ARTIFICIAL SAND PRODUCTION FROM QUARRY TAILLINGS

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OBJECTIVE

1. Obtain artificial sand from fine quarry tailings using Vertical Shaft Impact Crusher – VSI – in order to substitute natural sand;

2. Optimize the artificial sand production process establishing the best production parameters through testing different samples in the same crushing circuit.
PARTICIPATING INSTITUTIONS

• CETEM – Centro de Tecnologia Mineral
• COPPE/UFRJ – Metallurgical Engineering
• COPPE/UFRJ – Civil Engineering
• Pedra Sul Mineração Ltda
• Pedreira Vigné Ltda
• Convem Mineração Ltda
• Pedreira Santa Luzia Ltda
• Ibrata Mineração Ltda
• Pedreira São Pedro Ltda
INTRODUCTION

- Extraction of natural sand from riverbeds
  - Environmental impacts
  - Exploitation prohibition
- Urban areas don’t hold up the sand extraction activity anymore
- Extraction at far-off districts (+ 200 km)
  - 65% of sand cost comes from transportation
  - Final product cost rises
- Concrete: 1:2 m³ coarse aggregate and sand relation
INTRODUCTION

Aggregates consumption for civil construction per inhabitant

<table>
<thead>
<tr>
<th>Countries</th>
<th>Consumption (ton per capita)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BRAZIL</td>
<td>2</td>
</tr>
<tr>
<td>USA</td>
<td>7.5</td>
</tr>
<tr>
<td>Western Europe</td>
<td>5 a 8</td>
</tr>
</tbody>
</table>


Sand and crushed stone production in Brazil from 1997 - 2001

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand production (ton)</td>
<td>128,6</td>
<td>125,4</td>
<td>203,6</td>
<td>225,7</td>
<td>236,1</td>
</tr>
<tr>
<td>Crushed stone (ton)</td>
<td>88,5</td>
<td>86,5</td>
<td>87,7</td>
<td>155,7</td>
<td>162,8</td>
</tr>
</tbody>
</table>

Source: Anepac/DNPM

- Actual exploitation process won’t tolerate an increase on sand demand
- Artificial sand becomes a promising alternative
• Requirements for artificial sand:
  - Appropriate particle size distribution;
  - Appropriate particle shape and superficial texture;
  - Good particle mechanical strength and stability;
  - No contamination.

• Vertical Shaft Impact Crusher (VSI):
  - Autogenous rock against rock;
  - Produce isometric particles shapes;
  - Able to control and standardize the particle size distribution.
EXPERIMENTAL PROCEDURE

• Collection of data from production of crushed stones and sand;
• Technical evaluation of crushed stone production plants at metropolitan area of Rio de Janeiro;
• Pilot scale tests for
  – Technological and size distribution characterization;
  – Material classification to separate fine particles (minus 74 μm)
• Analysis of crushing plant circuits
  – Evaluate the feasibility of obtaining a fine fraction product suitable to be used as artificial sand
EXPERIMENTAL PROCEDURE

• Crushing circuit

Drawer Feeder → BC 1 → VSI Crusher → BC 2 → BC 3 → Vibratory screen → + 3 mm → BC 3 → BC 1

Air Separator → - 3 mm, + 0.074 mm → - 0.074 mm

• Sampling points

1. Feed
2. VSI discharge
3. Circulating load
4. Undersize

BC: belt conveyor
EXPERIMENTAL PROCEDURE

Tests conditions

• Material used: charnockite (a type of granite)
• Feed sizes
  • - 12.5 + 4.8 mm
  • - 12.5 mm
• Fresh feed rate: 2.2 t/h to 4.1 t/h
• Rotor opening: 40 or 80 mm
• Number of tests: 15
## EXPERIMENTAL PROCEDURE

<table>
<thead>
<tr>
<th>Fresh Feed</th>
<th>Rotor opening (mm)</th>
<th>Feed rate (t/h)</th>
<th>d50 (mm)</th>
<th>% CL</th>
</tr>
</thead>
<tbody>
<tr>
<td>- 12.5 + 4.8 mm</td>
<td>40</td>
<td>2.2</td>
<td>7.5</td>
<td>59.99</td>
</tr>
<tr>
<td>- 12.5 + 4.8 mm</td>
<td>40</td>
<td>4.1</td>
<td>6.5</td>
<td>73.78</td>
</tr>
<tr>
<td>- 12.5 + 4.8 mm</td>
<td>80</td>
<td>3.4</td>
<td>5.4</td>
<td>60.99</td>
</tr>
<tr>
<td>- 12.5 + 4.8 mm</td>
<td>80</td>
<td>3.7</td>
<td>5.1</td>
<td>76.40</td>
</tr>
<tr>
<td>- 12.5 + 4.8 mm</td>
<td>80</td>
<td>3.9</td>
<td>3.8</td>
<td>114.10</td>
</tr>
<tr>
<td>- 12.5 + 4.8 mm</td>
<td>80</td>
<td>4.1</td>
<td>3.5</td>
<td>104.35</td>
</tr>
<tr>
<td>- 12.5 mm</td>
<td>40</td>
<td>2.7</td>
<td>2.5</td>
<td>31.44</td>
</tr>
<tr>
<td>- 12.5 mm</td>
<td>40</td>
<td>4.0</td>
<td>2.8</td>
<td>66.14</td>
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<tr>
<td>- 12.5 mm</td>
<td>80</td>
<td>2.8</td>
<td>2.7</td>
<td>60.87</td>
</tr>
<tr>
<td>- 12.5 mm</td>
<td>80</td>
<td>3.6</td>
<td>2.4</td>
<td>70.91</td>
</tr>
<tr>
<td>- 12.5 mm</td>
<td>80</td>
<td>4.3</td>
<td>2.8</td>
<td>46.22</td>
</tr>
</tbody>
</table>
EXPERIMENTAL PROCEDURE

- Crushing circuit final product classification at the Air Separator Sturtevant

  Coarses out
  Sand for concrete – between 3 and 0,074 mm

  Fines out
  Sand for mortar – smaller than 0,074 mm
EXPERIMENTAL PROCEDURE

• Particle size distribution analysis

• Mortar workability evaluation
  - March funnel
  - Flow Table

• Particle’s morphology analysis
  - Optical microscopy for image capture
  - Image analysis (Adobe Photoshop)
  - Set up a methodology for image analysis in 2D
EXPERIMENTAL PROCEDURE

- Image analysis
  - Up to 150 particles photographs
  - Geometrics measurements
    - PPDA
    - Spherecity
    - Aspect ratio

\[
PPDA = \frac{\text{Perimeter}^2}{\text{Area}}
\]

\[
\text{Spherecity} = \frac{4 \cdot \pi \cdot \text{Area}}{\text{Perimeter}^2}
\]
PARTIAL RESULTS
Products comparison – Opening 8 cm

- Test 3 - tx 3.87 t/h - Ab 8 cm
- Test 4 - tx 4.14 t/h - Ab 8 cm
- Test 5 - tx 3.41 t/h - Ab 8 cm
- Test 8 - tx 3.65 t/h - Ab 8 cm

Graph showing the accumulated passing of particle size in mm for the mentioned tests.
Rotor opening influence on the particle size distribution

![Graph showing the influence of rotor opening on particle size distribution. The x-axis represents the particle size (mm), and the y-axis represents the accumulated passing (%). Two lines are depicted: one for an opening of 8 cm and another for an opening of 4 cm.](image-url)
Mortar workability related to the grain size

![Graph showing the relationship between flow table (mm) and grain size (mm). The graph includes two linear regression lines with R² values of 0.1449 and 0.6237. The data points are represented by different markers for d50 and d80.](image-url)
Shape parameters analysis

<table>
<thead>
<tr>
<th>- 0.42 + 0.297 mm</th>
<th>Spherecity</th>
<th>PPDA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Natural sand</td>
<td>0.79</td>
<td>16.02</td>
</tr>
<tr>
<td>Artificial sand</td>
<td>0.64</td>
<td>19.82</td>
</tr>
</tbody>
</table>

PPDA and Spherecity are equivalent

<table>
<thead>
<tr>
<th>- 0.42 + 0.297 mm</th>
<th>Aspect ratio</th>
<th>Spherecity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Natural sand</td>
<td>1.35</td>
<td>0.79</td>
</tr>
<tr>
<td>Artificial sand</td>
<td>1.37</td>
<td>0.64</td>
</tr>
</tbody>
</table>

Length and width individual analysis are inefficient.

Aspect ratio analysis is complementary to the spherecity analysis.
CONCLUSIONS

• As the rotor opening increases the particle size distribution becomes finer;

• As the feed rate increases the circulating load rises and the particle size distribution becomes finer;

• The VSI crushing process improve particle sphericity, specially for coarser fractions.
NEXT STEPS

• Proceed with the particle size analysis of samples;

• Remove the material finer than 200# using the Air Separator Sturtevant to fit the artificial sand into the ABNT standards;

• Finish the workability and shape analysis of the final product (artificial sand);

• Test - 200# product for mortar use;

• Test different rocks from others quarries plants

• Application tests will be conducted in the civil construction (concrete and mortar).
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