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Diamond Wire Application for Black Granite Block Mining in Säo Paulo

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ABSTRACT: The mmmg of Dimension Stone Blocks of black granite in the State of Säo Paulo, Brazil, by quarrying is presented The rock commercially named Piracaia Granite is used as construction material or in funeral arts, as outside as well as inside cover for walls and floors The applied mining techniques changed The older extraction of the surface outcrop boulders changed to methods of massive rock exploitation For this it was necessary to adopt new non-conventional procedures One of those methods consists of block sawmg by diamond wire to create some primary vertical and horizontal faces The Brazilian practice gained in using this exploitation of the granite block in the rock massive is described here Conventional methods using black powder to create secondary planes to conform the block are also used The complete mining sequence of the extraction and transportation to the city of Sâo Paulo is presented

1 INTRODUCTION

The past, present and future of the dimension stone industry m Brazil, as an important mineral resource for raw material production m the arts (statuary and tombstones), building materials or industrial elements, were presented by two of the authors in a paper m Italy (Hennies & Stelhn Jr, 1996) In that article it was shown that the transformation m a final product for use needs, in many cases, a more or less complex preparation system and this can cause problems to meet the new and increasing exigencies of the environmental preservation rules now determined by the national legislation

In an event in Ukraine, a description of the exploitation using flame jet technology was presented about the winning of blocks (Hennies et al, 1999)

More recently another analysis about a global overview of the Brazilian Dimension Stone Industry was presented in the Check Republic (Hennies et al, 2002)

The exploitation of a specific Dimension Stone Quarry is an art and technique that takes advantages of the rock characteristics Here it is presented the mam sequence of the block mining for its future transformation in plates, which is the mam problem to be discussed here Next, the main environmental problems such as noise, dust and water pollution will be analyzed The technological characteristics of black granite and its application will be presented at the final section of the paper

2 THE DIMENSION STONE QUARRY

About 2 km from the city of Piracaia is located a Dimension Stone Quarry that produces blocks of Piracaia black granite The access to the quarry is by a dirt road after crossing a river in the west of the city of Piracaia

Figure 1 shows the geographical localization of the city of Piracaia to the North of the city of Säo Paulo, and also the mine site Figure 2 shows a photograph of the black granite quarry

As said before, in Brazil two different kinds of dimension stone quarries can be distinguished, the boulder quarry and the rock quarry

In the past, mainly m the granite areas, the win ning of blocks was realized from the surface by extracting the outcrop of boulders that was shaped to a standard size

These blocks wcie then transported to the plant for beneficiatıon and transformation in a final end product near the consumption centers, or for further selling This first kind of dimension stone quarry was called the boulder quarry

In the case of Piracaia black granite, the exploitation dates from the 1930s This can be seen m a curious photograph existing in the enterprise of Brothers Fiorehnni, which until today has a beneficiatıon plant and a commercial shop to sell granites, m Piracaia

Figure 3 shows a big block that was exploited and for its transportation a special cow car was constructed

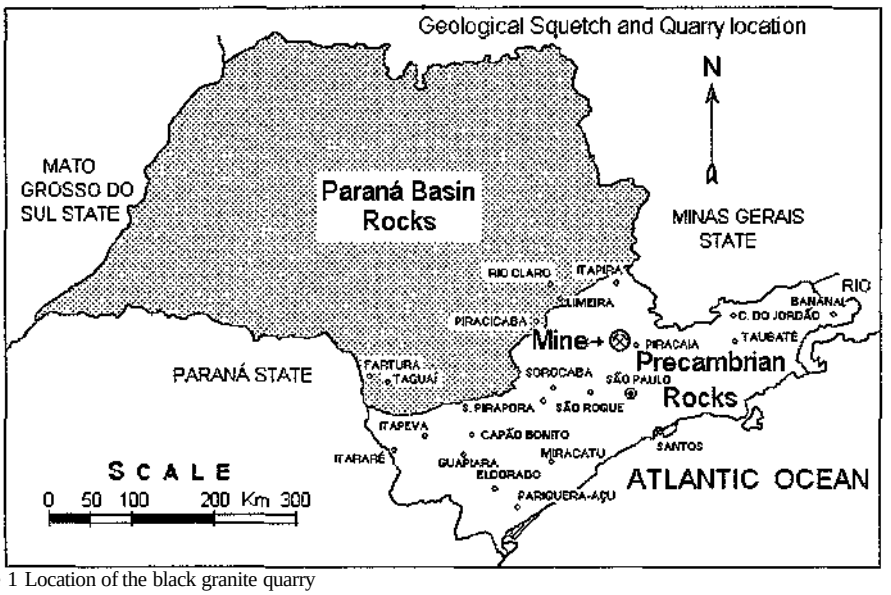

Figure 1 Location of the black granite quarry

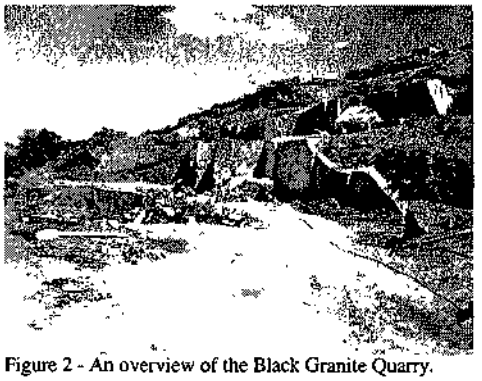

Figure 2 - An overview of the Black Granite Quarry.

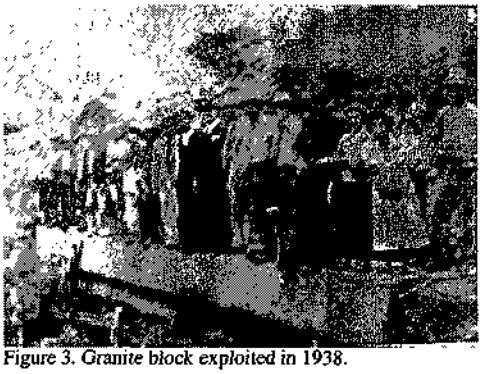

Figure 3. Granite block exploited in 1938.

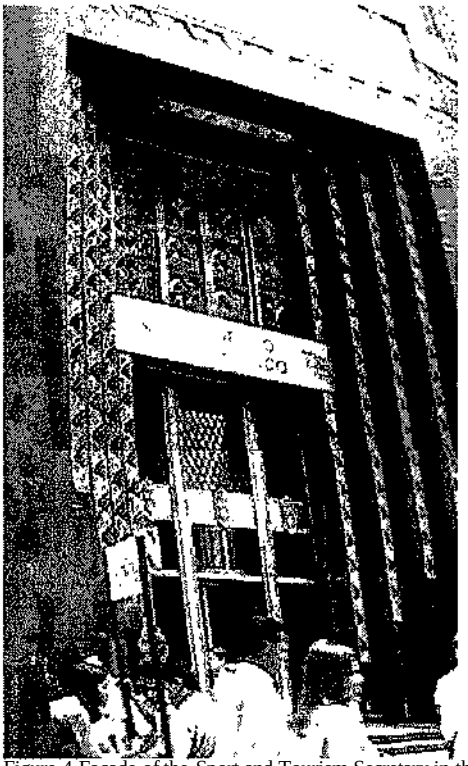

Figure 4 Façade of the Sport and Tourism Secretary in the center of Sâo Paulo city with the roof of Piracaia granite.

This block was applied in the façade of a building in the center of Sâo Paulo city. Now this building is a State Department of the Sâo Paulo government, and it is shown in Figure 4.

The extraction rate increased, and to maintain a more regular production level, it was necessary to adopt new procedures for the winning of the blocks, which began to be extracted from the rock massive. In this other kind of quarry called rock quarry, a greater mass of fresh rock exists that is subdivided in major pieces.

These quarries created by dimension cutting characteristically remove blocks by sawing or splitting operations and the blocks have the shape of parallelepipeds.As a consequence the faces of these quarries are usually very steep transverses by stepped-down benches. For the winning of the blocks of the massive it was necessary to use a non-conventional method of primary surface creation not previously used, which consists of a diamond wire machinery. A new enterprise called Granite Marie! exploits the blocks by the non-conventional methods using the diamond wire technology.

The conventional sizing of the block using drilling and charging with black powder, used first is also employed to cut the other block faces.

The total output of the quarry stands now at the level of about 100 cubic meters a month or about 400 cubic meters yearly.

The following item makes some basic considerations about the diamond wire technique, with the sequence of the unit exploitation operations to win the granite blocks in the quarry.

3 DIAMOND WIRE TECHNOLOGY

Recently a revolutionary method appeared for precise cutting of dimension stone that is known by the name of diamond wire technology.

The diamond wire can be considered an advance or evolution of the helical wire, normally used for the attainment of blocks in softer rocks such as marble. It consists of the helical wire, an extensive special steel handle moved by an engine and guided by pulleys. In the rock cut areas, an abrasive (in general quartz sand) is added to the wire to erode the rock.

The diamond wire is equally composed of a steel wire, along which there are pearls in the shape of impregnated synthetic diamond cylinders. With this, the feeding of the abrasive is dispensable.

The abrasive cylinders are spaced by springs that are encapsulated in plastic or rubber, to prevent their unfastening. Initially, this cover was absent, causing a series of accidents due to the unfastening of the springs.

In Figure 5, two types of diamond wires are illustrated, for cutting marble and granite, showing their constituent elements: pearls composed of impregnated steel leagues of synthetic diamonds, steel wire, spacing springs, and covering of rubber or resistant plastic.

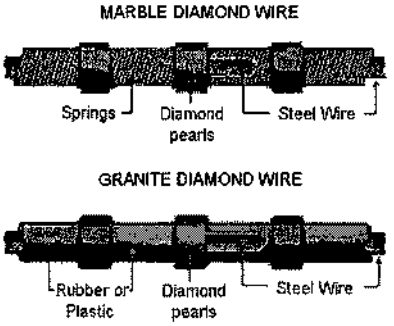

Figure 4 Elements of a diamond wire saw.

With its fast action of clean cut, the diamond wire has proven to be an efficient system of non-destructive extraction and demolition in the unit mining operations. Created in the quarries, the diamond wire has become a prerequisite for improvement of the recovery conditions in the extraction of dimension stone blocks.

For the separation and extraction of the blocks from the bulk it is necessary to generate plain or free faces, which can be obtained with the diamond wire.

Figure 6 presents a detail of the generation of a face of vertical cut in the quarry wall, with the diamond wire. In the upper portion of the figure the beginning of the cut operation is shown, to generate a plan of separation and in the lower partit is shown the operation in its final phase of cut.

The cut work with diamond wire is obtained by the action of its elements of abrasion with the attrition and displacement on the rock, where a motor pulley carries through this operation, and a pulley guide, giving the direction of the plane where it desires to carry through the cut.

In the initial phase of the operation the execution of drill holes must be open and serve as a way to pass the diamond wire. In this occasion, in various equipment two pulleys still exist that drive the strength of the wire, whose effort can be controlled, and that keep the adherence of the diamond wire to the rock.

Another aspect that can be highlighted is that with the continuation of the cut there is a reduction of the perimeter of the wire in contact with the rock. To prevent works from shortening the wire, the displacement of all the equipment is normally made on tracks, allowing the total sawing cut to be carried through without the need to interrupt the work to promote this shortening.

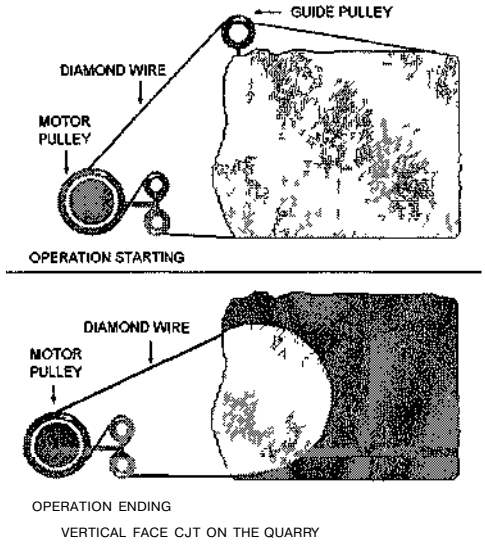

Figure 6 Vertical cut face on the quarry by diamond wire

Figure 7 shows one schematic view of winning blocks in quarries using the sawing cut with diamond wire In this figure it is seen on the left the sequence of separation of the great blocks with two cuts using diamond wire in the floor and the wall Next, the dismemberment of these great blocks by a series of parallel drill holes is shown until the desired dimen sions of the blocks are reached The right of this fig ure shows the diamond wire cuttmg_an immense block

Figure 8, shows the sawing equipment used m the quarry of Piracaia black granite, being possible to observe the metallic trail structure, with tracks, for its displacement

4 SEQUENCE OF BLOCK EXTRACTION

In Brazil, if a greater stone block is to be divided into smaller units in a quarry, as m the cases of granite rock boulder quarries, it is essential that the block in question be completely free around all its faces

For most dimension stone quarrying, the success of the art depends largely upon taking advantages of joints and cleavage planes in the rock

In the black granite rock there is a rift along which it may be split with comparative ease The rift of the black granite is the surface parallel plane (ı e , parallel to its outcrop) Unfortunately, this granite has no joints m the planes perpendicular to the rift that are the head and gram , along which it splits less easily in an orthogonal attitude

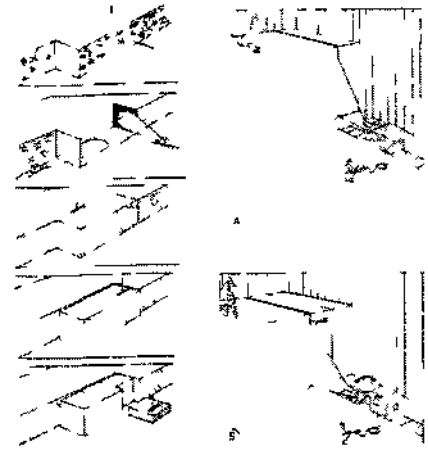

Figure 7 Block winning with diamond wire equipment

Figure 8 Diamond wire equipment at quarry

The head direction, which is the worst to split, is a direction perpendicular to the valleys, and the grain, or third direction of intermediate splitting is parallel to the valley

The head direction is the most difficult surface to obtain This surface is created by the use of the dia mond wire machinery (see Figure 9)

Currently, two groups of benches exist in the quarry, where the granite blocks are extracted The sequence of the unit operations of block exploitation consists of the following stages

1 Removal of the overburden,
2 Preparation of the group of benches to cut the great block
3 Cut in the vertical plane and floor by the diamond wire,

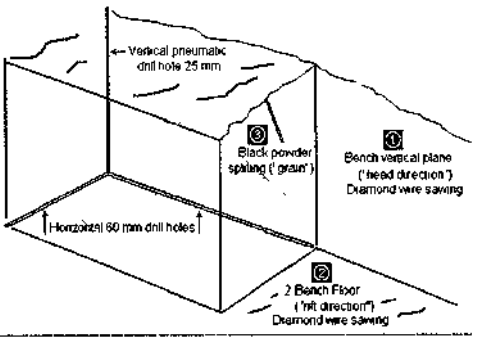

Figure 9 Schema of the holes opened to pass the diamond wire to detach great blocks.

4 Hand held drill is used to open a hole that is fired with black powder for dismemberment of the great block;
5 Final retaliation of the blocks to desired dimension with line of parallel drilling holes of small distance.

The first unit operation of exploitation of the quarry consisted of the removal of the soil overburden to display the bulk rock. This operation was carried through with conventional pressure water jet. Figure 2 gives a good idea of the thickness of this overburden.

Next, the advanced diamond wire system is used for clipping the great blocks. To do that, two stages are necessary: first the preparation of the group of benches for the cut, and finally the cut with the diamond wire.

In the preparation phase, two horizontal drill holes with 60 mm of diameter are carried through with special equipment, beyond a vertical drill hole opened with hand held pneumatic hammer. The three holes must meet in the heath of the rock; so that steel cables can be passed through them, and next to pull the diamond wire.

Figure 9 shows a project of these holes for the preparation of the group of benches for the separation of the great blocks.

Nor all granites present three orthogonal directions of partition. This is the case of the Piracaia granite. In the winning of blocks of dimension stone these directions are called rift, head, and grain. The rift is the most well defined direction, and the head of orthogonal direction to the plane of the rift is in general less well defined. In the case of the Piracaia granite, the grain, instead of its plane, isorthogonal, having an angle of 57°, which causes certain upheavals.

The two orthogonal drilled horizontal holes are elaborated on the plane of the rift. The hand held hammer opens a vertical hole orthogonal to this plane. Carried through these three holes, steel cables are crossed to make it possible to follow the passage of the diamond wires.

The following unit operation constitutes of the cut of two planes of the great blocks with the diamond wire equipment. The machinery of the diamond wire cuts the two planes, one at the base of the great block in the direction of the rift, and the other in the direction of the head. Figure 8 shows the employed diamond wire machine.

This machinery works on a rail structure that permits its dislocation to obtain the cut. The guide of tracks permits vertical or horizontal slots to be cut.

Figure 10 shows a detail of its guide pulley.

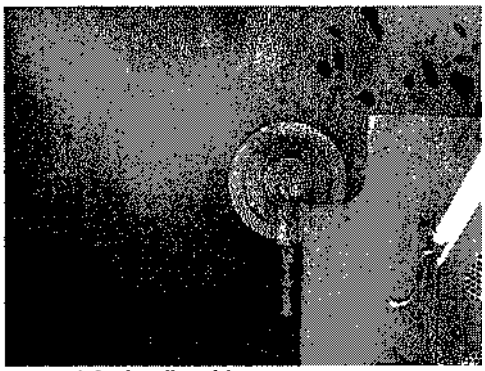

Figure 10 Guide pulley of the equipment.

Figure 11 shows a detail of the surface generated by the sawing of the granite with the diamond wire.

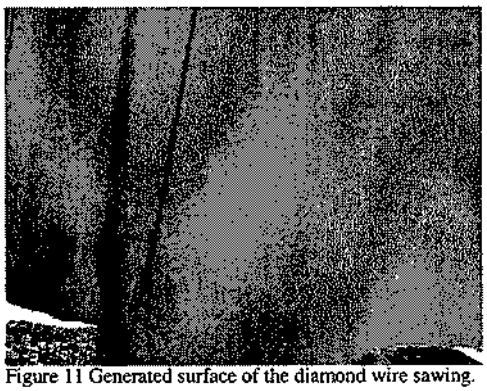

Figure 11 Generated surface of the diamond wire sawing.

The great blocks are next subdivided by following different cuts, so that they reach appropriate dimensions for handling and final transportation.

Thus an initial clipping is made by a hole made by the hand held pneumatic hammer and using as explosive black powder in the orthogonal plane of the grain.

Figure 12 shows a detail of this obtained cut, detaching the effect of obtained cut, the place of the drilled hole and the loaded black powder.

Figure 12 Black powders splitting of the great diamond sawed blocks

The last unit operation consists of the attainment of parallelepipedic blocks through the use of a series of closely spaced parallel holes drilled with the manual hammer.

In Figure 13 it is possible to see a worker doing this last unit operation, with the use of the hand held pneumatic drill. In this photograph, it is possible to sr~ better th^ v-r+ici' flee *n"* the bci-h ^enrnted "> ' ilk 1'ı inni J ı ,u «•\ in '

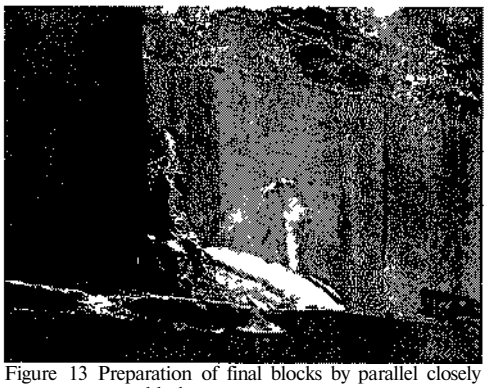

Figure 13 Preparation of final blocks by parallel closely spaced holes.

Figure 14 shows the details of a final block obtained by this technique.

Figure 15 shows a set of final blocks ready to be transported for further improvement in the beneficiation plant in the city of Piracaia.

5 OTHER PROCEDURES

For some types of rocks containing quartz in greater amount (above 30%) as in the case of other granites, flame channeling is employed. The rock shows the proper splitting (thermal breakage) characteristics for this method to be applied.

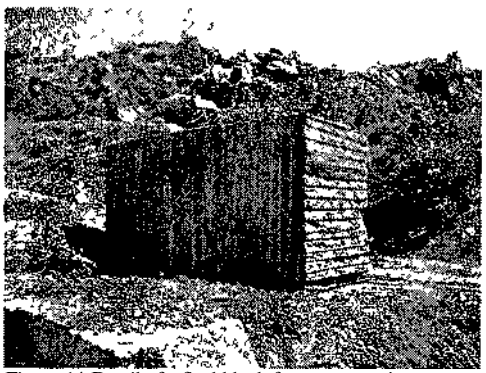

Figure 14 Detail of a final block for transportation.

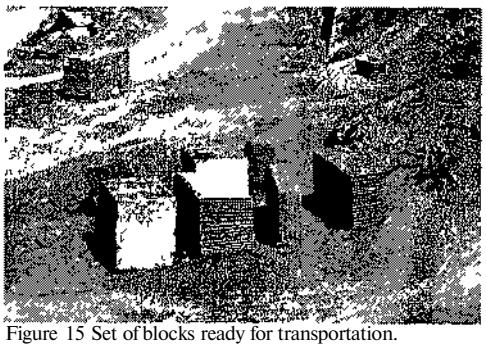

Figure 15 Set of blocks ready for transportation.

In the case of Piracaia black granite, whose amount of quartz is only at the level of 6%, this technique may not be easy to present good results. Experiments will be necessary.

Analyzed under environmental aspects, the technique of diamond wire sawing method is not noisy and the operator and his helper need not use individual ear protection equipment.

The productivity of the surface generation by the non-conventional diamond wire sawing equipment in this black granite is about four square meters per hour.

Laboratory assaying of Piracaia black granite was made to cut it with steel wires (Stellin et al, 2001). The productivity in this test shows that the sawing by steel wires using sand as abrasive is about 0.3 to 0.4 square meter per hour. When compared to other harder granites as the red Capào Bonito granite with

higher quartz content, there is a little higher productivity

6 TECHNOLOGICAL CHARACTERISTICS

The mam technological characteristic of black granite as dimension stone can be divided m petrography, general information, physical and technological specifications

In the area now under exploitation there are two different outcrops of rock, the most exploited in which the benches were open, coarser granular granite appears

Close to that area to the north, finer granular gran ite occurs

Two thin slides of the granite that characterize its petrography were analyzed under the microscope

Figure 16 shows a thm section of the normally exploited coarser Piracaia black granite, while Figure 17 presents a thin section of the finer type

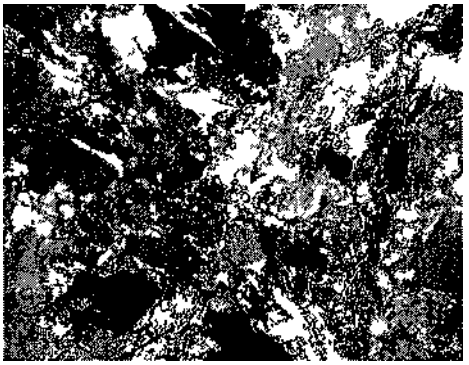

Figure 16 Thin section of coarser Piracaia black granite

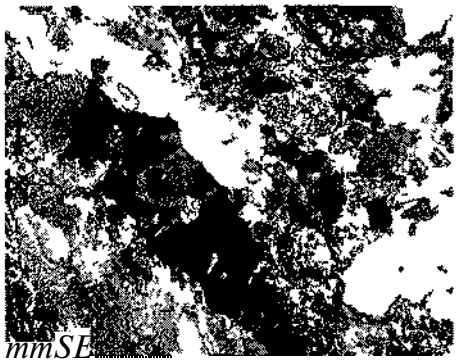

Figure 17 Thin section of finer Piracaia black granite

Regarding general information about the rock type, its commercial name, deposit type, geological reserves, present quarry production and its production capacity, and raw block dimensions, this data is given in Table 1

Table 1 General Information about black granite

Rock Type	Granite
Commercial Name	Piracaia black granite
Quarry location	Sao Paulo State Brazil
Deposit Tjpe	Massive Rock Quarry
Geological Reserves	>100 000 cubic meters
Monthly Production	100 cubic meters^
Production Capacity	150 cubic meters
Raw Block Dimension	From4 5 m to 7 5m

Table 2 presents the main pétrographie charactens tics of Piracaia black granite

Table 2 Pétrographie Charactenstics of black granite

Property	Characteristic
Common Color	Black
Structure	Massive
Uniformity	*JML*
Texture	Granular
Grain Size	3 to 10 mm
Microfissuraf State	Weak
Alteration Grade	Weak (hydrotermal)

Table 3 Physical Mechanical and other technological charactenstics of black granite (source Caruso et al, 1990)

Property	Value	Test
Dry Density	J2_844kg/nri	(ASTM C97 ABNTNBR12 766)
ApparentJ'orosity	0 50%	(AŞTMÇ97 ABNT NBR 12 766)
Water Absorption	0 18%	(ASTM C97 ABNT NBR 12 766)
Amsler Abrasionjlesistence	1 05 mm/lOOOm	JABNT NBR 12 042)
Impact Strength Test	0j!8 m	(ABNT NBR 12 764)
Linear Thermal Expansion	6 3 mm/m °C X 10î	(ASTM E288 ABNT NBR 12 765)
Compression Breaking Load at Natural State	167 1 MPa	(ASTM CI70 ABNT NBR 12 767)
Compression Breaking Load after Freezing/Thawing	1495 MPa	(ASTMC170 ABNT NBR 12 767)
Modulus of Rupture	15 75 MPa	
Bending Test	17 8 MPa	(ASTM C99~ ABNT NBR Ï2~763)
Staüc Deformabılity Modulus	J2963Gpa	JASTMTJ3148)
Ultrasonic Pulse Velocity	_m/s	(ASTMJJ 2845)
Ammonium Hydroxide (NH4OH)	Unaltered aspect	(ABNT NBR 9 446)
Sodium Hypochlonde (NaC10,H_2Q)	Unaltered aspect	

Ultrasonic pulse velocity 5,010

The mineralogical composition of Piracaia black granite has about 35% of Plagıoclase (andesıne-ohgoclase) 20-25% Hornblende, 15% biotite, 15% perthıtıc Microchne (+ Ortoclase), 5% of Quartz, about 5% of Sphene (+ opaque minerals) The other minerals that appear as accessories in less than 5% are Apatite and Epidote Secondary minerals are Carbonates The pétrographie classification of this granite is as a Bıotıte-hornblende quartz monzomte There are no great differences m mineralogical constitution between the finer and coarser types, only the size of crystals

In Table 3 are presented the mam physical, mechanical and technological specifications of Piracaia black granite associated with the used norms

For the determination of the parameters the tests used the standard proposed by the North American Norms (emitted by ASTM - American Society of Testing Materials) or by the Brazilian standard Association (ABNT - Associaçâo Brasıleıra de Normas Técmcas)

7 APPLICATION OF BLACK GRANITE

In this topic, after the description of the entire sequence to obtain blocks of black granite, some applications of the construction material will be discussed

The use of dimension stone has two mam applications in the market, as construction material or as art material

In the past, dimension block was used as a structural element of the buildings in civil construction

Today, the evolution of cıvıl construction makes use of tiles of dimension stone to cover only surfaces such as walls and floors, outside and inside Plates are also very largely used for lavatory parts

Many new skyscrapers of the city of Sâo Paulo used this black granite as an external cover, which gives to the building a respectable aspect

Due to its black color, its application as tombstone is also very common in all Sâo Paulo city cemeteries

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