Re-engineering of natural stone production chain through knowledge based processes, eco-innovation and new organisational paradigms

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The Need for Stone

Stone is a vital raw material

From the early dawn of human kind it has played a significant role in the development of human civilization and surely will continue to play an equally important role in the future.
Natural stones (marbles, granite, limestone etc) with their unique physical and aesthetic properties, comprise an ideal raw material for the construction industry.
Significance of the Stone Sector

Natural stones find numerous uses in the construction industry in indoor and outdoor applications and they significantly contribute to the improvement of the quality and the overall aesthetics and performance of buildings and open spaces.
Global Stone Production

The world stone production and the volume of the global stone market will experience a five time increase until 2025.

**Raw material**
- Value: 20 billion € for 2003

**Finished products**
- Value: 35 billion € for 2003
The EU Stone Sector has a leading position in the global stone and equipment market.
The Stone Sector is an integral part of the construction industry. Therefore, better performance of the Stone Sector means better performance of the construction industry.
**Current Stone Production chain**

**Quarrying**
- 1000tn Marble
- 220 tn blocks
  - 15 blocks (1.5x1.4x2.8 m)
- Waste 780 tn

**Block Sawing**
- (strips/slabs) 145 tn, 10 blocks
- 35% of blocks rejected due to fractures
- 18% waste generation
- 10% of blocks unexpectedly broken due to fractures

**Building Application**
- 1 building (70 tn, 1900 m² floor)
- 3% destroyed due to poor maintenance

**Calibration, Polishing, Sizing**
- ~100 tn, ~2700 m² (~15 mm thickness)
- 15% of broken Slabs/Tiles
- 20% of slabs rejected
- 10% waste generation

**Efficiency**
- Calibration, Polishing, Sizing: ~100 t, ~2700 m² (~15 mm thickness)
  - 70% efficiency
- Block Sawing: (strips/slabs) 145 t, 10 blocks
  - 70% efficiency
Drilling

220 tn blocks
15 blocks (1.5x1.4x2.8 m)

Waste 780 tn

Building Application
1 building (70 tn, 1900 m² floor)

3% destroyed due to poor maintenance

Block Sawing
(strip/slabs) 145 tn, 10 blocks

Efficiency 70%

35% of blocks rejected due to fractures
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~100 tn, ~2700 m² (~15 mm thickness)

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Current Stone Production chain
New Drilling Technology

Main issues to be addressed

- Low drilling speed (up to 2 m/min)
- High noise and vibration levels
- Hydraulic system

I-STONE Technology

- High drilling speed (up to 3 m/min)
- No vibration, low noise
- Electrical motor
Quarrying
1000tn Marble

Waste 780tn 18% waste
generation

10% of blocks unexpectedly broken due to fractures
220 tn blocks
15 blocks (1.5x1.4x2.8 m)

Block Sawing
(strips/slabs) 145 tn, 10 blocks

Efficiency
70%

Building Application
1 building (70 tn, 1900 m² floor)

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Fractured Stone Blocks

35% of blocks rejected due to fractures

Calibration, Polishing, Sizing
~100 tn, ~2700 m² (~15 mm thickness)

Efficiency
70%

15% of broken Slabs/Tiles
20% of slabs rejected
10% waste generation

Current Stone Production chain
Technology for fracture detection

No currently available technology for detection and reinforcement of fractured blocks

Fracture

Break along the fracture

Fault detection system

Non-destructive techniques based on sonic and ultra sonic waves:

- Detection depth up to 2.5 m
- Detection accuracy ±1 cm
Technology for repairing fractured blocks

**Block impregnation system**

- Vacuum bag and metal chamber technology
- Infiltration of resins into stone block fractures
- Consolidation of fractures up to 1m depth

**Vacuum application**

- Piece of Fabric
- Resin Flow
- Vacuum Bag
- Sealant tape

**Resin infiltration**

- Crack filled with resin
Quarrying

1000tn Marble

Waste 780 tn

Block Sawing

( strips/slabs) 145 tn, 10 blocks

18% waste generation

10% of blocks unexpectedly broken due to fractures

220 tn blocks
15 blocks (1.5x1.4x2.8 m)

Building Application

1 building (70 tn, 1900 m² floor)

3% destroyed due to poor maintenance

Blocks Sawing and Cutting

Block Sawing

Efficiency: 70%

Calibration, Polishing, Sizing

Efficiency: 70%

~100 tn, ~1.2 m² (~15 mm thickness)

15% of broken Slabs/Tiles

20% of slabs rejected

10% waste generation

Current Stone Production chain
Block sawing

20% of the stone material is currently lost during cutting due to the disc thickness.
High Speed Cutting

- Development of extra thin cutting disks
- New generation of diamond segments
- Development of a high speed cutting system

<table>
<thead>
<tr>
<th></th>
<th>Existing technology</th>
<th>I-STONE technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Segment width [$w_s$] (mm)</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>Disk width [$w_d$] (mm)</td>
<td>5</td>
<td>3.5</td>
</tr>
<tr>
<td>Tooth height [$h_t$] (mm)</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Cutting speed (m/s)</td>
<td>32</td>
<td>45-60</td>
</tr>
<tr>
<td>Feed rate (m/min)</td>
<td>4</td>
<td>13-17</td>
</tr>
<tr>
<td>Removal rate (cm²/min)</td>
<td>400</td>
<td>520-580</td>
</tr>
</tbody>
</table>
Quarrying
1000tn Marble

Waste 780 tn

10% of blocks unexpectedly broken due to fractures
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Block Sawing
(strips/slabs) 145 tn, 10 blocks

Efficiency
70%

Building Application
1 building (70 tn, 1900 m² floor)

3% destroyed due to poor maintenance

Calibration, Polishing, Sizing
2700 m² (~15 mm thickness)

Efficiency
70%

Fractured slabs/tiles

35% of blocks rejected due to fractures

18% waste generation
10% of blocks unexpectedly broken due to fractures

15% of broken Slabs/Tiles
20% of slabs rejected
10% waste generation

Current Stone Production chain
Slab/tile consolidation system

No currently available technology for fractured slabs/tiles consolidation

Pilot plant design

- Lifting crane manual slab loading unit
- Slabs pack support
- Tilting roller bench for slabs trays
- Integrated vacuum station and consolidant application unit, with slabs conveyor
- Roller bench for slabs trays
- Elevator for slabs trays
- Stock tower oven
Quarrying

1000tn Marble

Waste 780 tn

220 tn blocks
15 blocks (1.5x1.4x2.8 m)

Block Sawing

(strips/slabs) 145 tn, 10 blocks

10% of blocks unexpectedly broken due to fractures

18% waste generation

New stone products

Building Application

1 building (70 tn, 1900 m² floor)

3% destroyed due to poor maintenance

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3% destroyed due to poor maintenance

Efficiency
Calibration, Polishing, Sizing
~100 m² ~2700 m² (~15 mm thickness)

Efficiency

35% of blocks rejected due to fractures

3% destroyed due to poor maintenance

Efficiency

18% waste generation

10% of blocks unexpectedly broken due to fractures

15% of broken Slabs/Tiles

20% of slabs rejected

10% waste generation

Current Stone Production chain
Multi functional stone products

Reuse of stone wastes for the production of:

- Synthetic stone blocks with PCMs
- Stone pulverisation technique
- Stone-cement products
Current Stone Production chain

**Quarrying**
- 1000tn Marble
- 220 tn blocks
- 15 blocks (1.5x1.4x2.8 m)
- Waste 780 tn

**Block Sawing**
- (strips/slabs) 145 tn, 10 blocks
- 85 tn unsuitable fractured blocks
- Waste 26 tn
- 15 tn, 1 block unexpectedly broken due to fractures

**Building Application**
- 1 building (70 tn, 1900 m² floor)
- 15 blocks
- 3% destroyed due to poor maintenance

**Calibration, Polishing, Sizing**
- ~100 tn, ~2700 m² (~15 mm thickness)
- Efficiency 70%

**Virtual stone selection and application system**
- 15 tn Broken Slabs/Tiles
- 5 tn slabs Rejected Slabs/tiles
- Waste 10 tn

Efficiency 70%
Virtual stone selection system

to bridge the gap between stone producer and user
Quarrying
1000tn Marble
Waste 780 tn

Block Sawing
(strips/slabs) 145 tn, 10 blocks
Waste 26 tn
15 tn, 1block unexpectedly broken due to fractures

Building Application
1 building (70 tn, 1900 m² floor)
3% destroyed due to poor maintenance

Calibration, Polishing, Sizing
~100 tn, ~2700 m² (~15 mm thickness)
Efficiency 70%

Stone quality

15 tn Broken Slabs/Tiles
15 tntn, 5 slabs Rejected Slabs/tiles
Waste 10 tn

Waste 75 75 tntn unsuitable 5 fractured blocks
5 fractured blocks
70%
1-3% of natural stone products used in building facades in EU need to be repaired every year, due to:

- unsuitable material
- poor construction
- poor maintenance

- Modelling and evaluation of stone behaviour in construction applications in real conditions
- Stone staining sensitivity
- Expert system to choose the right stone for the right application
Design of a new stone production chain

Quarrying
1000tn Marble

Waste 780 tn

Building Application
1 building (158 tn, 3910 m² floor)

1% destroyed due to poor maintenance

Block Sawing
(strip/slabs) 205 tn, 14 blocks

Waste 20 tn

Calibration, Polishing, Sizing
~185 tn, ~4500 m² (~15 mm thickness)

Diagnostic & Impregnation System

220 tn blocks
15 blocks (1.5x1.4x2.8 m)

15 tn unsuitable
1 fractured block

New Products

TiO₂, PCMs
Binding Materials

Virtual Stone selection & application

Consolidation
90% Efficiency

Slab/Tile

Consolidation
90% Efficiency

Slab/Tiles
13 tn Broken
3 tn slabs Rejected
Waste 10 tn

90% Efficiency

~15 mm thickness

Diagnostic & Impregnation System

Waste 3 3 tntn

Slabs/Tiles
1133 tntn

Broken

Waste 2200 tntn

15 15 tntn unsuitable
1 fractured block

Diagnostic & Impregnation System

Waste 10 10 tntn
To transform the rather traditional Stone Sector into a modern, competitive and knowledge-based industry and ensure a lasting technological superiority of EU over its competitors.

The re-engineering of the stone production chain, in order to considerably increase its efficiency and productivity, minimise the huge amount of stone wastes produced and disposed in the environment, produce a new generation of multifunctional products based on stone wastes and safeguard quality in stone application and use.