A study on best available techniques for the management of stone wastes

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Introduction – Natural stone

- **Marble**: commercial name for a wide family of calcareous rocks, considered soft rocks

- **Granite**: commercial name for a wide family of siliceous rocks, considered hard rocks
Introduction – Stone industry

Basic phases
- Quarrying
- Processing
Introduction

- Product of quarrying:
  Commercial block of stone
  (1.5 x 1.4 x 2.8 m)
Introduction

Main products of processing phase:

<table>
<thead>
<tr>
<th>Product</th>
<th>Length (m)</th>
<th>Width (m)</th>
<th>Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slab</td>
<td>2.5 – 3.5</td>
<td>1.3 – 2.0</td>
<td>20 - 80</td>
</tr>
<tr>
<td>Strip</td>
<td>1.0 – 3.5</td>
<td>0.15 – 0.65</td>
<td>10 - 50</td>
</tr>
<tr>
<td>Tile</td>
<td>0.15 – 0.65</td>
<td>0.15 – 0.65</td>
<td>10 - 12</td>
</tr>
<tr>
<td>Super thin tile</td>
<td>0.15 – 0.65</td>
<td>0.15 – 0.65</td>
<td>&lt; 10</td>
</tr>
</tbody>
</table>
Introduction – Stone production chain

Quarrying
- Waste 50-95%

Calibration, Polishing, Tile Cutting (~15 mm thickness)
- 35% of blocks rejected due to poor properties
- 10% of blocks unexpectedly broken due to fractures
- 12% sand & sludge
- 8% of slabs rejected
- 10% of broken Slabs/Tiles

Block Sawing (strips/slabs)
- 18% sand & sludge
- 70% Efficiency

Efficiency
- 70%
The problem of stone exploitation

- Stone wastes are generated in huge quantities
  - Quarrying activities: 50% to 95%
  - Processing activities: 30% to 40%

<table>
<thead>
<tr>
<th>Activity</th>
<th>Parameter</th>
<th>ton</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quarrying</td>
<td>gross extraction</td>
<td>153,750,000</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>net extraction</td>
<td>75,000,000</td>
<td>49</td>
</tr>
<tr>
<td></td>
<td>quarry waste</td>
<td>78,750,000</td>
<td>51</td>
</tr>
<tr>
<td>Processing</td>
<td>gross processed</td>
<td>75,000,000</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>net production</td>
<td>44,250,000</td>
<td>59</td>
</tr>
<tr>
<td></td>
<td>processing waste</td>
<td>30,750,000</td>
<td>41</td>
</tr>
</tbody>
</table>

World data for 2003, Stone 2004
Stone waste types

- Quarrying waste types:
  - Defective or “third choice” blocks
  - Large irregular blocks ($\geq 0.2 \text{ m}^3$)
  - Small irregular blocks (dimension $< 0.5 \text{ m}$)
  - Small particles (splints, chips), and fine size sand and slurry
Stone waste types

- **Processing waste types**
  - Large to medium size broken pieces called scrap
  - Medium to small size pieces like splints, flakes, chips
  - Fine size particles mainly in the form of slurry.
Properties of stone wastes

- Stone waste is inert material since it originates from the same stone deposit as the products.
- Stone waste does not have adequate properties to be used for ornamental and dimensional purposes.
- But can be used in a variety of other uses with proper management.
Waste Management - General

Waste management aims at:
- the reduction of waste

This is achieved through:
- the modification of productive processes to adopt cleaner technologies
- the reuse of waste materials
Waste Management Hierarchy

Hierarchy according to directive 91/156/EEC:

- Prevention or reduction of waste production;
- Recovery of wastes by means of recycling, re-use, reclamation or any other process;
- Safe disposal of wastes.

1st Level: Waste reduction

- Best available techniques for quarries:
  - Using of clean technologies like diamond tools, ramps and access roads,
  - Adopting exploitation methods like underground quarrying
1st Level: Waste reduction

Best available techniques for processing plants:
- Reinforcement of mechanically unsound blocks
- Thinner cutting disks
- Recycle of slurries with decantation and pressing
Reduction of wastes at the source

Why the use of these techniques promotes the sustainability of the stone industry?

- Create less waste
- Need less energy
- Less land use
- Less visual disturbance
- Less rehabilitation costs
2nd Level: Waste recovery

Options for waste recovery

Stone wastes

Waste recovery

No treatment

Re-employ

In the same use (3rd choice blocks for mass production of low quality elements)

Other uses (armourstones)

With treatment

Re-use (industrial minerals)

Recycling (artificial stones, aggregates)
Best available techniques according to waste type

- Recovery of quarry wastes:
  - *third choice blocks*:
    - low price elements for external uses
    - stored and occasionally processed for large quantities of elements without high quality standards
  - *large shapeless blocks*:
    - armourstone,
    - aggregates
  - *small shapeless blocks*:
    - aggregates
  - *small to fine size particles*:
    - construction admixtures, plasters and mortars
Best available techniques

- Recovery of processing wastes:
  - *Scrap*:
    - choice scraps low-cost rustic floorings and coverings, generally for outdoor applications
    - non-choice scraps can be crushed for aggregate production
  - *Splints, chips*:
    - used for aggregate
    - as land-fillers for agricultural purposes
Best available techniques

- *Calcareous sludge* can be used to:
  - neutralize acidic industry by-products or contaminated agricultural land
  - de-sulphurise the fumes produced by high-power thermoelectric plants
  - as additive in hydraulic mixtures, plasters.
  - produce paper fillers, polymeric fillers (PVC), water paints, artificial stones.

- *Granite sludge* produced by disk saws or by the polishing process can be used in:
  - ceramic industry
  - moulding of plastics (PVC) when the inert material does not need to be calcareous.
The best techniques include the:

- Common disposal sites for quarry clusters
- Careful selection of disposal site
- Backfilling if possible
- Special treatment of sludge
  - Special zones for storage and treatment
  - Transportation of mud by specialized companies
Application of Sustainable Indicators

- Assessment before selecting a recovery option should be carried out.
- The assessment of the performance of a waste recovery option is very case sensitive due to the plethora of factors that affect it.
- Indicators can be established to assess sustainability.
- The established SDIs are divided in 3 categories:
  - Environmental (i.e. energy, transport, etc.)
  - Economical (i.e. cost, added value, etc.)
  - Social (i.e. new jobs created)
Sustainable indicators

- Environmental indicators:
  1. Specific volume of stone waste managed
  2. Indicative water consumption during treatment per tonne of stone waste
  3. Energy consumption
  4. Chemicals/Reagents consumption
  5. Use of dangerous substances (reagents, chemicals)
  6. Transport constraints (average distance that can be covered from source to customers)
  7. Environmental incidents (reportable)
Sustainable indicators

- **Economical indicators:**
  1. Overall indicative treatment and handling costs
  2. Indicative capital costs of waste management facilities (if applicable)
  3. Indicative savings from landfill fees and rehabilitation costs
  4. Total R&D expenditure/turnover
  5. Profit making/Added value
Sustainable indicators

- Social indicators
  - Direct and indirect employment
  - Risks of accidents

- Based on these SDIs, some of the best available options for waste recovery are evaluated on a qualitative sense in order to demonstrate their application
Re-employ of quarry wastes

- in those uses that the material properties and size allow it (no treatment needed)
  - large shapeless blocks can be used as armourstone
  - 3rd choice blocks can be used for mass production of low quality elements (footpaths, cobblestone, dry wall)
Re-employ of quarry wastes

- Indicative SDI assessment for armourstone:

<table>
<thead>
<tr>
<th>Category</th>
<th>Indicator</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental</td>
<td>Specific volume of stone waste managed</td>
<td>Variable, depending on the waste quality and end-use requirements.</td>
</tr>
<tr>
<td></td>
<td>Energy consumption</td>
<td>Low energy consumption for handling</td>
</tr>
<tr>
<td></td>
<td>Transport (average distance)</td>
<td>Low to High: Depending on the stone size, the price of armour stone may enable it to be transported to regional or national markets and still remain economically viable.</td>
</tr>
<tr>
<td>Economic</td>
<td>Overall indicative treatment and handling costs</td>
<td>Low, Potentially high transport costs.</td>
</tr>
<tr>
<td></td>
<td>Profit making/Added value</td>
<td>Low - High price: profit increases with size</td>
</tr>
<tr>
<td>Social</td>
<td>Direct and indirect employment</td>
<td>Variable, depending on production rate</td>
</tr>
<tr>
<td></td>
<td>Risk for accidents</td>
<td>Low</td>
</tr>
</tbody>
</table>
Re-employ of quarry wastes

### Indicative SDI assessment for footpaths, drywall:

<table>
<thead>
<tr>
<th>Category</th>
<th>Indicator</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental</td>
<td>Specific volume of stone waste managed</td>
<td>Low-Medium: depending on the local market demand</td>
</tr>
<tr>
<td></td>
<td>Energy consumption</td>
<td>Low: for handling.</td>
</tr>
<tr>
<td></td>
<td>Transport constraints (average distance)</td>
<td>Low: Transportation will generally be limited to local markets; however special stone characteristics may enable economical access to regional markets.</td>
</tr>
<tr>
<td>Economic</td>
<td>Overall indicative treatment and handling costs</td>
<td>Low: for handling</td>
</tr>
<tr>
<td></td>
<td>Profit making/Added value</td>
<td>Low price €/t but proportional to the volume of material used</td>
</tr>
<tr>
<td>Social</td>
<td>Direct and indirect employment</td>
<td>Variable, depending on production rate</td>
</tr>
<tr>
<td></td>
<td>Risk for accidents</td>
<td>Low</td>
</tr>
</tbody>
</table>
Re-employ of processing wastes

in those uses that the material properties and size allow it (no treatment needed)

i.e.: large to medium sized scraps can be used for low cost floorings and coverings for external applications
Re-employ of processing wastes

Indicative SDI assessment for external coverings:

<table>
<thead>
<tr>
<th>Category</th>
<th>Indicator</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental</td>
<td>Specific volume of stone waste managed</td>
<td>Low - Medium, depending on the market demands</td>
</tr>
<tr>
<td></td>
<td>Energy consumption</td>
<td>Low - Medium: for handling, selection</td>
</tr>
<tr>
<td></td>
<td>Transport constraints (average distance)</td>
<td>Low - Medium: Transportation limited to local markets; however special stone characteristics may enable economical access to regional markets.</td>
</tr>
<tr>
<td>Economic</td>
<td>Overall indicative treatment and handling costs</td>
<td>Low-Medium handling and transportation cost</td>
</tr>
<tr>
<td></td>
<td>Profit making/Added value</td>
<td>Medium price (up to €5-8/m²) depending on stone characteristics and the relative market</td>
</tr>
<tr>
<td>Social</td>
<td>Direct and indirect employment</td>
<td>Variable, depending on production rate</td>
</tr>
<tr>
<td></td>
<td>Risk for accidents</td>
<td>Low</td>
</tr>
</tbody>
</table>
Re-use of processing wastes

- In those uses that the material properties and size allow it (after treatment):
  - i.e. crushing and pulverizing the stone waste (<90 microns – Carbonate waste only) to produce cement and quicklime
Re-use of processing wastes

- Indicative SDI assessment for cement and quicklime:

<table>
<thead>
<tr>
<th>Category</th>
<th>Indicator</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental</td>
<td>Specific volume of stone waste managed</td>
<td>High: Potential demand is high</td>
</tr>
<tr>
<td></td>
<td>Energy consumption</td>
<td>Medium-High for waste processing.</td>
</tr>
<tr>
<td></td>
<td>Transport constraints (average distance)</td>
<td>Medium-High: Carbonate wastes fetching a high price may be transported to regional or national markets and still remain economically viable</td>
</tr>
<tr>
<td>Economic</td>
<td>Overall indicative treatment and handling costs</td>
<td>Medium-High for waste material.</td>
</tr>
<tr>
<td></td>
<td>Profit making/Added value</td>
<td>High price €/t</td>
</tr>
<tr>
<td>Social</td>
<td>Direct and indirect employment</td>
<td>Variable, depending on production rate</td>
</tr>
<tr>
<td></td>
<td>Risk for accidents</td>
<td>Low – Medium</td>
</tr>
</tbody>
</table>
Re-cycle of quarry wastes

- Re-cycle of waste (after treatment) in those uses that the material properties and size allow it:
  - i.e. crushing the stone waste to produce aggregates for concrete or asphalt mixes
Re-cycle of quarry wastes

- Indicative SDI assessment for aggregates:

<table>
<thead>
<tr>
<th>Category</th>
<th>Indicator</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental</td>
<td>Specific volume of stone waste managed</td>
<td>Considerably variable depending on final aggregate requirements. All large to small waste material can be crushed.</td>
</tr>
<tr>
<td></td>
<td>Energy consumption</td>
<td>Medium: Depends on the crusher plant size and production capacity.</td>
</tr>
<tr>
<td></td>
<td>Transport constraints (average distance)</td>
<td>Low: Haulage of aggregates over long distance is not cost effective.</td>
</tr>
<tr>
<td>Economic</td>
<td>Overall indicative treatment and handling costs</td>
<td>Medium treatment and handling costs.</td>
</tr>
<tr>
<td></td>
<td>Profit making/Added value</td>
<td>Low - Medium price €/t but proportional to the volume used</td>
</tr>
<tr>
<td>Social</td>
<td>Direct and indirect employment</td>
<td>Variable, depending on production rate</td>
</tr>
<tr>
<td></td>
<td>Risk for accidents</td>
<td>Low</td>
</tr>
</tbody>
</table>
Re-cycle of processing wastes

Re-cycle of waste (after treatment) in those uses that the material properties and size allow it:
  - i.e. use the stone sludge to produce artificial stones and tiles
Re-cycle of quarry wastes

**Indicative SDI assessment for artificial stones and tiles:**

<table>
<thead>
<tr>
<th>Category</th>
<th>Indicator</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental</td>
<td>Specific volume of stone waste managed</td>
<td>Low-Medium: Dependent on local and regional markets</td>
</tr>
<tr>
<td></td>
<td>Energy consumption</td>
<td>Medium-High for: handling, processing</td>
</tr>
<tr>
<td></td>
<td>Transport constraints (average distance)</td>
<td>Medium-High: Transport to markets at similar distances to those for natural stone.</td>
</tr>
<tr>
<td>Economic</td>
<td>Overall indicative treatment and handling costs</td>
<td>Medium-High: Dependent on processing method, cost of waste preparation, and binder cost.</td>
</tr>
<tr>
<td></td>
<td>Profit making/Added value</td>
<td>Medium-High value €/t.</td>
</tr>
<tr>
<td>Social</td>
<td>Direct and indirect employment</td>
<td>Variable, depending on production rate</td>
</tr>
<tr>
<td></td>
<td>Risk for accidents</td>
<td>Low</td>
</tr>
</tbody>
</table>
Conclusions

- Disposal of leftover natural stone should be considered the worst possible option.
- Ways to recover the stone waste should be always sought out, for the sustainable development of stone industry.
- In order to select the most appropriate option for waste recovery several factors should be considered.
- The most important factor is the suitability of the material properties for the foreseen recovery option.
Conclusions

- Two groups of BAT to manage stone material:
  - Equipment and processes that allow prevention and reduction of waste
  - Applications that permit re-employ, reuse and recycling
- Correct waste management is profitable for both human and the environment
- The concept of “stone waste” must be replaced by the concept of “leftover, usable stone material”
Conclusions

- The set of 14 SDI is adequate for the performance assessment of possible waste recovery options, accounting for a variety of factors.

- It is proved that with the increase of treatment, the energy consumption and the treatment cost are increased but also the added value of recovered waste increases accordingly.
The End

- The EC funded project I-STONE is acknowledged for this work. (www.istone.ntua.gr)

- Thank you for your attention!