

## Green Foundry Life project (LIFE17 ENV/FI/000173)

Steel pouring at the CTIF's experimental foundry



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## SUMMARY

### Green Foundry Life project (LIFE17 ENV/FI/000173)

#### CTIF – Centre Technique des Industries de la Fonderie

Once the steel parts have been cast by the different partners of the Green Foundry Life project in order to compare the emissions generated in the foundry between organic and inorganic sand, CTIF carried out several works.

- For phase B3 of the project, concerning the impact of inorganic sand on the quality of steel castings:
  - Determination of roughness indices of the castings by the different partners,
  - Measurement of gas contents (on parts) that can be generated by the sand,
  - Structural investigations on samples taken from the parts to check the absence of defects due to exogenous gas generated by the sand.
- For phase B4.5 of the project, concerning inorganic sand waste:
  - Mechanical treatment tests,
  - Hydromechanical treatment tests,
  - Ultrasonic treatment tests,
  - Characterisations of sand samples carried out before and after treatment, to observe the impact of the different technologies on inorganic sands, and to select sand batches to be tested in leaching (sand batches before treatment, least treated sand batches and best treated sand batches).
- For phase B4.6 of the project, regarding options for reusing inorganic sand waste in geo-construction:
  - Leaching tests on inorganic sand waste,
  - Leaching tests on treated sands,
  - A synthesis of the results obtained in relation to the reference documents of the different countries taking part into this project (Germany, Spain, Finland, France, Italy, Poland).

### Parts cast by the different partners of the project and characterized by CTIF



CTIF : Casting made of structural steel standard EN GS240,  
 INOTEC : Casting made of stainless steel ASTM A747 Cb7-Cu2 (Unified Numbering System 324 J92110),  
 GEOPOL and PEAK : Castings made of stainless steel ASTM A297 HH (UNS 401 J93503).

### Roughness Indexes of Steel Parts Cast by the Project Partners

| Parts           | Roughness indexes measured<br>on <b>moulding surfaces</b><br>2S1 < standard < 8S1 | Roughness indexes measured<br>on <b>finishing surfaces</b><br>2S2 < standard < 5S2 | Results obtained compared to standard NF 1370 and<br>the BNIF's RT n°359, for steel parts |                                                            |
|-----------------|-----------------------------------------------------------------------------------|------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|------------------------------------------------------------|
|                 |                                                                                   |                                                                                    | <b>Casting surfaces</b>                                                                   | <b>Finishing surfaces</b>                                  |
| CTIF<br>Label O | External surface = 4S1<br>Internal surfaces = 2S1 to 6S1                          | *                                                                                  | Compliant with the standard<br>Compliant with the standard                                | Compliant with the standard<br>Compliant with the standard |
| CTIF<br>Label I | External surface = 4S1<br>Internal surfaces = 2S1 to 6S1                          | *                                                                                  | Compliant with the standard<br>Compliant with the standard                                | Compliant with the standard<br>Compliant with the standard |
| GEOPOL          | 2S1 to 6S1                                                                        | 5S2                                                                                | Compliant with the standard                                                               | Compliant with the standard                                |
| INOTEC          | 2S1 to 6S1                                                                        | 5S2                                                                                | Compliant with the standard                                                               | Compliant with the standard                                |
| PEAK            | 2S1 to 5S1                                                                        | 5S2                                                                                | Compliant with the standard                                                               | Compliant with the standard                                |

\* No reference plate corresponding to a simple sandblasting operation



## Synthesis of carbon, sulphur and gas content measurements

| Samples         | Content %<br>C<br>surface | Content %<br>C<br>inside | Content %<br>S<br>surface | Content %<br>S<br>inside | Content %<br>N<br>surface | Content %<br>N<br>inside | Content %<br>O<br>surface | Content %<br>O<br>inside | Content %<br>H<br>surface | Content %<br>H<br>inside |
|-----------------|---------------------------|--------------------------|---------------------------|--------------------------|---------------------------|--------------------------|---------------------------|--------------------------|---------------------------|--------------------------|
| CTIF O1         | 0,20                      | 0,21                     | 0,0037                    | 0,0035                   | 0,0080                    | 0,0085                   | 0,0082                    | 0,0082                   | <0,0001                   | <0,0001                  |
| CTIF O2         | 0,22                      | 0,22                     | 0,0035                    | 0,0040                   | 0,0080                    | 0,0080                   | 0,0072                    | 0,0062                   | <0,0001                   | <0,0001                  |
| CTIF O3         | 0,19                      | 0,21                     | 0,0040                    | 0,0040                   | 0,0080                    | 0,0080                   | 0,0063                    | 0,0085                   | <0,0001                   | <0,0001                  |
| CTIF I1         | 0,20                      | 0,21                     | 0,0040                    | 0,0040                   | 0,0080                    | 0,0080                   | 0,0174                    | 0,0075                   | <0,0001                   | <0,0001                  |
| CTIF I2         | 0,19                      | 0,21                     | 0,0038                    | 0,0040                   | 0,0080                    | 0,0080                   | 0,0084                    | 0,0065                   | <0,0001                   | <0,0001                  |
| CTIF I3         | 0,18                      | 0,21                     | 0,0042                    | 0,0040                   | 0,0080                    | 0,0080                   | 0,0065                    | 0,0106                   | <0,0001                   | <0,0001                  |
| GEOPOL W37-20/1 | 0,058                     | 0,049                    | 0,011                     | 0,010                    | 0,0380                    | 0,0380                   | 0,0200                    | 0,0195                   | 0,0008                    | 0,0008                   |
| GEOPOL W37-20/2 | 0,058                     | 0,046                    | 0,011                     | 0,010                    | 0,0385                    | 0,0390                   | 0,0181                    | 0,0206                   | 0,0008                    | 0,0008                   |
| GEOPOL W37-20/3 | 0,058                     | 0,050                    | 0,011                     | 0,010                    | 0,0385                    | 0,0385                   | 0,0179                    | 0,0187                   | 0,0008                    | 0,0008                   |
| INOTEC 1        | 0,045                     | 0,045                    | 0,017                     | 0,016                    | 0,0165                    | 0,0170                   | 0,0085                    | 0,0087                   | 0,0001                    | 0,0002                   |
| INOTEC 2        | 0,053                     | 0,054                    | 0,019                     | 0,020                    | 0,0170                    | 0,0160                   | 0,0089                    | 0,0091                   | 0,0001                    | <0,0001                  |
| INOTEC 3        | 0,052                     | 0,051                    | 0,019                     | 0,023                    | 0,0175                    | 0,0160                   | 0,0095                    | 0,0087                   | 0,0001                    | 0,0003                   |
| PEAK W37/1      | 0,060                     | 0,050                    | 0,013                     | 0,010                    | 0,0360                    | 0,0390                   | 0,0205                    | 0,0329                   | 0,0007                    | 0,0006                   |
| PEAK W37/2      | 0,054                     | 0,051                    | 0,011                     | 0,010                    | 0,0365                    | 0,0380                   | 0,0173                    | 0,0196                   | 0,0007                    | 0,0009                   |
| PEAK W37/3      | 0,052                     | 0,049                    | 0,011                     | 0,010                    | 0,0365                    | 0,0370                   | 0,0180                    | 0,0196                   | 0,0008                    | 0,0009                   |

Theoretical thresholds for the occurrence of defects: H < 5 ppm, N < 100 ppm or several hundred ppm if high alloying element contents, S < 150 ppm, O < 150 ppm or more if high Cr content.

Exceedance / standard

## Action B4.5 Treatment tests of inorganic sand waste

### Summary of the characterization of the sands to be treated

| Laboratory Inspections on the sand samples                                                 | Ref SN BE01 | INOTEC before T | CTIF IE before T | W37-20 before T | W37 before T |
|--------------------------------------------------------------------------------------------|-------------|-----------------|------------------|-----------------|--------------|
| Fineness index                                                                             | 46          | 49              | 46               | 46              | 46           |
| Distribution 50-70-100 (%)                                                                 | 95,03       | 85,27           | 89,71            | 86,21           | 86,90        |
| Distribution 200-270-bottom (%)                                                            | 0,18        | 1,30            | 1,10             | 0,64            | 0,42         |
| Residual aggregates (% sieve 6+12+20)                                                      | 0,00        | 0,24            | 0,28             | 0,46            | 0,30         |
| Theoretical specific surface (cm <sup>2</sup> /g)                                          | 159         | 169             | 157              | 161             | 159          |
| Breakage of sand grains observed under the optical microscope (high/low/not)               | No          | Low             | Low              | Low             | Low          |
| Aggregates observed under optical microscope (yes/no)                                      | No          | Yes             | Yes              | Yes             | Yes          |
| Presence of fines (no/low/significant)                                                     | Low         | Significant     | Significant      | Significant     | Significant  |
| Grain shape observed under the light microscope (general trend: spherical/angular)         | Spherical   | Sph+Ang         | Sph+Ang          | Sph+Ang         | Sph+Ang      |
| Appearance of grains observed under the optical microscope (general trend: smooth/rough)   | Smooth      | Smooth+Rou      | Smooth+Rou       | Smooth+Rou      | Smooth+Rou   |
| Amount of black grains (general tendency: no/low/significant)                              | No          | Low             | Low              | Low             | Low          |
| Quantity of light-coloured grains with black spots (general tendency: not/low/significant) | No          | Significant     | Significant      | Significant     | Significant  |
| Amount of light-coloured, unstained grains (general trend: no/low/significant)             | Significant | No              | No               | No              | No           |
| Electrical conductivity of sand (μS/cm)                                                    | 500 - 520   | 907             | 1357             | 1045            | 957          |
| pH of the sand                                                                             | 8,30 - 8,40 | 10,07           | 10,36            | 9,70            | 9,79         |
| Acid demand of sand (ml HCl)                                                               | 1,2 - 2,0   | 28              | 38,1             | 16,2            | 15,5         |
| Samples retained for leaching test                                                         |             | X               | X                | X               | X            |
| UPDATED on November 26th 2021                                                              |             |                 |                  |                 |              |

## Results of the sand characterization after mechanical treatment

| Laboratory checks on the sand samples                                                      | Ref SN BE01 | INOTEC      | CTIF IE     | GEOPOL W37-20 | PEAK W37    |
|--------------------------------------------------------------------------------------------|-------------|-------------|-------------|---------------|-------------|
| Fineness index                                                                             | 46          | 50          | 49          | 52            | 55          |
| Distribution 50-70-100 (%)                                                                 | 95,03       | 92,00       | 94,68       | 90,27         | 90,75       |
| Distribution 200-270-bottom (%)                                                            | 0,18        | 0,92        | 1,04        | 1,89          | 2,28        |
| Absence of residual aggregate (%)                                                          | 0,00        | 0,00        | 0,00        | 0,08          | 0,04        |
| Theoretical specific surface (cm <sup>2</sup> /g)                                          | 159         | 176         | 170         | 184           | 195         |
| Breakage of sand grains observed under the light microscope (high/low/no)                  | no          | low         | low         | significant   | significant |
| Aggregate removal observed under optical microscope (yes/no)                               | no          | yes         | yes         | yes           | yes         |
| Amount of fines produced by the treatment (no/low/significant)                             | no          | significant | significant | significant   | significant |
| Grain shape observed under light microscope (general trend: spherical/angular)             | Spherical   | Sph+Ang     | Sph+Ang     | Sph+Ang       | Sph+Ang     |
| Appearance of grains observed under the light microscope (general trend: smooth/rough)     | smooth      | smooth+Rug  | smooth      | smooth        | smooth      |
| Amount of black grains (general tendency: not/low/significant)                             | no          | significant | low         | low           | low         |
| Quantity of light-coloured grains with black spots (general tendency: not/low/significant) | no          | significant | significant | significant   | significant |
| Amount of light-coloured unstained grains (general trend: not/low/significant)             | significant | no          | low         | low           | low         |
| Electrical conductivity of treated sand (μS/cm)                                            | 500 - 520   | 863         | 1262        | 997           | 842         |
| pH of the treated sand                                                                     | 8,30 - 8,40 | 10,01       | 10,17       | 9,57          | 9,44        |
| Acid demand of treated sand (ml HCL)                                                       | 1,2 - 2,0   | 27,5        | 35,9        | 20,9          | 17,1        |
| Samples retained for leaching test                                                         |             | X           | X           | X             | X           |
| Updated on 26/11/2021                                                                      |             |             |             |               |             |

## Results of the sand characterization after hydromechanical treatment

| Laboratory checks on the sand samples                                                  | Ref SN BE01 | INOTEC      | CTIF IE     | GEOPOL W37-20 | PEAK W37    |
|----------------------------------------------------------------------------------------|-------------|-------------|-------------|---------------|-------------|
| Fineness index                                                                         | 46          | 49          | 47          | 48            | 49          |
| Distribution 50-70-100 (%)                                                             | 95,03       | 92,64       | 95,42       | 94,68         | 93,94       |
| Distribution 200-270-bottom (%)                                                        | 0,18        | 0,14        | 0,04        | 0,00          | 0,06        |
| Absence of residual aggregate (%)                                                      | 0,00        | 0,04        | 0,00        | 0,04          | 0,08        |
| Theoretical specific surface (cm <sup>2</sup> /g)                                      | 159         | 172         | 160         | 169           | 172         |
| Breakage of sand grains under the light microscope (significant/low/no)                | no          | low         | low         | low           | low         |
| Aggregate removal observed under optical microscope (yes/no)                           | no          | yes         | yes         | yes           | yes         |
| Amount of fines produced by the treatment (no/low/significant)                         | no          | low         | low         | low           | low         |
| Grain shape observed under the optical microscope (general trend: spherical/angular)   | Spherical   | Sph+Ang     | Sph+Ang     | Sph+Ang       | Sph+Ang     |
| Appearance of grains under the optical microscope (general trend: smooth/rough)        | smooth      | smooth      | smooth      | smooth        | smooth      |
| Amount of black grains (general trend: no/low/significant)                             | no          | low         | low         | low           | low         |
| Quantity of light-coloured grains with black spots (general trend: no/low/significant) | no          | significant | low         | low           | low         |
| Amount of clear unstained grains (general trend: no/low/significant)                   | significant | significant | significant | significant   | significant |
| Electrical conductivity of treated sand (μS/cm)                                        | 500 - 520   | 523         | 516         | 507           | 511         |
| pH of treated sand                                                                     | 8,30 - 8,40 | 8,78        | 8,73        | 8,72          | 8,45        |
| Acid demand of treated sand (ml HCL)                                                   | 1,2 - 2,0   | 5,8         | 2,2         | 0,6           | 1,5         |
| Samples retained for leaching test                                                     |             | X           | X           | X             | X           |
| Updated on 26/11/2021                                                                  |             |             |             |               |             |

## Results of the characterization of the sands after ultrasonic treatment

| Laboratory checks on the sand samples                                                  | Ref SN BE01 | InoEC       | CTIF IE     | GEOPOL W37-20 | PEAK W37    |
|----------------------------------------------------------------------------------------|-------------|-------------|-------------|---------------|-------------|
| Fineness index                                                                         | 46          | 50          | 47          | 49            | 50          |
| Distribution 50-70-100 (%)                                                             | 95,03       | 93,02       | 96,10       | 94,14         | 93,98       |
| Distribution 200-270-bottom (%)                                                        | 0,18        | 0,18        | 0,06        | 0,04          | 0,10        |
| Absence of residual aggregate (%)                                                      | 0,00        | 0,04        | 0,04        | 0,06          | 0,12        |
| Theoretical specific surface (cm <sup>2</sup> /g)                                      | 159         | 176         | 162         | 171           | 175         |
| Casse grains de sable observée au microscope optique (significant/low/no)              | no          | low         | low         | low           | low         |
| Sand grain breakage observed by optical microscope (significant/low/no)                | no          | yes         | yes         | yes           | yes         |
| Aggregate removal observed under optical microscope (yes/no)                           | no          | low         | low         | low           | low         |
| Amount of fines produced by the treatment (no/low/significant)                         | Spherical   | Sph+Ang     | Sph+Ang     | Sph+Ang       | Sph+Ang     |
| Appearance of grains under the optical microscope (general trend: smooth/rough)        | smooth      | smooth      | smooth      | smooth        | smooth      |
| Amount of black grains (general trend: no/low/significant)                             | no          | low         | low         | low           | low         |
| Quantity of light-coloured grains with black spots (general trend: no/low/significant) | no          | significant | low         | low           | low         |
| Quantity of clear unstained grains (general trend: no/low/significant)                 | significant | low         | significant | significant   | significant |
| Electrical conductivity of treated sand (μS/cm)                                        | 500 - 520   | 525         | 521         | 515           | 518         |
| pH of treated sand                                                                     | 8,30 - 8,40 | 8,76        | 8,77        | 8,79          | 8,58        |
| Acid demand of treated sand (ml HCL)                                                   | 1,2 - 2,0   | 7,5         | 4,5         | 1,5           | 1,6         |
| Samples retained for leaching test                                                     |             |             |             |               |             |
| Updated on 26/11/2021                                                                  |             |             |             |               |             |

## Action B4.6 Options for reusing inorganic sand waste

### Identifying options for reusing inorganic sands

| Process                     | Options        | Accepted in center   | Use of the material in geo-construction (document from Finland) |                              |                              |                            |            |                                                   |                                       |
|-----------------------------|----------------|----------------------|-----------------------------------------------------------------|------------------------------|------------------------------|----------------------------|------------|---------------------------------------------------|---------------------------------------|
|                             | Samples tested | waste inert          | Roadway covered <sup>(1)</sup>                                  | Roadway paved <sup>(1)</sup> | Field covered <sup>(1)</sup> | Field paved <sup>(1)</sup> | Embankment | Floor structure of industrial or storage building | Crushed stones and ash <sup>(2)</sup> |
| Untreated sands             | INOTEC         | No                   | Yes                                                             | Yes                          | Yes                          | Yes                        | Yes        | Yes                                               | Yes                                   |
|                             | CTIFIE         | No                   | No                                                              | No                           | No                           | No                         | No         | No                                                | No                                    |
|                             | GEOPOL W37-20  | No                   | No                                                              | No                           | No                           | No                         | No         | No                                                | No                                    |
|                             | PEAK W37       | No                   | No                                                              | Yes                          | No                           | No                         | No         | Yes                                               | No                                    |
| Mechanical processing       | INOTEC         | No                   | Yes                                                             | Yes                          | No                           | Yes                        | Yes        | Yes                                               | Yes                                   |
|                             | CTIFIE         | No                   | No                                                              | No                           | No                           | No                         | No         | No                                                | No                                    |
|                             | GEOPOL W37-20  | No                   | No                                                              | No                           | No                           | No                         | No         | No                                                | No                                    |
|                             | PEAK W37       | No                   | No                                                              | Yes                          | No                           | No                         | No         | Yes                                               | No                                    |
| Hydro mechanical processing | INOTEC         | Yes                  | Yes                                                             | Yes                          | Yes                          | Yes                        | Yes        | Yes                                               | Yes                                   |
|                             | CTIFIE         | Yes                  | Yes                                                             | Yes                          | Yes                          | Yes                        | Yes        | Yes                                               | Yes                                   |
|                             | GEOPOL W37-20  | No                   | Yes                                                             | Yes                          | Yes                          | Yes                        | Yes        | Yes                                               | Yes                                   |
|                             | PEAK W37       | Yes except in Italie | Yes                                                             | Yes                          | Yes                          | Yes                        | Yes        | Yes                                               | Yes                                   |

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| Process                     | Options        | Accepted in center   | Use of the material in road engineering (2019 Cerema guide France) |                                     |                                     |
|-----------------------------|----------------|----------------------|--------------------------------------------------------------------|-------------------------------------|-------------------------------------|
|                             | Samples tested | waste inert          | Alternative material for type 1 use                                | Alternative material for type 2 use | Alternative material for type 3 use |
| Untreated sands             | INOTEC         | No                   | Yes                                                                | Yes                                 | Yes                                 |
|                             | CTIFIE         | No                   | Yes                                                                | Yes                                 | Yes                                 |
|                             | GEOPOL W37-20  | No                   | No                                                                 | No                                  | No                                  |
|                             | PEAK W37       | No                   | No                                                                 | No                                  | No                                  |
| Mechanical processing       | INOTEC         | No                   | Yes                                                                | Yes                                 | No                                  |
|                             | CTIFIE         | No                   | Yes                                                                | Yes                                 | Yes                                 |
|                             | GEOPOL W37-20  | No                   | No                                                                 | No                                  | No                                  |
|                             | PEAK W37       | No                   | No                                                                 | No                                  | No                                  |
| Hydro mechanical processing | INOTEC         | Yes                  | Yes                                                                | Yes                                 | Yes                                 |
|                             | CTIFIE         | Yes                  | Yes                                                                | Yes                                 | Yes                                 |
|                             | GEOPOL W37-20  | No                   | Yes                                                                | Yes                                 | No                                  |
|                             | PEAK W37       | Yes except in Italie | Yes                                                                | Yes                                 | Yes                                 |

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## Conclusion

The laboratory work carried out during this project made it possible to verify the impact of an inorganic sand on the quality of small steel castings.

It was found that the condition of the casting and finishing surfaces of the parts complied with the NF1370 standard according to BNIF technical recommendation no. 359 (Bureau de Normalisation des Industries de la Fonderie).

The contents of carbon, sulphur, nitrogen, hydrogen and oxygen measured on the part samples did not reveal any major problem.

The structural investigations carried out on the samples taken from the parts also confirmed that inorganic sand would apparently not have a major impact on the occurrence of defects (for the small steel parts tested in this project).

Treatment trials carried out on inorganic sand waste have shown that hydromechanical and ultrasonic technologies are particularly effective in obtaining an inert sand waste after treatment, or in allowing the treated sand to be reused in foundry, geo-construction or road engineering.



Nevertheless, these hydromechanical and ultrasonic treatment processes need to be tested on an industrial scale to verify whether these emerging technologies would be viable, compared to solutions using conventional technologies (mechanical, thermal, thermomechanical).

In this context, it would be interesting to develop a pilot capable of treating 250 kg of sand per cycle to check the feasibility and determine the consumption ratios, the production/maintenance ratios and the sand treatment costs in €/t, and to compare the results obtained with those of conventional installations. The study of this (these) industrial pilot(s) would also enable a representative life cycle analysis and carbon impact calculation to be carried out, to find out whether the hydromechanical and ultrasonic technologies can be transferred to industry for the treatment of used foundry sand.