, due to a lack of really effective techniques and machinery. On the other hand, on custom production coming from workshops, calibration is replaced by more specific sizing processes, such as milling.

In marble calibration (soft stone), the stone characteristics easily allow good precision and productivity; special attention must be paid in order to avoid damages to the product.

When comparing the different tools for granite, advantages and disadvantages are linked to the related calibrating solution. Fixed and adjustable diamond rolls (also coupled with diamond plates) are precise, the peripheral grinding speed can be adjusted precisely on optimal values, the tool consumption is low and regular, the product surface is smooth or very smooth and the productivity is high. Mobile rolls are less precise, and productive and cause more tool wear. For “compact” disc arrays, the resulting stone surface is sometimes not very smooth and also precision can be affected by the different behaviour of each disc. For calibrating rotary diamond heads, the results can vary according to the sturdiness of the head supporting system; also the variation of the actual peripheral sawing speed along the tool width can significantly affect the tool wear and limit the calibrating productivity.

### 4.8. TOOLS FOR HONING AND POLISHING

#### *4.8.1. Machines and processes*

This kind of tools applies to many different machines and processes :

- Polishing machine for granite strips (Process: strip/tiles polishing, granite)
- Polishing machine for marble strips (Process: strip/tiles polishing, marble)
- Belt polishers for slabs (marble) (Process: slab polishing, marble)
- Belt polishers for slabs (granite) (Process: slab polishing, granite)
- Bridge polishers for large marble slabs (Process: slab polishing, marble)
- Bridge polishers for large granite slabs (Process: slab polishing, granite)
- Chamfering (squaring) machine (Process: chamfering marble/granite)
- Edge polishers (Laboratory)

- Contouring machines, automatic or CNC (Laboratory)

### *4.8.2. Description*

Polishing is the operation that gives a “mirror” finish to the stone surface. This is achieved by conditioning the stone surface geometry at a microscopic level. The parameter that is modified, in a controlled way, by polishing is the surface roughness: when this becomes very low (close to the visible light wavelength) the surface tends to behave like a mirror, reflecting most of the incoming light (i.e. the angles of the incident and reflected light beams are close to equal).

The polished stone surface quality can therefore be checked by measuring its roughness or light reflection characteristics. The latter system is most common in the ornamental stones field; specific instruments (“reflectometers”) are available on the market, suitable to be used by processing plant operators.

The tools employed for this purpose are (in theory) a set of abrading pads, having progressively decreasing roughness. They produce an abrasion on the surface that is at the first stages quite coarse; hence, the whole surface obtains a similar grade of finishing. In the following stages, roughness is progressively decreased by means of abrasives, having finer and finer grain.

The polishing heads must be free to move vertically in order to follow the geometry of the surface, while they must apply a controlled and constant load to the polishing tools (the polishing force). These two conditions are necessary in order to perform the polishing process.

Strictly speaking, polishing should not be intended to modify or condition in a controlled way other parameters, such as thickness, or to remove the flaws caused by sawing. Of course, thickness (and other characteristics) can be also modified as a side effect of polishing, due to material removing. In some cases, when the material to be removed is minimum and the geometric tolerance required is not strict, thickness modification can be achieved in a single operation together with polishing. Of course, polishing must be performed without causing defects (scratches, “burns”) on the surface, especially in the case of marble, limestone, and “soft stones” in general (containing Calcite or other soft minerals).

For all the above reasons, polishing is usually performed after the thickness calibration.

At a closer look, polishing can be divided into different steps (from coarse polishing to the final operations), having different names:

Honing: It eliminates the scratches left by the abrasive during the previous stages and gives to the stone a typical visual aspect, smooth but not “mirror” finished. Often the stone is marketed as honed, for external applications or for special architectural requirements. Honing can be obtained by coarse grain abrasive tools and also by diamond tools.

Polishing: It gives a sufficient finish to the stone to take its typical “mirror” finish. The full set of grains, from coarse to fine is necessary.

Glazing: This name describes an operation that can be performed at the end of the polishing process, with the use of extremely fine grain tools together with special products, such as wax. It is not strictly necessary and nowadays it tends to be less employed than before.

Different sequences of tool grain sizes (always from a coarse to fine) are employed in the polishing process according to the following parameters:

- type of stone to be polished: marble or granite (soft or hard stone), stone composition (mineralogical/chemical), hardness of the minerals, cracks, cutting direction.
- type of polishing/honing machine employed (size and number of heads, production capacity, heads power).
- specific experience of the machine operators.
- indication given by the tool manufacturer.
- quality of the water employed for lubro-refrigeration and waste removal.
- economic choices related to the production costs (expected quality of the product and quality demands of the tools to be employed); productivity (for instance expressed in square meters per hour, per shift, per month).

It is important to underline that the abrasives performance is strictly influenced by external factors, especially for the non-synthetic abrasives. Abrasives, with identical manufacturing characteristics, employed on similar machines for the same processing operation, can give different results according, for instance, to different stocking conditions. This is one of the reasons why the manufacturers insist on strictly following the instructions given for the tolls stocking.

Another important factor in the use of this kind of tools is the chemical and physical conditions of the water employed for lubrication. Dirty water or polluted by agents coming from the processes and not duly treated by depuration units, can result in low overall quality, when polishing tools are employed.

### *4.8.3. Reasons for the many different tool shapes available*

There are really many shapes available for polishing tools. One reason surely is the wide range of machines and processes where they apply: different kinds of processing machines (polishing machines, chamfering machines), laboratory machines (edge polishers, contouring machines, CNC milling machines). Each kind of machine is specialised in specific processes and their tool heads are adapted to work under special conditions. The tools are designed to be employed with all the heads, hence the differences in shapes.

Another important reason is that they are used for processing different kind of stones. In Figure 124 two polishing plates for marble are shown; one is mounted on a machine for mass production of tiles, the other on a manual machine for slabs. Their shapes are quite similar. In fact not much polishing pressure is needed to polish marble (and soft stones). The polishing pressure is given by the polishing force divided by the active tool polishing surface during the process. So the flat surface of the tools is perfectly acceptable for the purpose: the wide contact surface between the tool and the stone results in quite low polishing pressure, but this is not necessarily a problem.

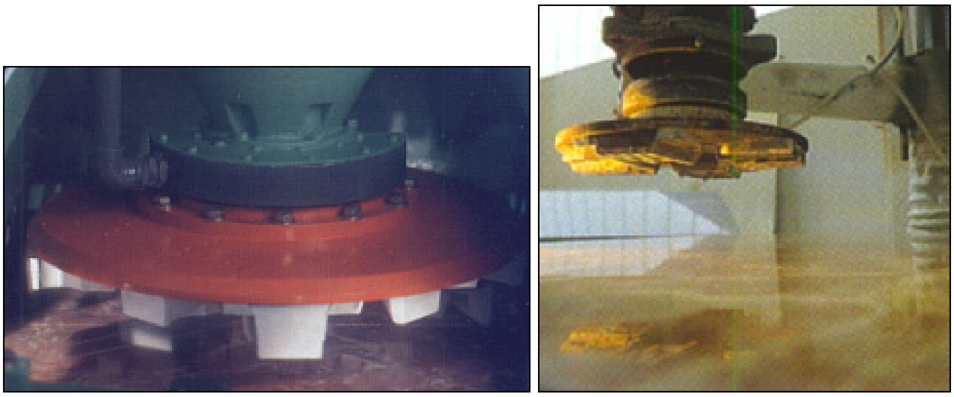


**Figure 124.** "Frankfurt" tools employed in a processing line (left) and in a manual machine (right)

**Figure 125.** Other polishing pads for marble

When coming to granite (and hard stones) polishing, the situation is different, because a high polishing pressure is required in order to attack the stone surface. The pressure cannot be increased only by increasing the polishing force, because this may result in fractures (especially for strip or tiles processing). So, when the thickness of the stone is a limitation, the solution is to reduce the contact surface between the stone and the tool. For this reason the polishing pads have a slightly rounded shape: the contact between tools and stone is reduced (theoretically) to a line, in practice, to a narrow band. In order to avoid flattering of the polishing pads, an slow oscillating motion must be provided from the polishing head to each tool. Figures 126-128 show many heads of this kind (older models on the left side).

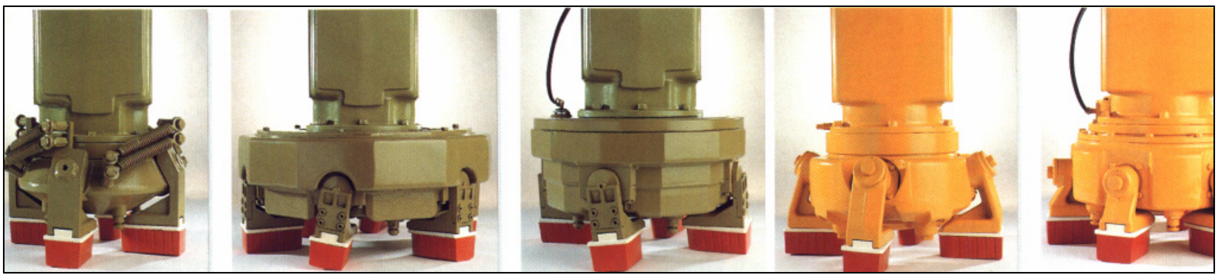


**Figure 126.** Granite - Polishing heads with oscillating arms

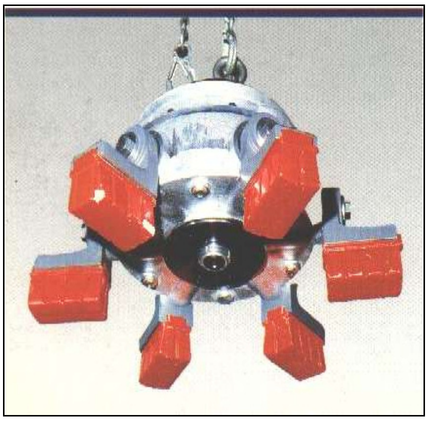
 

**Figure 127.** Granite - Polishing heads with oscillating arms

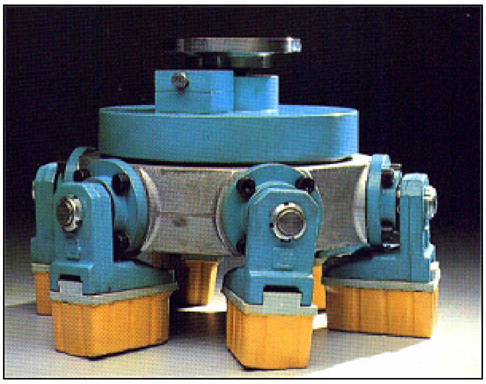


**Figure 128.** Granite - Polishing heads with oscillating arms

A similar effect can be obtained in other ways. Figure 129 presents a polishing head, where the polishing tools are rolls that rotate while the whole head also rotates.

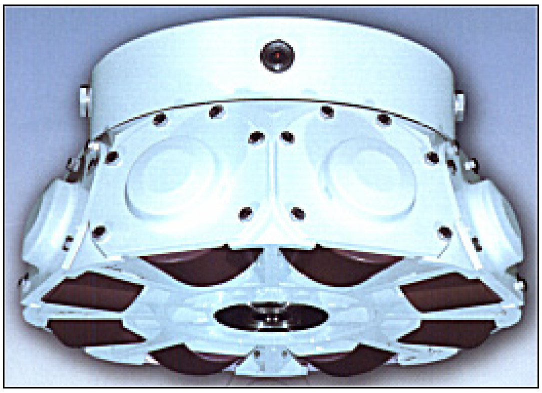


**Figure 129.** Polishing head with rolls

Satellite heads are also employed for polishing. Usually, "flat" satellites are used for marble (Figure 130) and "conical" satellites for granite.

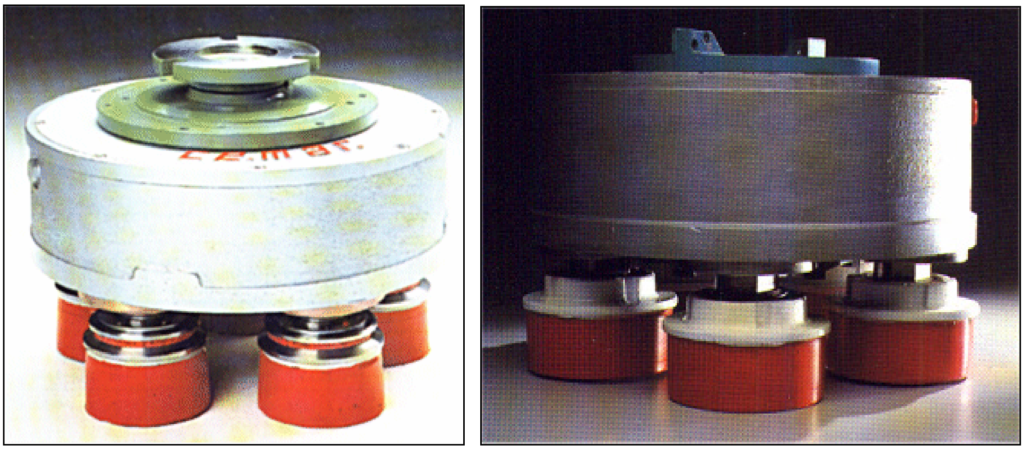


**Figure 130.** Satellite polishing heads

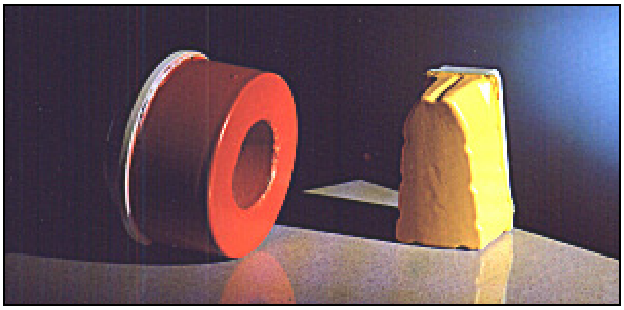


**Figure 131.** Abrasive polishing tools for satellite heads (left) and oscillating arms (right)

Diamond grains can be employed in coarse grain abrasive tools. This is a quite recent development that shows many advantages when employed at the first stages of the process. It is important to know that diamond tools have similar shapes with the traditional polishing tools and are available in many constructive types, as it is possible to see in Figure 132 and 133.

**Figure 132.** Diamond polishing tools for Polishing heads with oscillating arms (granite)

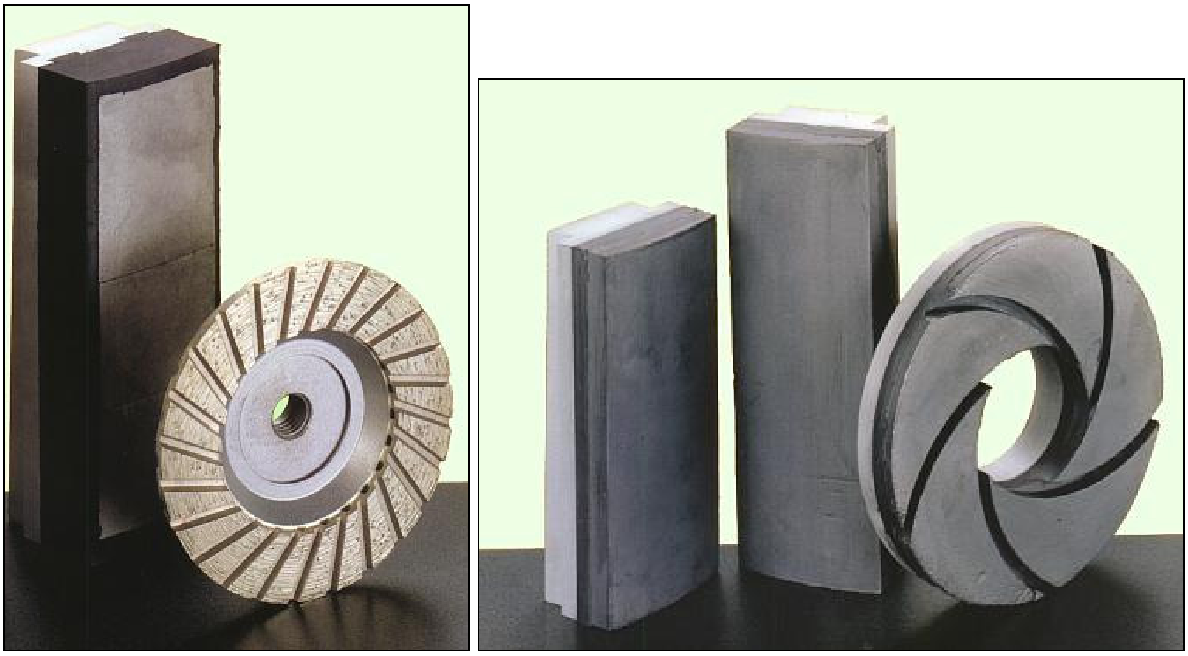


**Figure 133.** Diamond tools with metal bond (left) and resin bond (right)

Figure 134 shows calibrating pads to be mounted on a manual polishing machine, in order to calibrate slabs in a small workshop.

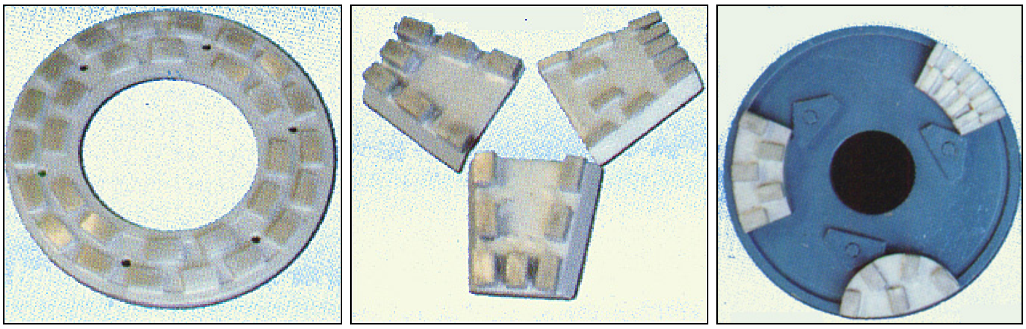


**Figure 134.** Calibrating pads for manual machine

### *4.8.4. Polishing Tools Composition*

MAGNESIAN TOOL (stabilized compounds)

These tools are used for processing granite and, especially, marble. They are made mainly of magnesium oxi-chloride and silicon carbide filled with inert minerals. One disadvantage of these tools is their short stock life: without stabilisation it can be very short (such as 2 weeks), afterwards oxidation can alter the tool behaviour and characteristics. The stabilisation process aims to improve the tool life during storage, up to many months. The tools quality/performance/cost ratio is average.

## SYNTHETIC TOOLS.

These tools are used for processing granite and marble in all polishing stages (especially the final ones). These tools are much less affected by the problem of alteration while in storage. The most common components of Synthetic Tools are Silicon Carbide (or other abrasive) and Resin (bond).

*Information on Silicon Carbide and other abrasives.*

It is a synthetic abrasive, processed in electric furnaces, crushed and selected according to grain size. It is available on the market under many commercial names, according to the manufacturer (carborundum, crystolon, carborite, silicoro, etc). It also widely employed for grinding aluminium, cast iron, brass, bronze, copper, ceramic and porcelain. It has superior hardness, if compared to natural abrasives like quartz, silica and corundum ($Al_2O_3$). On the other hand, its resistance to crushing can be lower when used to grind or polish very hard materials.

## DIAMOND TOOLS

Usually employed in modulgranite and slab polishing, in the first polishing stages: coarse polishing and honing, where a high removal ratio is required. Moreover, the tool wear behaviour is critical in order to improve the tool life (a short tool life means frequent stops for tool replacement and hence a loss in production). Mounted on long polishing lines, they allow a great removal ratio at higher speed than traditional abrasives.

| **Main use** | Marble and granite coarse polishing stages | Marble and granite honing |
|---|---|---|
| **Kind of abrasive** | Metallic bonded diamond abrasive | Resin bonded diamond abrasive |

The main advantages of using diamond instead of standard abrasives are the following:

- High productivity (Increase in speed from 10% to 20%)
- High grinding capacity
- Reduced time and less polishing stages to obtain a finished product
- Better capacity to close the pores in the stone (better polishing quality)
- Less machine pauses for changes in operations (less dead time, due to a longer tool life)
- High reduction of energy costs (reduction of energy consuming)
- Reduction of cost for waste
- Reduction of needed storage area
- High durability
- Reduction of pollution

The development of new bonds and impregnations has extended the use of diamond tools to further polishing stages subsequent to surfacing, i.e. smoothing and polishing. This development is linked to the above mentioned advantages.

### *4.8.5. Abrasive Grain size*

Abrassive grain size is of outmost importance for the polishing process. Grain size is in relation with the polishing stage, from the initial stages (coarse grains for coarse polishing or honing) to the final ones (fine grains for fine polishing). Grain size is defined by a number, usually the mesh in the last dividing wire sieve (units: meshes per inch). The higher the number, the finer the grain. Finer grains can be obtained by separation through water decantation. In such cases the grain size might be expressed in microns (it is the average grain size).

**Table 67.** Description of Polishing tools grain sizes

| **Denomination** | **Grain size** | | | | | |
|---|---|---|---|---|---|---|
| **Very coarse** | 6 | 8 | 10 | | | |
| **Coarse** | 12 | 14 | 16 | 20 | 24 | 30 |
| **Medium grain** | 36 | 40 | 46 | 50 | 60 | |
| **Fine** | 70 | 80 | 90 | 100 | 120 | |
| **Very fine** | 150 | 180 | 200 | 220 | 240 | |
| **Fine powder** | 260 | 300 | 400 | 500 | 600 | |
| **Very fine powder** | 700 | 800 | 900 | 1000 | 1200 | |

Grain size follows international standards, but many manufacturers identify their products with commercial or brand names (e.g.: LUX, EXTRALUX, LUX 1, LUX 2, LUX 3). Non standard products are also available, in which different grain sizes are mixed together.

Grain size sequences employed for polishing should be carefully chosen, keeping in mind many influencing factors, like:

- Material to be polished

- State of the surface (calibration performed before polishing)

- Number of polishing heads available in the processing line

- Number of tools per heads

- Required speed of the polishing line

-Type of polishing heads (polishing system)

- Power available on each polishing head

- Peripheral speed on each polishing head

- Pressure available on each polishing head and its adjustment possibilities

- Final polishing grade required

- Water flow available per head

- Possibility to divide the water flow to different heads (e.g. coarse and fine)

- Quality of the water available.

Water flow for cleaning the stone surface is not a trivial factor: coarse grains carried by the process water to a following finer polishing tool can cause scratches; these scratches can not be removed especially soft materials. Process water quality is also relevant: bad filtered water can damage the results of the polishing process. Also chemicals coming from other processes may interact with the abrasive tools components and alter the results of the polishing process.

Note: reducing the conveying speed (belt polishing machines) can improve the quality of the polished surface, when working wider strips, which cause processing problems.

In Table 69, few hypothetical sets of grain sizes for a 16 heads polishing line for granite, are presented according to stone hardness, size and cut.

*A= Head number (along the polishing line);*

*B= Hard granites, well cut;*

*C= Hard granites, poor cut or strips wider than 400 mm (up to 610 mm);*

*D= Medium Hard granites, well cut;*

*E= Medium Hard granites, poor cut or strips wider than 400 mm (up to 610 mm);*

*F= Soft Granite;*

*G= Soft Granite, poor cut or strips wider than 400 mm (up to 610 mm).*

**Table 68.** Polishing series (grain sizes / heads)

| A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|
| 1 | 24 | 16 | 24 | 16 | 24 | 24 |
| 2 | 24 | 24 | 24 | 24 | 36 | 24 |
| 3 | 36 | 36 | 36 | 36 | 60 | 36 |
| 4 | 36 | 36 | 60 | 60 | 120 | 60 |
| 5 | 60 | 60 | 120 | 120 | 220 | 120 |
| 6 | 120 | 120 | 120 | 120 | 320 | 220 |
| 7 | 120 | 120 | 220 | 220 | 400 | 320 |
| 8 | 220 | 220 | 320 | 320 | 400 | 400 |
| 9 | 320 | 320 | 400 | 400 | 600 | 400 |
| 10 | 400 | 400 | 400 | 400 | 600 | 600 |
| 11 | 600 | 600 | 600 | 600 | 800 | 800 |
| 12 | 800 | 800 | 800 | 800 | 800 | 800 |
| 13 | 800 | 800 | 800 | 800 | 1000 | 1000 |
| 14 | 1000 | 1000 | 1000 | 1000 | 1200 | 1200 |
| 15 | 1200 | 1200 | 1200 | 1200 | 1200 | 1200 |

### *4.8.6. Polishing Tools shapes.*

In all the following kinds of tools, different types of grains and different grading sequences could be suggested by different manufacturers, according to the machines and the material processed.

"FICKERT" TANGENTIAL

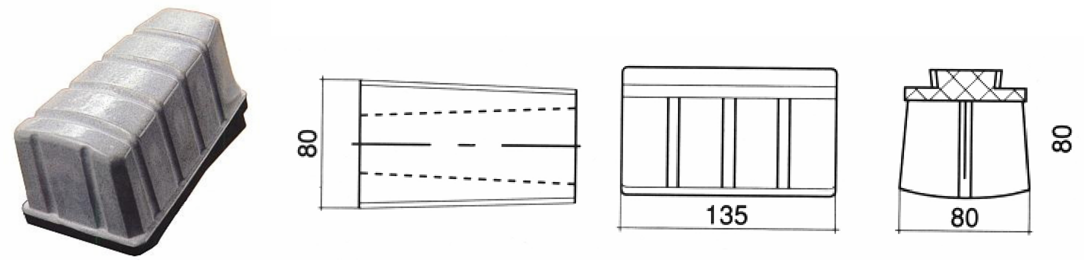



**Figure 135.** View of "Fickert" polishing tool

"Fickert" polishing tool is mounted on the polishing line with grading grains and is employed in various working phases: honing, finish and mirror like polishing.

| Standard Binder | Used with: | To process: | Standard grains used: |
|---|---|---|---|
| - Magnesian<br>- Synthetic | - Automatic or manual machines<br>- Bridge machines | Slabs, Strips, Modulgranite, Flooring | 16 + 24 + 30 + 36 + 46 + 60 + 80 + 100 +120 + 180 +220 + 280 +320 + 400 + 600 + 800 + 1000 + 1200 + 1500 + LUX and more polishing grains |

"PEDRINI" TANGENTIAL

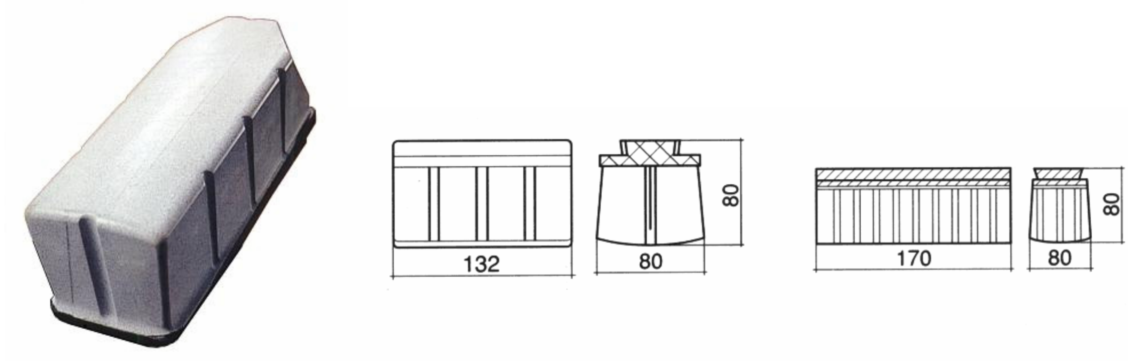



**Figure 136.** View of "Pedrini" polishing tool

It is used on the polishing line.

Its main advantages are: considerable ease in the productive process; total elimination of breakages during processing phases; a high cutting polishing action. The grading of grains results in the highest quality of polishing finish, with guarantee of extremely reduced production costs.

| Standard Binder | Used with: | To process: | Standard grains used: |
|---|---|---|---|
| - Magnesian<br>- Synthetic | Belt and bridge automatic or manual machines | Slabs,<br>Strips,<br>Modulgranite,<br>Flooring | 16 + 24 + 30 + 36 + 46 + 60 + 80 + 100 +120 + 180 +220 + 280 +320 + 400 + 600 + 800 + 1000 + 1200 + 1500 + LUX and more polishing and extra polishing grains |

"TERZAGO" ROLLER

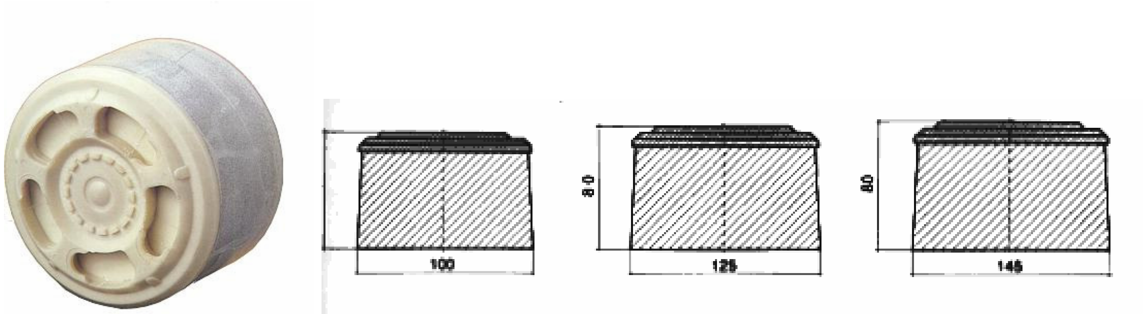



**Figure 137.** View of "Terzago" polishing tool

This type of tools is produced in all possible grain grading sizes in order to satisfy all demands.They represent one of the most efficient systems used for polishing available in the market.

| Standard Binder | Used with: | To process: | Standard grains used: |
|---|---|---|---|
| - Magnesian<br>- Synthetic | - Automatic or manual machines<br>- Bridge machines | Slabs<br>Strips<br>Modulgranite,<br>Flooring | 16 + 24 + 30 + 36 + 46 + 60 + 80 + 100 +120 + 180 +220 + 280 +320 + 400 + 600 + 800 + 1000 + 1200 + 1500 + various types of polishing and extra polishing grains |

ROLLERS WITH CONNECTING SCREW

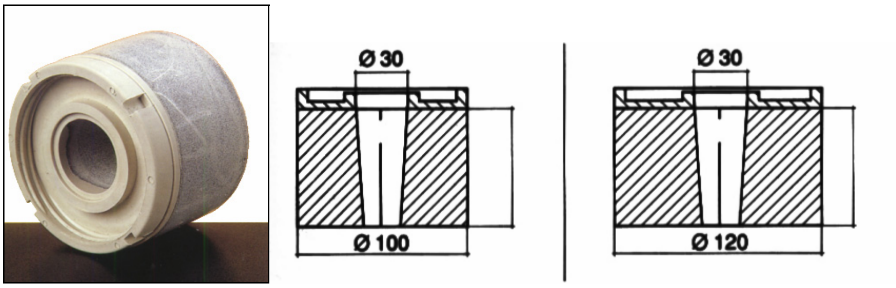



**Figure 138.** View of rollers with connecting screw

With this tool the highest polishing degree is obtained with the least possible number of grain grading sequences. Its main advantages are: ease with which the tool can be used; reduced poloshing time; excellent honing and mirror-like polishing on processed surfaces.

| Standard Binder | Used with: | To process: | Standard grains used: |
|---|---|---|---|
| - Magnesian<br>- Synthetic | Manual machines for floor laying operations | Laying flooring<br>Hand machines | 00 + 0 + 60 + 2 + 3 + 4 + 5 + 6 + 7 + 8 + 10 + LUX (others types of numerations) |

EDGE HONING ABRASIVES

**Figure 139.** View of edge honing abrasives

These abrasives considerably simplify the edge polishing operations of slabs and strips sides because they can be handled very easily and connected rapidly. Normally the edge machine is used separately from the other machines. Sometimes these tools are used in machines collocated in a automatic line. Usually, a few sequences of operations are required to obtain a perfectly polished surface, rarely obtained with standard manual polishing tools.

| Standard Binder | Used with: | To process: | Standard grains used: |
|---|---|---|---|
| - Magnesian<br>- Resinoid | - Manual and automatic edge honing/polishing | Flat edges of various thickness (also of important thickness) | Marble: 60 +120 + 220 + 320 + S.G. + 600 + D.T.G.*<br>Granite : 60 +120 + 220 + 320 + 400 + 600 + 800 + 1000 |

TORUS ABRASIVES WHEELS

**Figure 140.** View of Torus abrasives wheels

The torus wheel is a specific abrasive for polishing uneven surfaces have to be well balanced, with a defined degree of quality control. The torus wheels to permit a perfect formation and degree of finishing of the toroidal edge. This type of tool is used on board of automatic and semiautomatic machines (sometimes this operation is performed on the same machine that polished the edges).

| **Standard Binder** | **Used with:** | **To process:** | **Standard grains used:** |
|---|---|---|---|
| - Magnesian<br>- Resinoid | Manual, semiautomatic and automatic toroidal machines. | Torus or semi-torus edges of various types. | Marble: 60 +120 + 220 + 320 + S.G. + 600 + D.T.G.<br>Granite : 60 +120 + 220 + 320 + 400 + 600 + 800 + 1000 |

BEVELLING OR CHAMFERING WHEELS

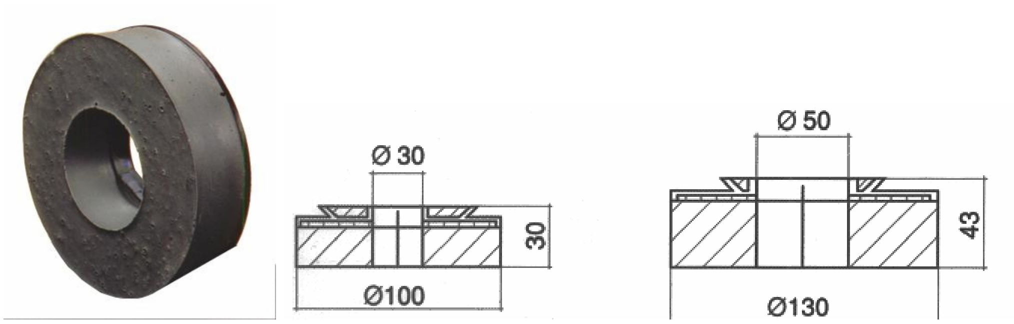



**Figure 141.** View of Bevelling wheel

The bevelling and chamfering wheel is a specific abrasive for grinding and polishing the edges of all types of machined materials (marble and granite), up to the polishing phase.

| **Standard Binder** | **Used with:** | **To process:** | **Standard grains used:** |
|---|---|---|---|
| - Magnesian<br>- Resinoid | Bevelling and chamfering machines. | Tiles bevelling, steps, thickness | Marble: 120 + 220 + S.G. + 600 |

PLATES

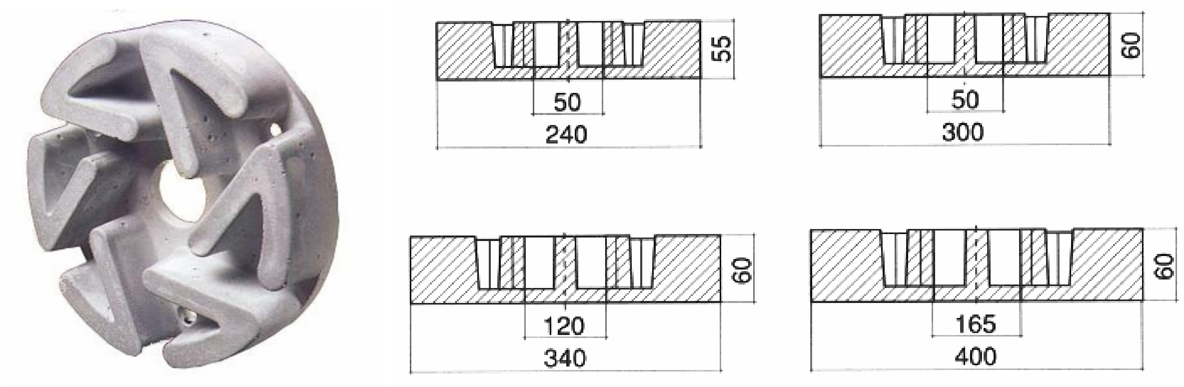



**Figure 142.** View of plates

The plates abrasive are mainly used for rough grinding and polishing, in particular types of work (ex: grave stone-art; interior decorating; building).

| **Standard Binder** | **Used with:** | **To process:** | **Standard grains used:** |
|---|---|---|---|
| - Magnesian<br>- Resinoid | - Manual machine<br>-Small conveyor belt machines<br>- Floor laying machines | - Slabs<br>- Flat edge<br>- Thickness<br>- Flooring | Marble: 1 + 60 + 2 + 3 + 400 + 600 + 800 + 1000 + D.T.G. *<br>Granite : 00 + 0 + 60 + 2 + 3 + 4 + 6 + 8 + 10 |

FRANKFURT

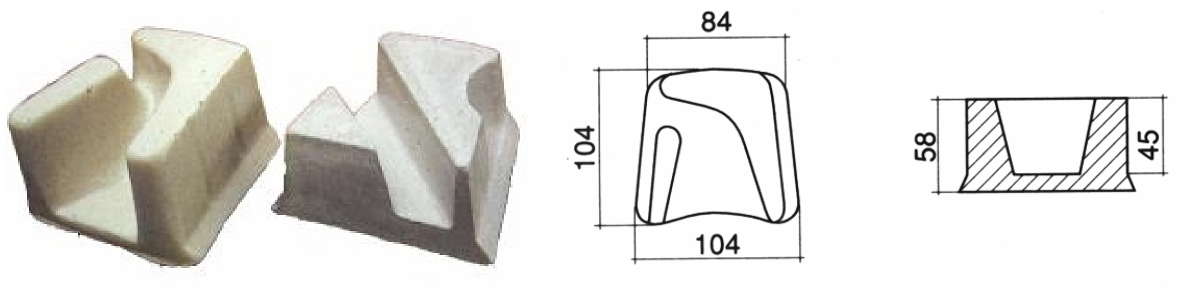



**Figure 143.** View of Frankfurt

These tools are used to honing and polishing of every type of marble. Their main advantages are:

- High productivity
- Low polishing costs
- Good quality of the finished products

| **Standard Binder** | **Used with:** | **To process:** | **Standard grains used:** |
|---|---|---|---|

| | | | |
|---|---|---|---|
| - Magnesian<br>- Resinoid<br>- Synthetic | - Manual machine<br>- Automatic polishing machine (conveyor belt machine)<br>- Bridge polishing machine | - Slabs<br>- Strips<br>- Tiles<br>- Modulmarble<br>- Large thickness | 36 + 60 + 120 + 180 + 220 + 280 + 320 + 400 + 600 + 800 + ext |

MUNCHEN

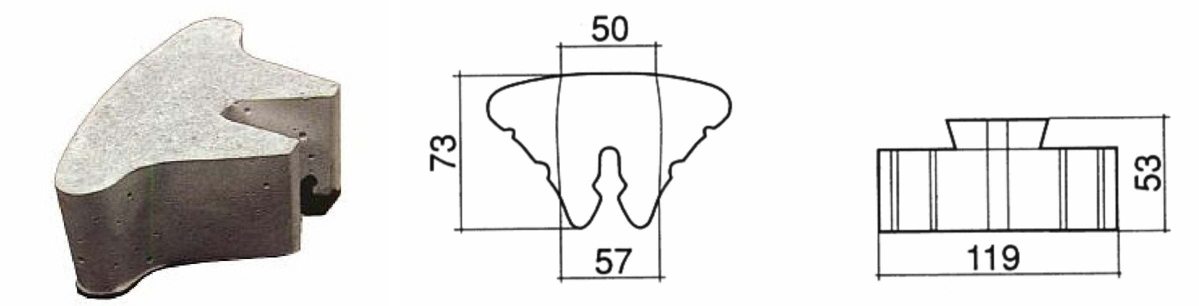



**Figure 144.** View of Munchen tool

The Munchen tools are used on special machines used for honing and polishing marble for specific applications:
- Polishing of marble stairs
- Floor laying operations
- Marble slab finish

| Standard Binder | Used with: | To process: | Standard grains used: |
|---|---|---|---|
| - Magnesian<br>- Resinoid | Automatic and manual specific machines | - Slabs<br>- Special pieces<br>- floorings<br>- steps | 00 + 0 + 36 + 46 + 60 + 90 + 120 + 220 + 400 + 600 |

CASSANI ABRASIVES

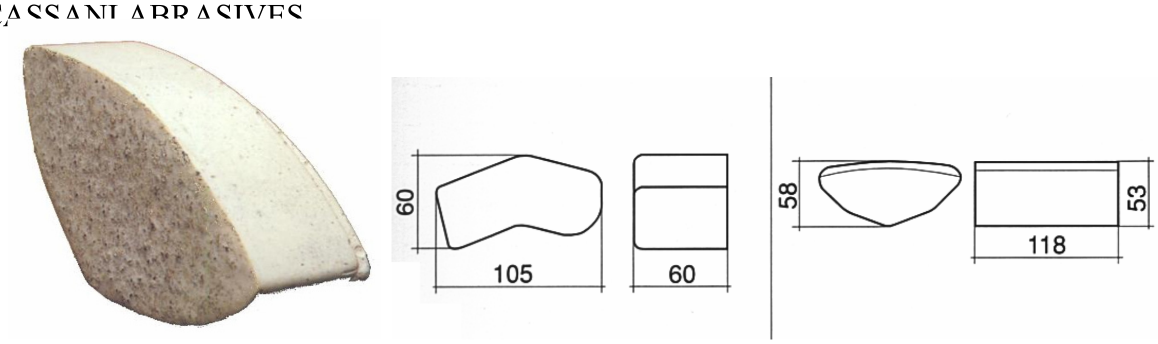



**Figure 145.** View of Cassani abrasives

They are employed on manual polishing machines.

| Standard Binder | Used with: | To process: | Standard grains used: |
|---|---|---|---|
| - Magnesian<br>- Resinoid | Manual machines | Slabs | 00 + 0 + 36 + 46 + 60 + 90 + 120 + 220 + XX + 400 + 600 + XX |

### *4.8.7. Advantages/Disadvantages*

The subject (polishing of natural stones) is so wide and so critical, and there are so many applications, that it not realistic to try to identify all possible advantages/disadvantages and probably, it will be of no use. Polishing operation is critical for the overall quality of the production process; as far as productivity is concerned (in a line for mass production, for instance) polishing is a relevant bottleneck, in the sense that any improvement of productivity in the polishing stage will probably affect the productivity of the whole line. Even if it is quite easy to improve production speed, it is not at all easy to do that without affecting the quality: "the slower the better" was an old golden rule. The struggle in finding a better combination of machine/head/tool/working parameters is always an open race.

Diamond tools are the real breakthrough achieved in the last years. Nowadays, all modern plants use diamond heads in the first polishing stages (coarse grain) for granite and their advantages are no more subject of disputes. For the last stages (finer grains) the traditional abrasive tools are still employed.

## 4.9. TOOLS FOR CHAMFERING (AND SIDE CALIBRATION) OF TILES

### *4.9.1. Machines and processes*

Machine: Chamfering (squaring) machine

Process: chamfering (marble/granite)

Process: side calibration of tiles, squaring (marble/granite)

### *4.9.2. Description*

In this chapter the operations performed in a tiles processing line in order to give to the tiles their final precise width (side calibration) and to manufacture a chamfer on the four upper corners of each tile (having an inclination of 30°, 60°, or usually 45° are considered). The chamfer is requested for aesthetical purposes and also to avoid cracks on sharp edges. Chamfers are usually requested on tiles for cladding, less for flooring.

"Squaring" is an operation (different from calibration) used to assure square corners to the tiles (90°). The same tools used for side calibration are employed also for this operation. Usually this operation is not necessary on stone tiles but is a part of the ceramic tiles processing.

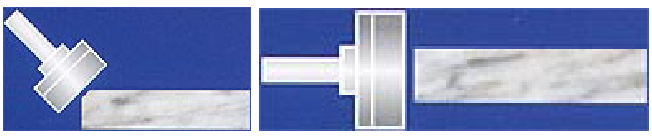


**Figure 146.** Chamfering (left) and Side calibration of tiles (right)

Figures 147-149 present some examples of side calibration and chamfering using machines of different manufacturers. The shapes of the chamfering tools are not very different. The calibrating tools show different diameters, continuous or segmented crown, single or double crown. Note: side calibration is performed before chamfering, hence in these figures the material flows right to left.

**Figure 147.** Chamfering (left) and Side calibration of tiles (right)

**Figure 148.** Chamfering (left) and Side calibration of tiles (right)

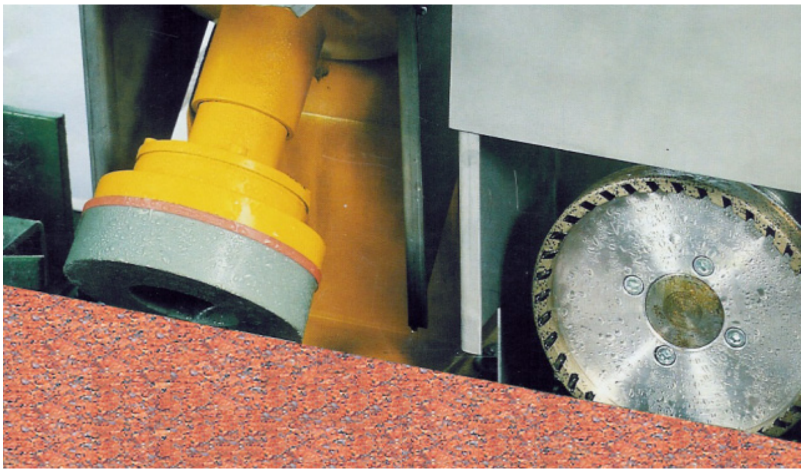


**Figure 149.** Chamfering (left) and Side calibration of tiles (right)

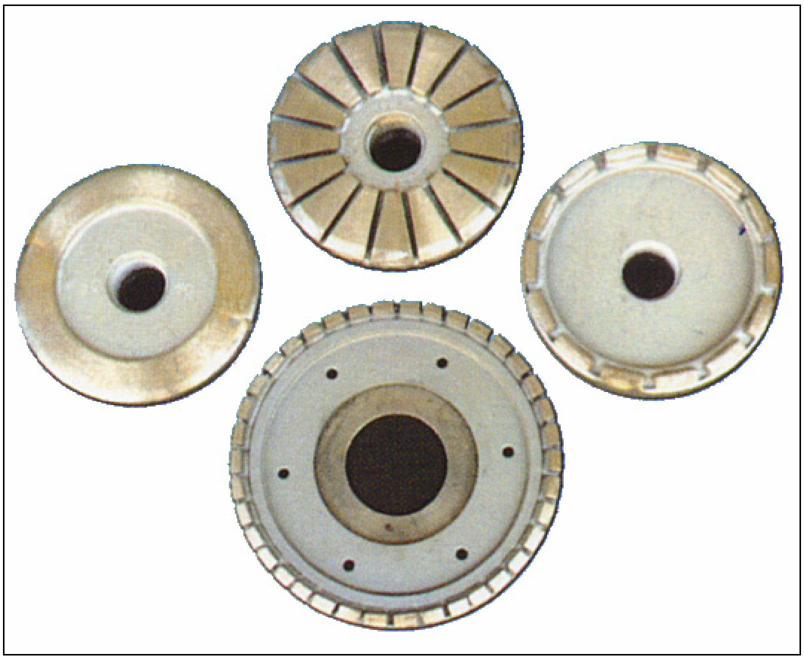


**Figure 150.** Tools for calibration and chamfering

### *4.9.3. Side calibration*

Side calibration is performed by **diamond tools**. A high removal rate is required for high production rates. Side polishing is not required on all tiles (where the sides are not visible). For the tiles in the batch where side polishing is required (tiles for visible corners), side polishing is performed with a special separate machine (edge polisher), usually located off-line.

The description of two diamond tools for side calibration, is given below.

-Front diamond wheels (continuous rim). This tool has an inclination of about $8^o$ in relation to the working annular surface. The calibrating head is mounted perpendicularly on the tile; the working inclination is given by the tool. The dimensions of the diamond section are: (inner) diameter 184 mm, (outer) diameter 200 mm, thickness 8 mm.

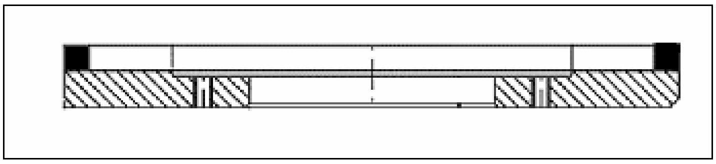


**Figure 151.** Front diamond wheel (continuous rim)

- Front diamond wheels (segmented rim). This tool has an inclination of about 2$^{o}$ in relation to the working annular surface. The calibrating head is mounted perpendicularly on the tile; the working inclination is given by the tool. The dimensions of the diamond section are: (inner) diameter 284 mm, (outer) diameter 300 mm, thickness 8 mm. Each diamond segment is 20 mm wide.

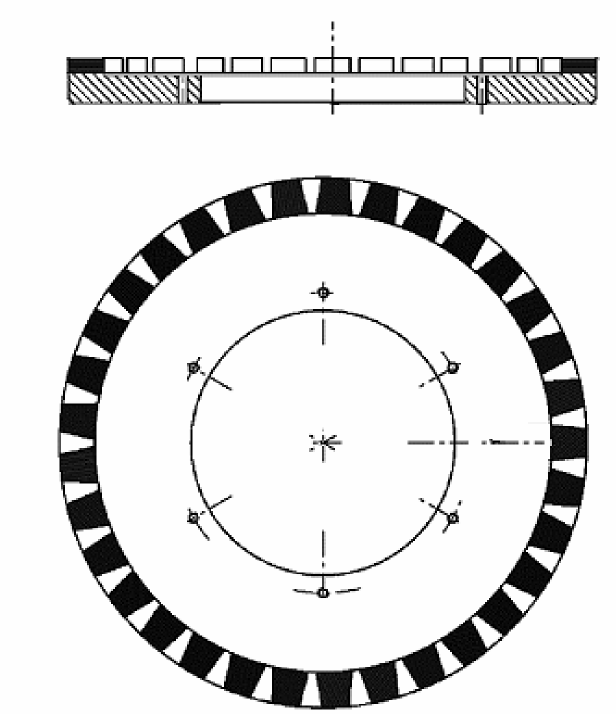


**Figure 152.** Front diamond wheel (segmented rim)

The composition and manufacture of the diamond rim and diamond segments are similar to that of the sawing discs with diamond segments.

### *4.9.4. Chamfering*

Chamfering is performed **diamond tools** and **abrasive tools**. A high removal rate is required for high production rates. Moreover, the chamfer must be polished (it is visible). For lower production rates, chamfering can be performed by abrasive tools only, which carry out both the chamfering and polishing of the cut surface. For higher production rates, chamfering can be performed in more steps, the first ones by means of diamond tools (for higher and constant removal rates, even at high production speed), while the polishing of the cut surface is performed by heads mounting abrasive polishing tools.

The description of two tools for chamfering is given below.

-Polishing cup wheels (diamond). Chamfering diamond cup with continuous rim. Usually, there is no inclination on the working surface. The dimensions of the diamond section are: inner diameter 110 mm, outer diameter 150 mm, thickness 10 mm.

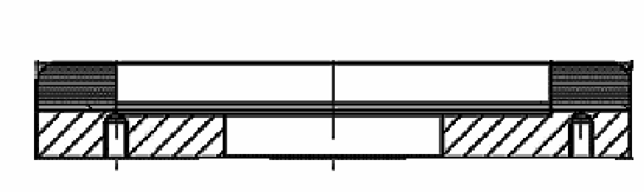


**Figure 153.** Polishing cup wheel

-Polishing cup wheels (abrasive). Abrasive polishing tool. “Poravit” disc, grain sizes mm 200, 220, 400, 600, 800. Dimensions: A=130, B=55, C=44, D=35 (Figure 152). NOTE: this kind of tools is also included in the tools for polishing.

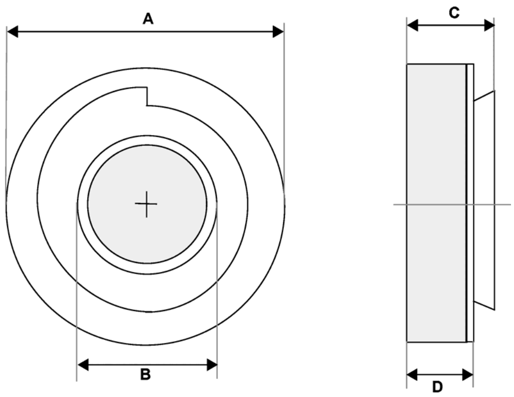



**Figure 154.** Polishing cup wheel (cross-cut)

### *4.9.5. Advantages/Disadvantages*

These tools are not very critical for the ornamental stone processing. This part of the process cannot be usually considered as a “bottleneck”. Nevertheless, it is necessary for tile production. The kinds shown here (and similar ones) are very effective for mass production of tiles.

## 4.10. DRILLING TOOLS

### *4.10.1. Machines and processes*

All the following machines are employed in the stone laboratory (workshop):
- Drilling machine
- Contouring Machines (automatic, CNC)
- Engraving machines
- Key hole saws

**Figure 155.** Drilling machine in operation

*4.10.2. Description and applications*

These drilling tools are Diamond drill bits and Diamond core drills.

Coring and non coring drills, drill up to 50 mm diameter and can be used with hand machines. For all of them, water drilling is required (5 to 10 min) at the peripheral speed of 2-2.5m/s. All coring drills for granite (segmented drills) and for marble (electroplated drills) are of the same fitting: ½ " gas. Diameters vary from 15 up to 50 mm by step of 5mm. For non coring drills, there are different fittings: metric or ½" gas. In case that the drilling machine is not equipped with water feed, a special connection between the machine and the drill can be fitted. Diameters vary from 7 to 14 mm by step of 1 mm.

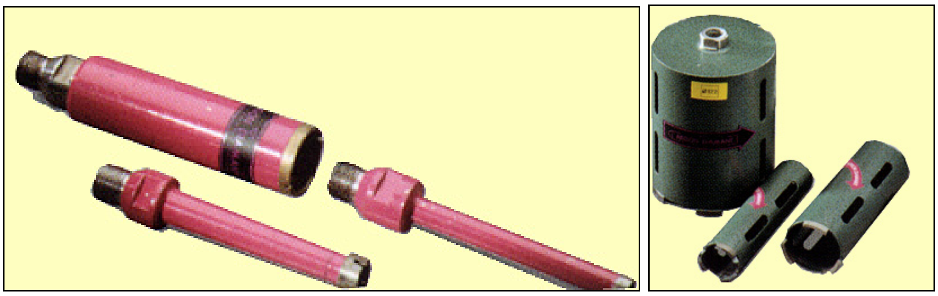


**Figure 156.** View of drills

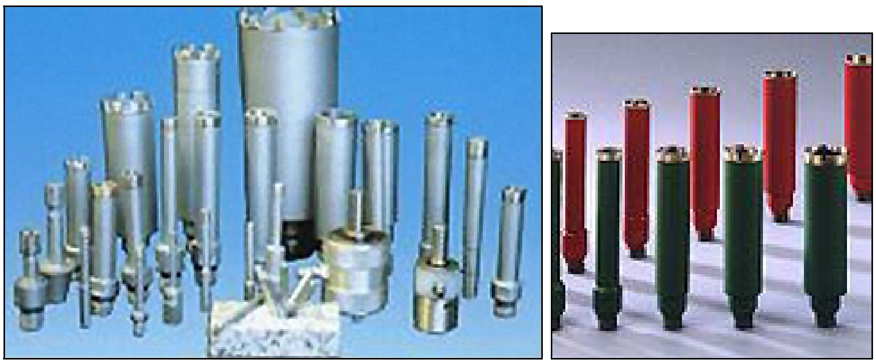


**Figure 157.** View of drills

### *4.10.3. Characteristics*

**Table 69.** Characteristics of drills

| | |
|---|---|
| **Water cooling** | 5 to 10 l/min |
| **peripheral speed** | 2-2.5m/s |
| **Diameter** | 15 - 50 mm by step of 5mm |

Diamond core drill
Diameter 15-60 mm
0.1-1 kg

Diamond drill bits
Diameter 4-13 mm
0.05-0.1 kg

Figure 156. Diamond drill cores and diamond drill bits

### *4.10.4. Advantages / Disadvantages*

These tools are not very critical for the ornamental stones processing. This part of the process cannot be usually considered as a "bottleneck". The tools shown here (and similar ones) are not relevant for mass production of tiles, but are widely employed in the laboratory.

## 4.11. EDGE PROFILING TOOLS

### *4.11.1. Machines and processes*

All the following machines are employed in the stone laboratory (workshop):

- Contouring Machines (automatic, CNC)
- CN milling centres equipped with additional vertical (inclinable) spindle
- Bridge milling machines - CN milling centers

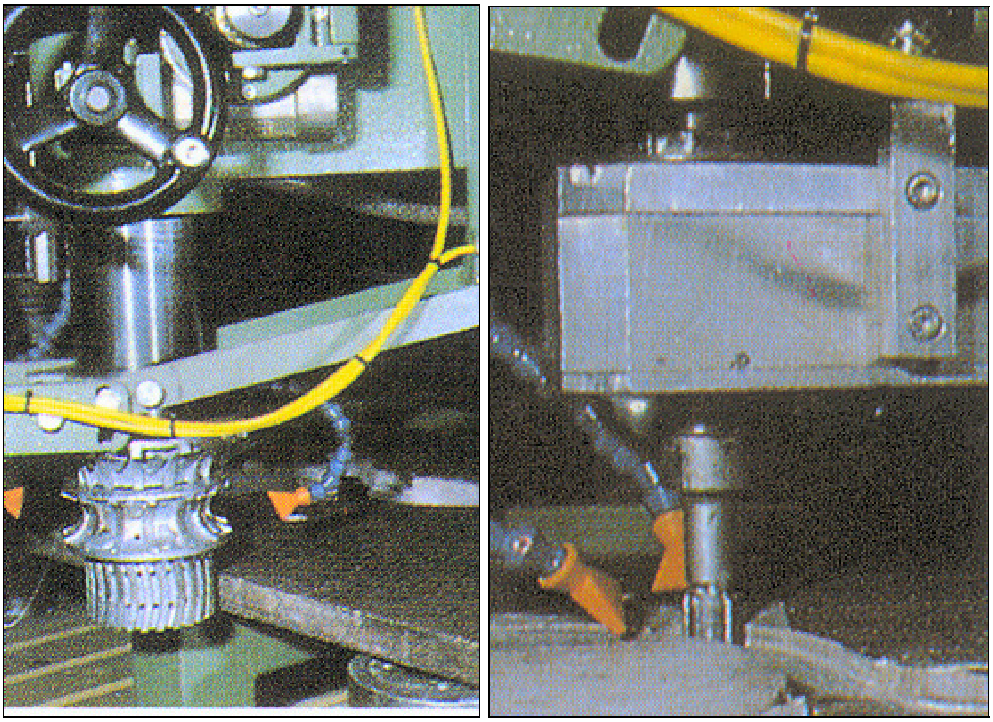


**Figure 158.** Contouring machine ("sagomatrice")

*4.11.2. Application*

These tools are used for manufacturing shaped profiles on slabs. Unitially, slabs are cut into various profiles, then the machine gives a defined shape to the edges of these profiles. This is the aim of these tools.

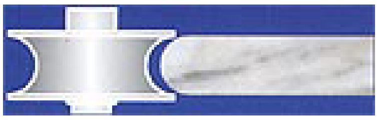


**Figure 159.** Scheme for profile making system.

*4.11.3. Characteristics*

In order to give a defined shape to the profile, diamond tools are employed, since a high removal rate is preferred. When the profile must be polished, abrasive tools are preferred, (see also the chapter regarding the polishing tools, and the paragraph "Torus abrasives wheels".

The profiling tools can be classified by their shape:

- Torus (torus)
- Half-torus (half-torus)
- Flat

The profiling tools are characterised mainly by their structure:

- electroplated diamond
- sintered diamond

*OG profile wheels*: electroplated and segmented tools for shaping, used on bridge and flag milling machines, belt shaping machines and other machines. Electroplated, brazed and segmented tools are used for half-torus, torus and other milling profiles on bridge cutters.

*Electroplated half-torus wheels*: electroplated tools for shaping used on bridge and flag milling machines, belt shaping and other machines.

*Electroplated torus wheels*: electroplated tools for shaping used on bridge and flag milling machines, belt shaping and other machines.

### *4.11.4. Advantages / Disadvantages*

These tools are not critical for ornamental stones processing. This part of the process cannot be usually considered as a "bottleneck". The tools shown here (and similar ones) are not suitable for mass production of tiles, but widely employed in the laboratory.

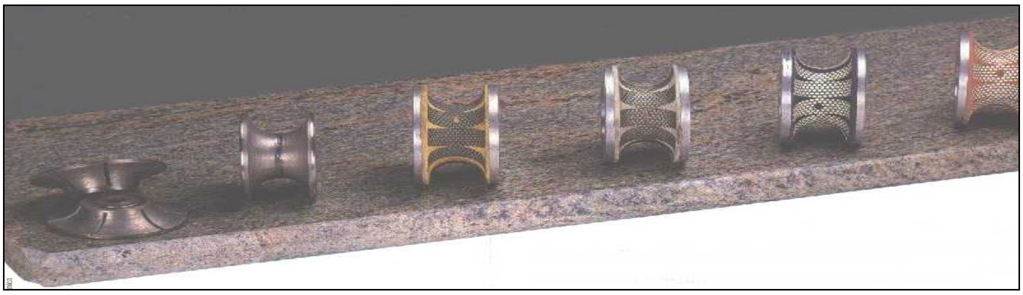


**Figure 160.** Edge profiling tools

**Figure 161.** Half torus wheel (left), Diamond profile wheels (right)

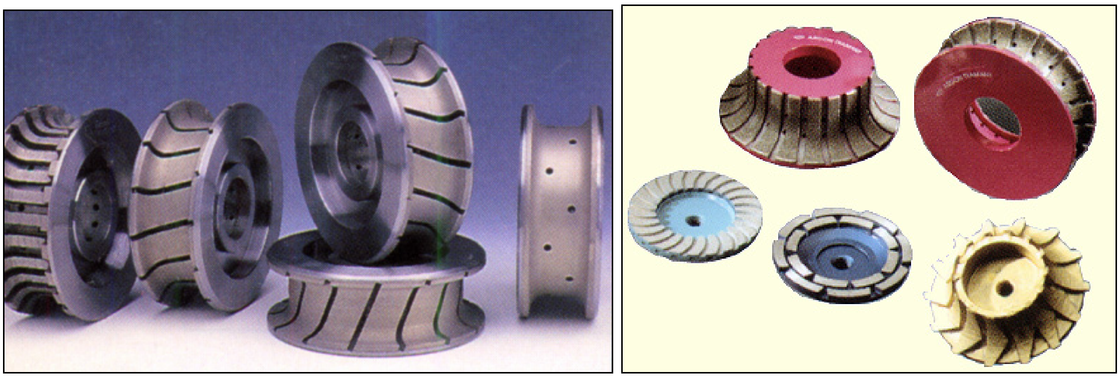


**Figure 162.** Tools for contouring machines

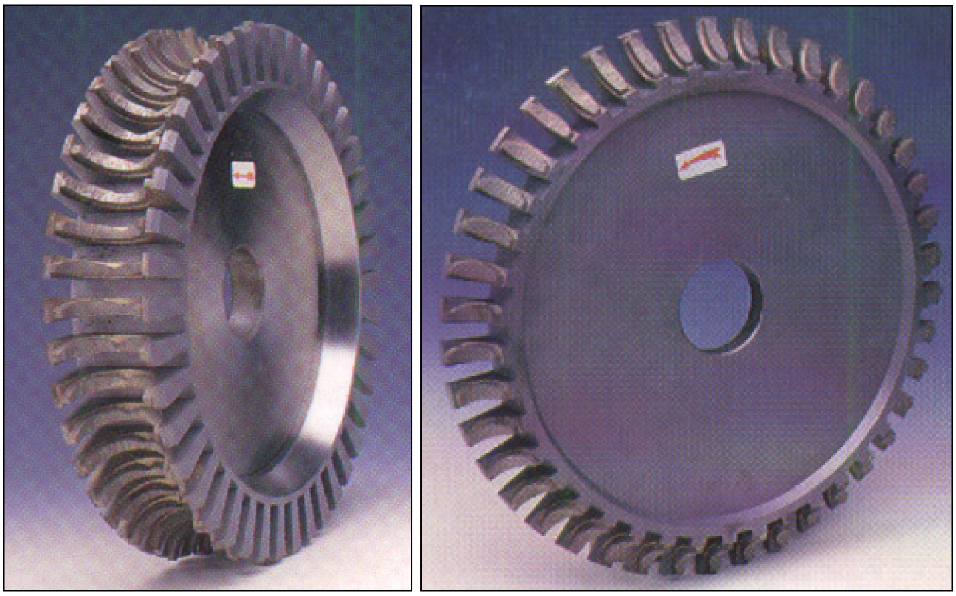


**Figure 163.** Tools for contouring machines (Torus and half-torus)

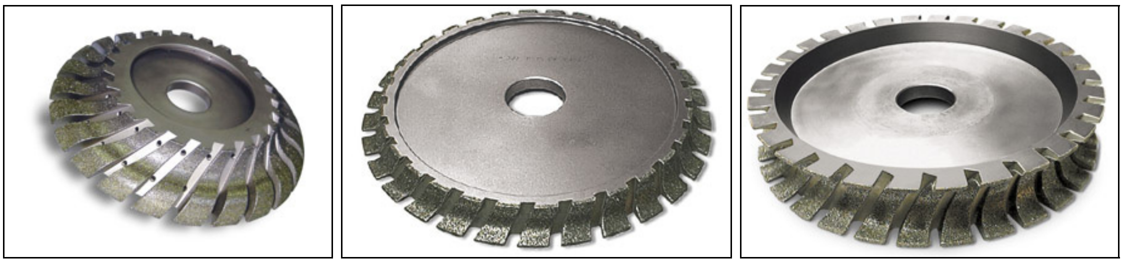


**Figure 164.** Profile wheel, electroplated half-torus wheel, electroplated torus wheel

## 4.12. TOOLS FOR MILLING AND CONTOURING MACHINES

### *4.12.1. Machines and processes*

The following machines are employed in the stone laboratory (workshop):

- Contouring machines (automatic, CNC)

- CNC bridge milling machine with vertical/inclined spindle

### *4.12.2. Description*

These tools are suitable for the above mentioned machines, which can perform an extremely wide range of operations, on slabs and small blocks, including many of the ones seen previously (drilling, edge profiling, chamfering, polishing, grinding). Moreover, such machines can cut slots by finger milling tools; in this way it is possible to virtually obtain any two-dimensional shape from a slab.

A CNC bridge milling machine is particularly suitable for use with diamond discs that can also be inclined during the operations (see the chapter regarding discs with diamond segments). The combination of diamond discs with all the tools that can be mounted on the milling head gives the possibility to obtain a very wide range of three-dimensional shapes from a small block.

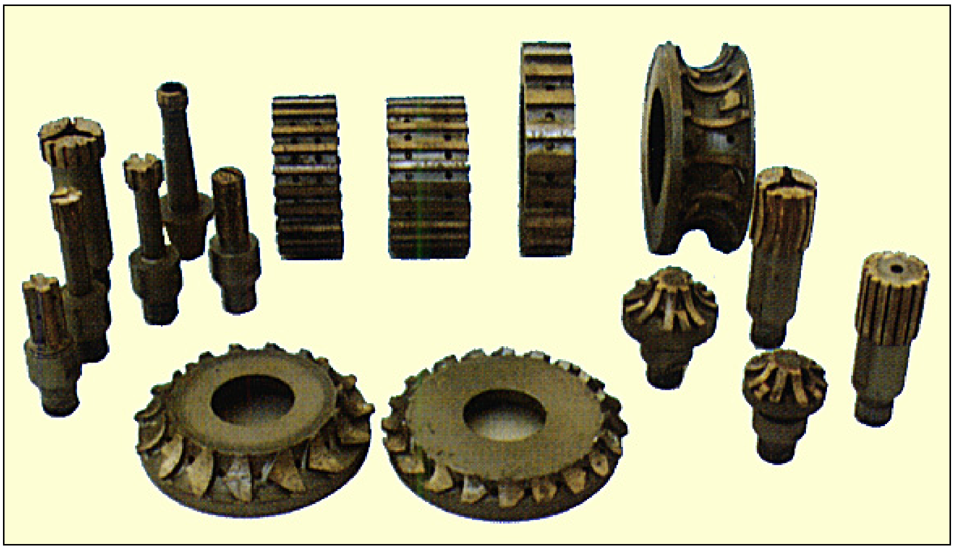


**Figure 165.** Tools for milling machines

### *4.12.3. Application*

The following tools (seen in the previous paragraphs) can be employed on these machines:

- drilling
- edge profiling
- chamfering
- polishing
- grinding
- diamond discs (only for bridge milling machines)

Their characteristics are similar to those seen in the relevant chapter; the main difference is in the connection to the head, which tends to be more standardised on the milling/contouring machines than on the others (usually “ISO cone” fittings) .

**Figure 166.** Tools for milling machines

*4.12.4. Characteristics*

In Figure 166, cross sections of typical milling tools together with their mounting device are shown. The mounting device is a standard ISO cone suitable to be mounted on clamping systems of vertical axis milling heads.

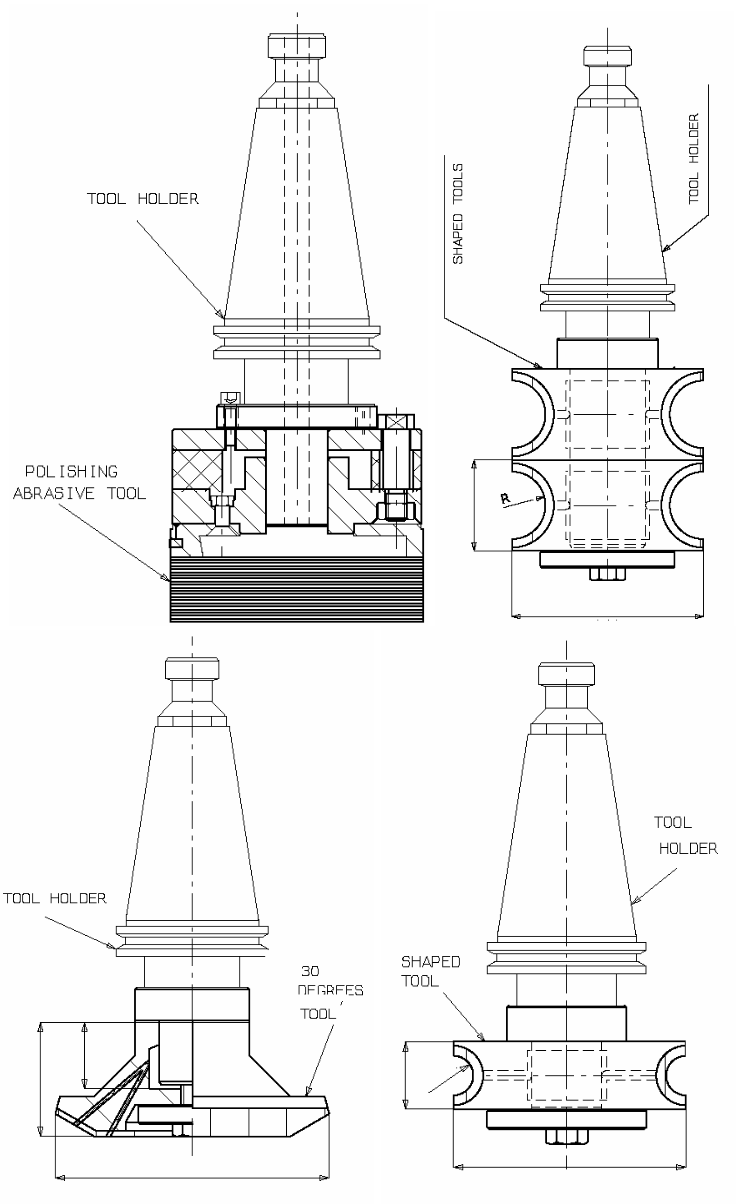



**Figure 167.** Typical Milling Tools

### *4.12.5. Advantages / Disadvantages*

The main limitation of these machines (and, therefore, of the relevant tools) is that they are hardly suitable for a real mass production. On the other hand, the stone products can reach a high added value through virtually unlimited design options.

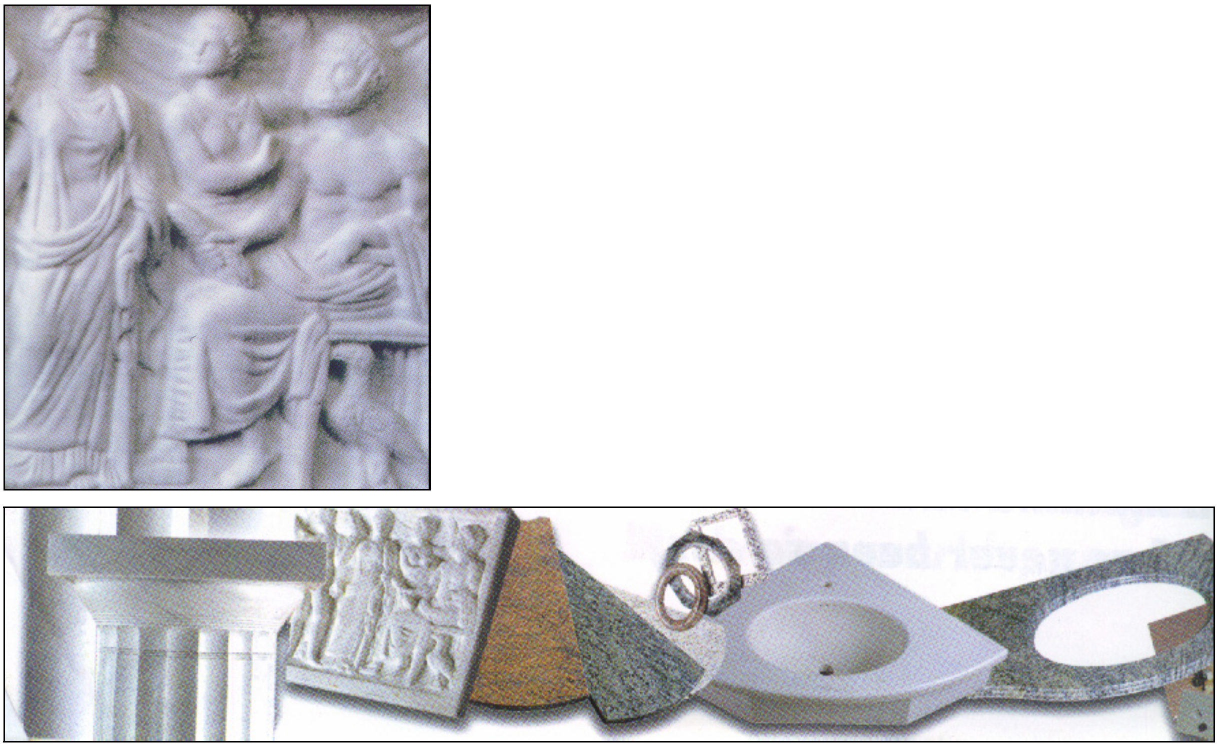


**Figure 168.** Wide range of products from a modern CN machining centers

## 4.13. TOOLS FOR BUSH HAMMERING

### *4.13.1. Machines and processes*

Bush hammering machines

Chiseling machines ("Spuntatrici")

Ribbing machines ("Rigatrici")

### *4.13.2. Application*

Both marble and granite can be processed by means of bush hammers, or similar tools, for the production of materials suitable to external uses (stairs, kerbstones, paving elements). Bush-hammers give a rough surface to the stone, when a rustic effect is desired. These tools are usually plates (mounting small rolls), rolls or crowns.

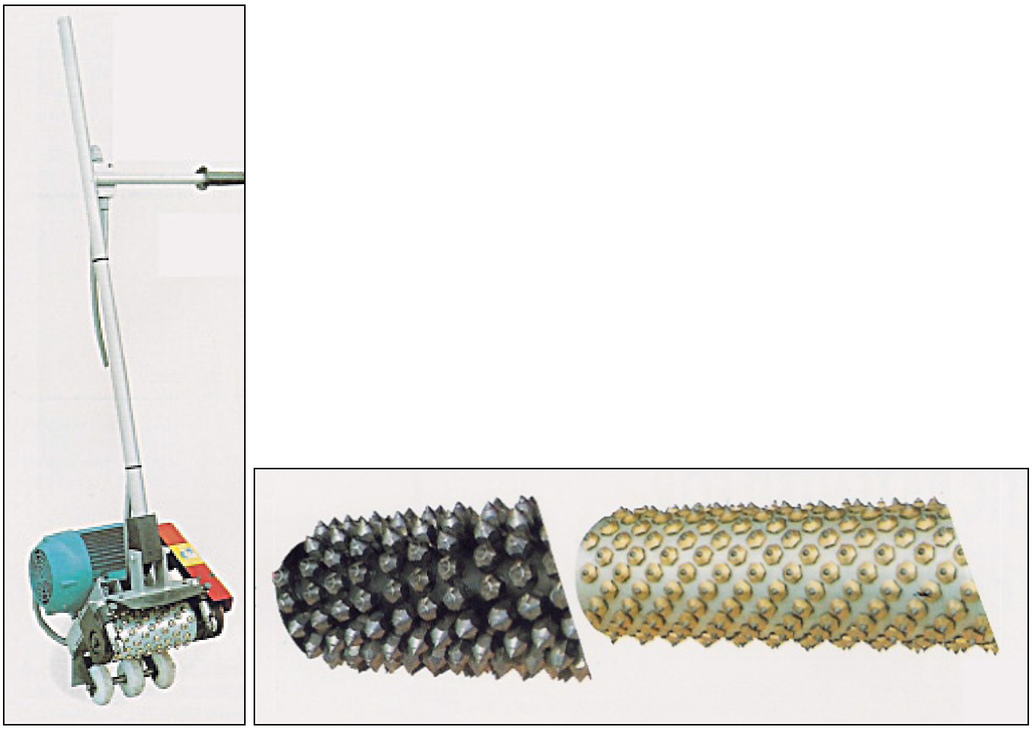


**Figure 169.** Hand ribbing machine and rolls

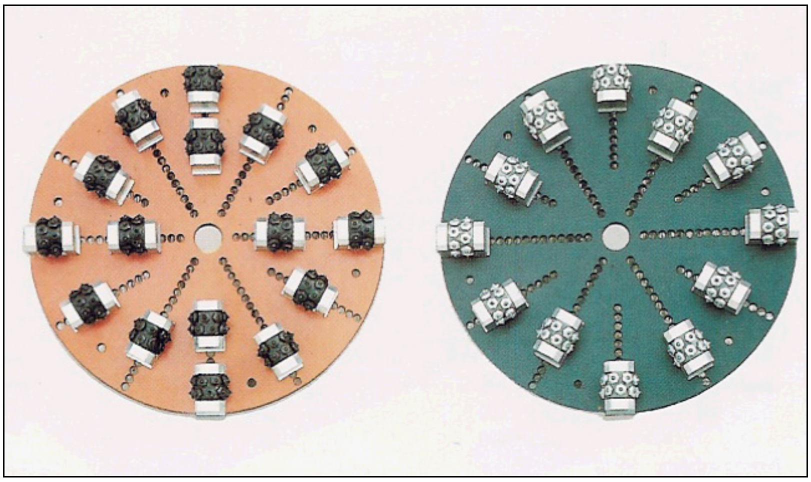


**Figure 170.** Bush-hammering plates (big size)

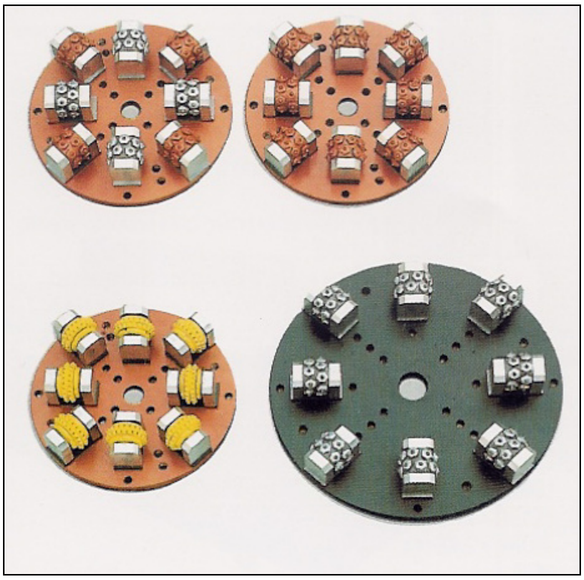


**Figure 171.** Bush-hammering plates (small size)

**Figure 172.** Chiseling-Ribbing crowns

### *4.13.3. Characteristics*

Table 71. Characteristics of bush-hammeting tools

| | |
|---|---|
| **Diameter of the plate** | 300 – 500 mm |
| **Number of tools per plate** | 6 – 20 |
| **Diameter of the roll or crown** | 150 – 300 mm |
| **Examples of commercial definitions of the finishing grade** | Fine rolled<br>Fine scratched<br>Medium rolled<br>Coarse grain |

### *4.13.4. Advantages/Disadvantages*

These tools are not very critical for ornamental stones processing. This part of the process cannot be usually considered as a “bottleneck”. The tools shown here (and similar ones) are widely employed in the laboratory and can be also employed in mass production of tiles (usually small batches) as well as in “field” machines.

## 4.14. TOOLS FOR HAND MACHINES

### *4.14.1. Machines and processes*

Hand machines are to be employed in the stone laboratory (workshop) or directly in the flooring / cladding site.

### *4.14.2. Description*

For all kinds of work with hand machines, technological developments have allowed an important extension of the range of suitable tools such as milling wheels, flexible tools for finishing and polishing, dry cutting blades and drills.

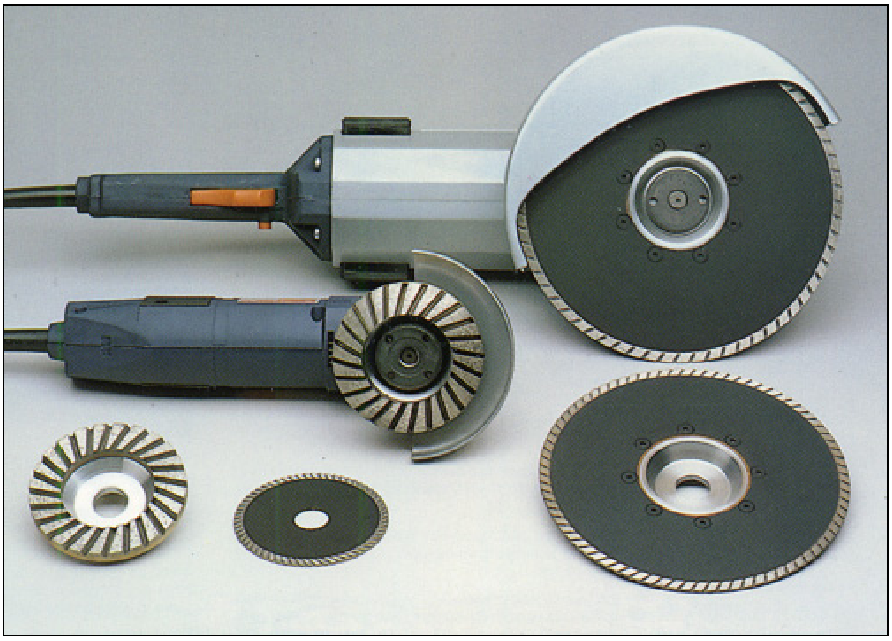


**Figure 173.** Hand machines and tools

### *4.14.3. Applications*

Figure 173 shows some applications of hand machines for cutting, chamfering and polishing.

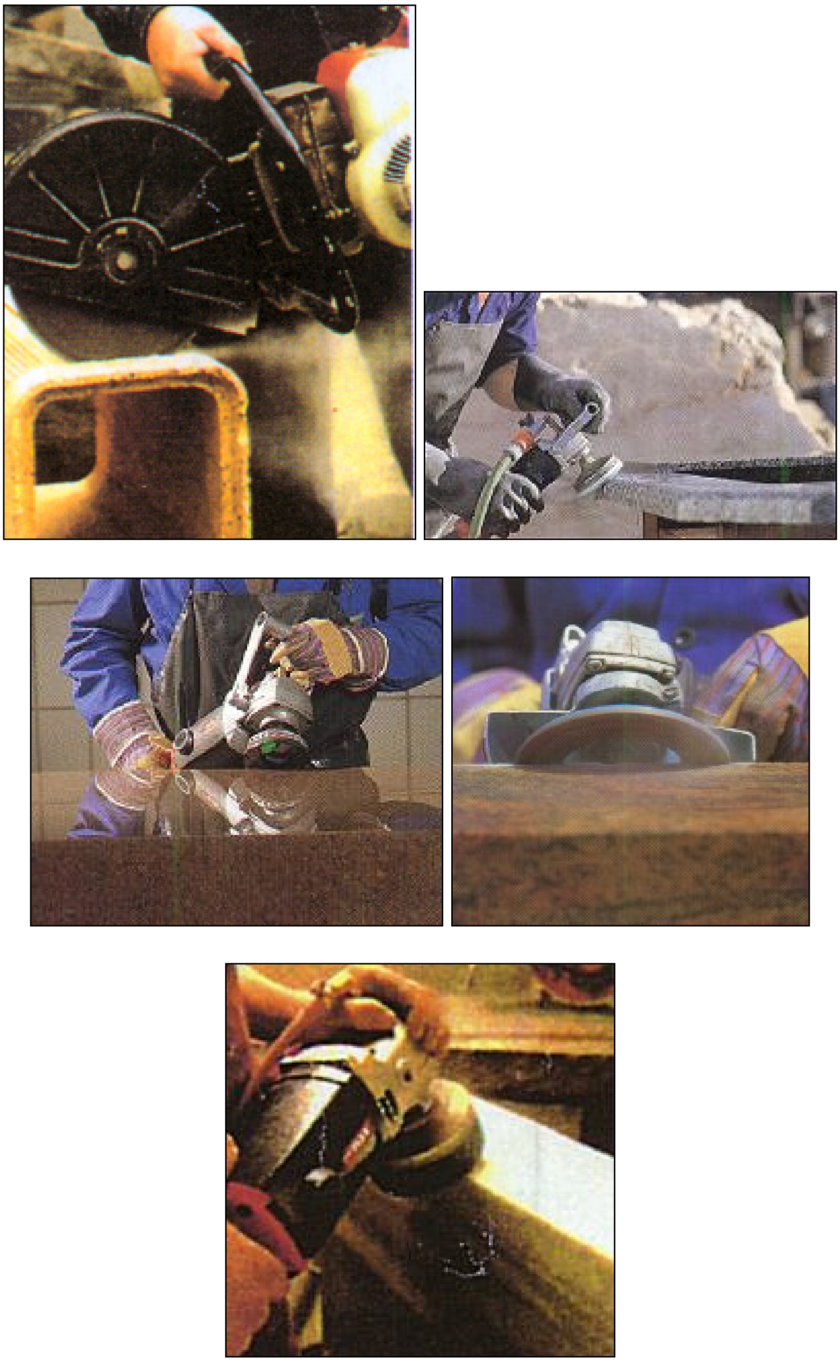


**Figure 174.** Applications of hand machines with different tools

**Figure 175.** View of tools for hand machine

**Figure 176.** Polishing and grinding tools for hand machines

**Figure 177.** Polishing pads for hand machine

**Figure 178.** View of sculpture tools

### *4.14.4. Characteristics*

Diamond tools are used in the cleaning and finishing processes of marble and other soft stones. These tools require high speed machines (between 5000 and 10000 revolutions per minute).

There are also sculpture tools. The shapes of sculpture tools are oval, conic, cylindrical and spherical.

### *4.14.5. Advantages/Disadvantages*

These kind of tools are practically not used in the production lines. They are used in the laboratory and are widely employed in the building industry. There are safety issues regarding the employment of manual machines and their tools.

## 4.15. SPLITTING BAGS, CUSHIONS

### *4.15.1. Description*

They are used for bench overturning. There are two versions of these bags:

- The first is the most used one and consists of *square b*ags about a meter per side, or rectangular (100 x 50 cm, 2 mm thick) that are connected by high-pressure pipes to a hydraulic unit. This consists of a hydraulic pump driven by a 3 HP electric or pneumatic motor, with a water pressure up to 30 bar.
- The second consists of *rectangular PVC bags* reinforced with a polyester support (200 to 280 x 160 cm). The bags are hooked up by pipes to a compressed air dispenser. Running pressure is 2-3 bar.

### *4.15.2. Applications*

Splitting bags are used in the initial stage of bench overturning. After this operation it is possible to insert the hydraulic jacks to complete the tip-over of the block.

**Figure 179.** View of splitting bags

### *4.15.3. Characteristics*

**Table 70.** Characteristics of splitting bags

| | Metal bags | PVC bags |
|---|---|---|
| **Opening (cm)** | 15-20 | 40 |
| **Deformation** | Irreversibly warping | Can be reused |

### *4.15.4. Advantages/Disadvantages*

*Advantages*: they do not damage the rock, they are very fast in use, no maintenance is required

*Disadvantages*: short strokes

## 4.16. HYDRAULIC JACKS

### *4.16.1. Description*

It is a steel cylinder, 30 to 40 cm long, containing a self-propelled piston that can jut out from one of the bases to a length of 10 to 20 cm. The cylinder is connected by high-pressure pipes to a hydraulic pump driven by an electric motor (3 HP), or a pneumatic (3.5 HP) or explosion (7 HP) engine.

### *4.16.2. Applications*

Hydraulic jacks are used to move and overturn benches. The cylinders (usually two) are wedges behind the bench, often in the space created by the inflated splitting bags. The advancing pistons give a push to the bench (about 150 to 160 tons per cylinder), able to overturn it.

**Figure 180.** View of hydraulic jacks

### *4.16.3. Characteristics*

**Table 71.** Characteristics of hydraulic jacks
**Table 72.**

| | |
|---|---|
| **Running pressure** | 700 bar |
| **Cylinder weight** | 80-95 kg |
| **Engine weight** | 100-130 kg |
| **Air consumption (by pneumatic engine)** | 3.2 $m^3$/min at 7 bar |

### *4.16.4. Advantages/Disadvantages*

Long strokes, but they need maintenance.

## 4.17. SPLITTERS / WEDGES

### *4.17.1. Description*

***Manual rock-splitting wedges***: they are made of three pieces of special metal, devoid of slag and hand-forged to limit warping to the minimum.

***Mechanical rock-splitting wedges***: these are cylindrical carriages with a 70-cm wedge at one end consisting of a central wedge and two side feathers. Inside the carriage there is a hydraulic system that moves the wedge, making it to penetrate deeply between the feathers. The carriage is connected by high-pressure pipes to a hydraulic pump. Another example is the Darda hydraulic rock splitter.

### *4.17.2. Applications*

Rock-splitting wedges are used to complete a cut pre-defined by drilling lines of small-diameter holes, or to square blocks. In the case of a cut that divides a bench, they are thrusted deep in the rock with a hand-worked mallet and the vertical push, transmitted to the sides, breaks the rock along the pre-defined cut line.

### *4.17.3. Characteristics*

**Table 73.** Characteristics of manual rock-splitting wedges

**Table 74.**

| | |
|---|---|
| Length | 135 – 800 mm |
| Diameter | 12 – 40 mm |

**Table 75.** Characteristics of mechanical rock-splitting wedges

| | **Mechanical rock-splitting** | ***Darda* hydraulic rock-splitting** |
|---|---|---|
| **Running pressure** | 700 bar | |
| **Carriage weight** | 40 kg | |
| **Splitting force (tn)** | 300 | 400 |
| **Holes dimensions** | 40-42 mm diameter, length 70 cm | 35 mm diameter |

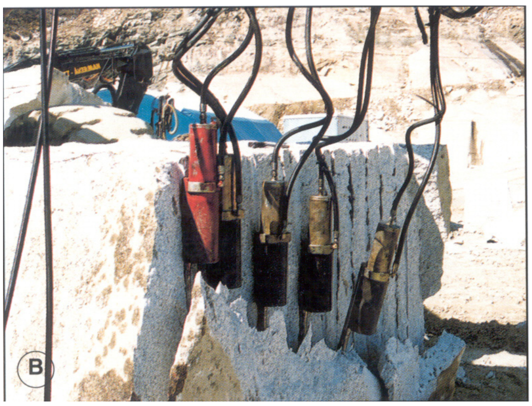



**Figure 181.** View of rock-splitter

*4.17.4. Advantages/Disadvantages*

The manual system is not up to date, it is slow and its manpower consumption is high. The mechanical type should be employed but of course it is expensive.

## 4.18. DUST COLLECTOR – DCT

*4.18.1. Description and application*

The DCT is used during the drilling operation in order to collect dust. Each DCT is designed to operate with a partial vacuum throughout the entire system.

*4.18.2. Characteristic*

DCT dust collectors operate more or less automatically. Most versions commence dust separation as soon as the flushing air control for rock drilling is opened until it is closed. The drill dust and cuttings empty straight into a plastic sack. No spill, no leakage and total control is present each time. Sacks can rapidly be changed by means of a simple hand movement. All DCT units are designed to be easily attached to different kinds of drill rigs.

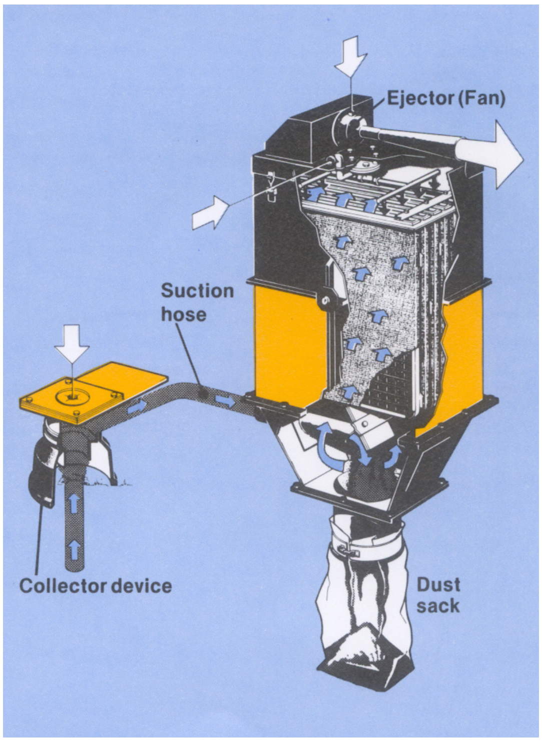



**Figure 182.** View of DCT

*4.18.3. Advantages/Disadvantages*

Advantages:

- No dust leakage;
- The drive ejector or hydraulic fan operates with clean, filtered air;

- Steady and high air flow speed in the suction hose;
- Reduced load on the filters.

### 4.19. INTEGRAL STEEL, ROD AND BIT

#### *4.19.1. Description and application*

For the drilling operation in a quarry, several tools are used:

- Integral steels to cut the block stone. They are made in one piece with a shank and a Widia insert on the top.
- Rods for drilling machine. Those have a bit at the end: tapered bit or cross bit; the first for soft material, the second for hard material.

For down-the–hole hammers, button bits are used with a bigger diameter. The button bit head can have several shapes, depending on the materials to be processed, standard type (high resistance), flat face (for hard material), concave (from normal to hard rock) and convex (for medium hard rock).

#### *4.19.2. Characteristics*

**Table 76.** Characteristics of integral steel

| Length mm | Diameter bit mm |
|---|---|
| 2400 | 32 |
| 3200 | 31 |
| 4800 | 29 |
| 7200 | 26 |

**Table 77.** Dimensions of button bit

| | | |
|---|---|---|
| Hole (”) | 3 | 4 |
| Bit (mm) | 90-100 | 105-121 |

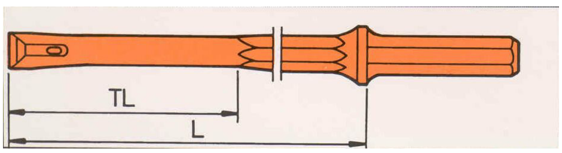



**Figure 183.** View of integral steel

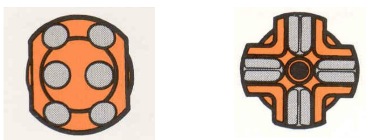


**Figure 184.** View of a tappered bit and a cross bit

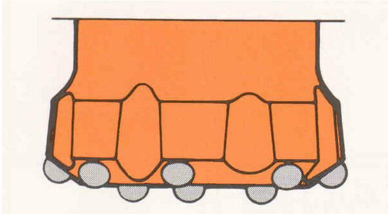


**Figure 185.** View of a button bit standard

*4.19.3. Advantages/Disadvantages*

When integral steels are worn, they have to be changed. The advantage of the button or cross bit is the possibility to substitute them, maintaining the rod. The tapered bit is characterized by a high penetration speed of compared to the cross bit.

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