CHARACTERISTICS AND MANAGEMENT OPTIONS FOR MIXED CONSTRUCTION WASTE RESIDUE

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ABSTRACT
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The world of today is not possible to imagine without recycling. The reuse of waste saves resources and environment. The trend is to follow a waste hierarchy saying: avoid, reduce, reuse, recycle, treat and dispose waste.

This thesis is seeking for alternatives for mixed waste residue from construction site and demountable waste remains after a recycling treatment. This particular waste is currently used to cover landfill. The aim is to find possibilities for reuse contents or the whole waste mixture. By the help of analyzing the physical characteristics of the waste mixture: dry residue, sieving, loss on ignition and gross calorific value the waste is assessed and alternative treatment methods for the current one suggested.

The sieving resulted in, that every size portion has nearly the same amounts of content. The waste consists of 29 % organic material and the gross calorific value is about 6 MJ/kg. The amount of organic waste can be utilized in an incinerating power plant where it is basically burned to produce energy. To increase the value of the gross calorific value the application of a double lane wind shifter is advisable. This machine separates the organic and inorganic materials of the waste by the help of different densities and flow resistances of the particles. The inorganic material can be applied for example in road works or cement works.
That is the reason why an implementation of a double lane wind shifter is suggested as a pre-treatment method.

Keywords: construction site, demountable, waste, recycling
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</tr>
</thead>
<tbody>
<tr>
<td>TAMK</td>
<td>Tampere University of Applied Sciences</td>
</tr>
<tr>
<td>EN</td>
<td>European Norm</td>
</tr>
<tr>
<td>CEN/TS</td>
<td>European Committee for Standardization - Technical Specification</td>
</tr>
<tr>
<td>SS</td>
<td>Single sample</td>
</tr>
<tr>
<td>MS</td>
<td>Mixed sample</td>
</tr>
<tr>
<td>GS</td>
<td>Gross samples</td>
</tr>
<tr>
<td>No.</td>
<td>Number</td>
</tr>
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1 INTRODUCTION

1.1 Background

The European Commission requested Finland to adjust environmental laws to the EU Waste Framework Directive by the end of 2010 (EUROPEAN COMMISSION, 2011). According to the European Commission companies have to ensure they treat it as good as possible, otherwise prices for dispose will increase immense. They have to follow the hierarchy: avoid, reduce, reuse, recycle, recover, treat, and dispose.

The 1996 established (Content Media Partner Nordic AB, 2015) Finnish company "Delete Finland Oy" is specialized in environmental services. Among others, in recycling construction site waste and demountable. The company employs 700 environmental service professionals and achieved a pro forma turnover with over 100 million Euros in 2014 (Delete Finland Oy, 2015).

In front of the treatment process every construction site and demountable waste container is weighed and classified in sorted construction site waste and mixed construction site waste. The sorted waste is divided into metals, combustible wastes, energy wastes, woods, concretes and bricks, tires and rubber wastes, hazardous waste and papers, plastics and cardboards. Every type of these presorted wastes has their own treatment process and is mainly reused as a recycling product. The mixed construction site and demountable waste with about 20.000 T/a, which are approximately 15 % of the total mass flow has to be managed by the company, contains mainly concrete, soil, plastic, gypsum, glass, polystyrene, wood and sand. The recycling of this waste starts with a separation in three different sizes by the help of two sieves, in parts with a diameter over 30 mm, from 3 - 30 mm and lower than 3 mm. All sieve residues (bigger than 3 mm) are separated and reused afterwards. Particles lower than 3 mm are going to landfill as mixed construction site waste together with bigger sized parts sorted out in the recycling process.
1.2 Aim

The aim of this thesis work is to find alternatives for the reuse of the mixed construction site waste which is going to landfill at the moment. The reusability means to use an object again after the initial purpose. If the object includes more than one component often treatment processes are used to separate the object into component parts. To separate the objects into component parts for example size separation with help from sieves, density separation via air separator or other processes are used. Therefore standardized analyses have to be done to define the contents and possibility for reuse them.

1.3 Management options

In consequence of the small particle size separation processes, to divide the material in every single component, are difficult and cost intensive. In central Europe these parts are often implemented in incinerating power plants. The organic matter will basically release energy in the burning process. This energy is used to evaporate water in a closed cycle. The steam is directed over the turbine's blades and spinning the turbine. The turbine rotates a generator producing energy (Westenergy Oy, 2015). The leftover consists of inorganic material and could be brought back together and may be used for road works or cement industry. For an implementation in an incinerating power plant the mixed waste has to be evaluated for example organic proportion, gross calorific value or the mass portions in different particle sizes are determined.
2 Theory

2.1 Dry residue

The total mass of a sample consist of the amount of dry and wet masses. Drying processes are based on the evaporation of liquids, which are bound to the surface, capillary or as water of crystallization to solid materials. This procedure takes effect when the moisture content is too low to extract via conventional mechanical treatment. Preconditions are different boiling points of the solid material and the drying gas. During the evaporative drying inert gas (for example air) flows through and next to the sample, whereby it removes the exhaust vapour of the sample from the system (Figure 1) (Schwister & Leven, 2013, p. 293).

![Figure 1 Drying furnace](FRANCE ETUVES SARL, 2010)

The waste binds a lot of water on the surface as well as inside because it is basically stored at the yard of the company "Delete Finland Oy" and exposed to higher rate of humidity.
2.2 Sieving

Sieving is a size separation of a material mixture into two or more portions by the help of one or more screening surfaces. Different types of screens and equipment are used, depending on the material have to be separated. The particle size in solid wastes is an important indicator for recovery of materials. Therefore mostly reciprocating screens, trommel screens and disc screens are used (Tchobanoglous, et al., 1993, pp. 73, 552). During the sieving process the sieving medium should be given continuously that all of the particles have a chance to pass the sieves. This can be achieved by shaking and tapping manually or by the help of a sieving machine. Still in most cases smaller particles adhere on the surface of bigger ones so an ideal, very sharp size separation is never obtained. The higher the movement results the higher the chance that all particles can pass the aperture (Merkus, 2009, pp. 224-225).

2.3 Crushing

Crushing is a particle size reduction can be performed for solids, liquids and gases. The two main procedures for solid materials are crushing and grinding. The aim of crushing can be to increase the surface, transportability, separation of unwanted components, ability of dosage and particle size distribution. The particles held together by the force of compounds, to reduce the size of the particles a higher forces than these are needed. That is the reason in particle size reduction a high amount of energy is needed. A reduction is technically limited because very small particles would agglomerate in processing. Agglomeration is the accumulation of small particles to a bigger one (Schwister & Leven, 2013, p. 197).
2.4 Loss on ignition

The determination of the rates of organic and inorganic compounds is realized by the help of loss on ignition. Therefore a sample has to be burned at a defined temperature for a specific time. The mass fraction left, after the amount of organic matters is reduced to ashes, is called “residue on ignition” and is the rate of inorganic compounds. The process ends when the sample achieved a constant mass. After cool down in a desiccator, the mass of inorganic parts can be weighed (EN 15169, 2007, p. 7; Bank, 2007, p. 802).

2.5 Gross calorific value

For an implementation in incinerating plants the gross calorific value and net calorific value are important data. This value is caused by bomb calorimeters where the enthalpy of combustion for hydrocarbons is determined (Polik, n.d.). The bomb calorimeters consist basically of an ignition unit, a stirrer, the bomb, a thermometer and a dewar vessel (Figure 6).

The sample is placed in the combustion bomb which is oxygen pressured. The closed bomb has to be placed in the dewar vessel and is surrounded by water. The stirrer is needed to ensure that the temperature is the same in the whole dewar vessel. By starting the process the timer starts and the displayed temperature has to be recorded. After a “Pre Period” where the temperature compensate the sample has to be ignited by the ignition unit. The organic components of the sample begin to burn and according to the type of sample and the amount of hydrocarbons the water temperature will rise more or less. After this “Rise Period” follows the “Post Period” where the temperature will discontinue rising (CEN/TS 16023, 2013).

Figure 2 Bomb calorimeter (Polik, n.d.)
3 MATERIALS AND METHODS

For analyzing the waste, EN based analyses were done in order to know the basic physical characteristics of the waste. These include the dry residue (EN 14346, 2006), contents in different particle sizes (EN 933, 1995), loss on ignition (EN 15169, 2007) and the gross calorific value (CEN/TS 16023, 2013) which were determined.

3.1 Sampling

A norm based sampling (CEN/TR 15310-4, 2006; EN 14899, 2005) in the backyard of the company “Delete Finland Oy” in Tampere was fulfilled on the 19\textsuperscript{th} February. Due to the volume amount of waste, 8 single samples and 2 mixed samples were obtained (LAGA PN 98, 2004, p. 18). The samples are collected in 5 litre plastic cups (LAGA PN 98, 2004, p. 26) and stored at 4 ± 2 °C in darkness and under refrigeration (CEN/TR 15310-4, 2006, p. 14). All parameters of sampling are registered in the sample record (Appendix 1. Sample record).

3.2 Dry residue

The method of determining the dry residue depends on the type of sample that needs to be analysed, in case of waste samples, the European Standard EN 14346 (EN 14346, 2006) is used in analysis. It contains two principles of analyses which are dependent on volatile components. Organic compounds are volatile, if they reach at a temperature of 293,15 K (20 °C) a steam pressure with the amount of 0,01 kPa or higher and show volatility under application terms (31. BImSchV, 2007, p. 3). To get the best results a small particle size is needed, that the amount of heat is evenly distributed on the surface of the solid materials.

Method A, should be uses if waste does not contain volatile matters. Then the sample is dried, in the oven on 105 ± 3 °C overnight to a constant mass. The difference in mass in- and output is the amount of moisture removed by the warm air.
Method B is the Karl-Fischer-titration and is used to measure the water content of a sample. The principle is usually used for liquid samples. In case of solid samples, in which volatile compounds are expected, it contains an extraction of the sample by using of methanol (EN 14346, 2006, p. 6).

Despite the fact that volatile compounds are expected Method A was used, because of unavailable equipment for the Karl-Fischer titration. The temperature was set on 55 °C in fact that materials with a melting point about 100 °C, like polystyrene, were existent.

The following formulas (EN 14346, 2006, pp. 7-8), for the calculation of results, are related to Method A.

For reliability of the results an additional measurement was performed, where the loss on moisture is determined over time (Figure 11). This is a suggestive measurement to show that after a specific amount of time the samples do not get drier anymore. Therefore 9 samples of mixed sample no. 9 are used and dried. Every 2 hours a sample is weighed to determine the dry residue.

\[
(1) \quad w_{dr} = \frac{(m_c-m_a)}{(m_b-m_a)} \ast f
\]

where

- \( w_{dr} \) is the dry residue of the sample, expressed as mass fraction in per cent [%] or in grams per kilogram [g/kg];
- \( m_a \) is the mass of the empty dish or crucible, expressed in grams [g];
- \( m_b \) is the mass of the dish or crucible containing the sample, expressed in grams [g];
- \( m_c \) is the mass of the dish or crucible containing the dried sample, expressed in grams [g];
- \( f \) is the conversion factor \( f = 100 \) for expression of results as mass fraction in per cent [%] and \( f = 1000 \) for expression of results in grams per kilogram [g/kg].
3.3 Sieving

For the screening process during the laboratory analyses sieves with standard based mesh openings of 4, 8, 16, 31.5 mm are used (Figure 18). Mass percentage of different size classes of the waste was determined in order to see if there were any differences in the waste composition in different size classes.

The following formulas are necessary for particle size distribution, density distribution, passage etc.

\[
\Delta Q_{3,i} = \frac{\Delta m}{m} \times f
\]

where
\[
\Delta Q_{3,i} \quad \text{is the mass percentage rate of the mass portion left on the sieve [%];}
\]
\[
\Delta m \quad \text{is the mass portion left in grams [g];}
\]
\[
m \quad \text{is the sum of all mass portions in grams [g];}
\]
\[
f \quad \text{is the conversion factor } f = 100 \text{ for expression of results as mass fraction in per cent [%].}
\]

\[
P = \Sigma_{i}^{i} \Delta Q_{3,i}
\]

where
\[
P \quad \text{is the sum of the mass percentage rate from sieve 1 to i expressed in percent [%];}
\]
\[
\Delta Q_{3,i} \quad \text{is the mass percentage rate of the mass portion left on the sieve [%]}
\]
(4) \( R = 100 - P \)

where

- \( R \) is the residue dependent on the current passage expressed in percent [\%];
- \( P \) is the sum of the mass percentage rate from sieve 1 to \( i \) expressed in percent [\%].
3.4 Crushing

For the measurements of dry residue, loss on ignition and gross calorific value the particles of the samples are crushed to a smaller particle size (EN 14346, 2006, p. 5). On hand are two kind of crushing machines, a jaw crusher and a cutting mill. The jaw crusher (Figure 2) chops the material in between the jaw liners. One of them is a fixed jaw the other is connected to a flywheel which is moving the jaw against the fixed one. The out coming particle size is set by the gap at the lower end of the jaws. The cutting mill (Figure 4) chops via shearing by the help of blades, which rotating with high speed. Due to the fact that the determination of the dry residue has to be done with small sized particles, the waste has to be crushed with the moisture content. This brings waste stuck in the machines. In case of a treating process the waste is needed in these small particle sizes it’s advisable to dry it beforehand.
3.5 Loss on ignition

According to the EN 15169 (EN 15169, 2007) the dried sample has to be burned at a temperature of 550 ± 25 °C for at least 20 min.

The formula for calculation of the loss on ignition can be found in the European Norm 15169 in chapter 10.2, the result is stated in percent.

\[
W_{LOI} = \left( \frac{m(d) - m(c)}{m(d) - m(a)} \right) \times 100
\]

where

- \( W_{LOI} \) is the loss on ignition of the sample in percent of the dry residue or water-free sample [%];
- \( w_w \) is the water content of the sample in percent [%];
- \( m(a) \) is the mass of the empty crucible in grams [g];
- \( m(c) \) is the mass of the crucible containing the ignition residue in grams [g];
- \( m(d) \) is the mass of the crucible containing the dried sample in grams [g].

The residue of ignition is the reciprocal of the loss on ignition.

\[
W_{ROI} = 100 - W_{LOI}
\]

where

- \( W_{LOI} \) is the loss on ignition of the sample in percent of the dry residue or water-free sample [%];
- \( W_{ROI} \) is the residue on ignition of the sample in percent of the dry residue or water-free sample [%].
3.6 Gross calorific value

For the measurements of gross calorific value the “1341 Plain Jacket Bomb Calorimeter” from the “Parr Instrument Company” is used. 3 subsamples of mixed waste sample no. 9 and 10 were used to obtain the results. Mixed waste samples were used to have components of all types of material. The sample of about 0.7 g was oxygen pressured at 30 bar in the combustion bomb. The dewar vessel was filled with 2 kg water with a temperature of 20 - 21 °C. After starting the process the temperature was noted every minute (CEN/TS 16023, 2013). Before the measurements the effective heat capacity of the calorimeter is determined by standardization with a certified benzoic acid pellet. The process is similar as the usual process mentioned in “1.3.5Gross calorific value”, the only difference is the calculation because the gross calorific value of benzoic acid pellet is known.

By the following formulas the gross calorific value is determined.

\[
\Delta T = T_F - T_I
\]

where

- \( \Delta T \) is the temperature rise, in Kelvin (K);
- \( T_F \) is the final temperature, in °C;
- \( T_I \) is the initial temperature, in °C.

\[
\varepsilon = \frac{m_{ba} \cdot q_{V,ba}}{\Delta T}
\]

where

- \( \varepsilon \) is the effective heat capacity of the calorimeter as determined in the calibration, in Joules per Kelvin (J/K);
- \( m_{ba} \) is the mass of benzoic acid, in grams (g);
- \( q_{V,ba} \) is the certified gross calorific value of benzoic acid at constant volume, in Joules per gram (J/g);
- \( \Delta T \) is the temperature rise, in Kelvin (K).
(9) \( q_{V,gr} = \frac{\varepsilon \Delta T}{m_1} \)

where

\( q_{V,gr} \) is the gross calorific value at constant volume of the sample as analysed, in Joules per gram (J/g);

\( \varepsilon \) is the effective heat capacity of the calorimeter as determined in the calibration, in Joules per Kelvin (J/K);

\( \Delta T \) is the temperature rise, in Kelvin (K);

\( m_1 \) is the mass of the waste sample, in grams (g).

(10) \( q_{V,gr,d} = q_{V,gr} \times \frac{100}{100-M_{ad}} \)

where

\( q_{V,gr,d} \) is the gross calorific value at constant volume of the dry sample, in Joules per gram (J/g);

\( q_{V,gr} \) is the gross calorific value at constant volume of the sample as analysed, in Joules per gram (J/g);

\( M_{ad} \) is the moisture content in the analysis sample, in percent by mass (%).
4 RESULTS

4.1 Sampling

The Table 1 shows a sample record of the samples taken on 19th of February on the yard of the company “DELETE Finland Oy”. Apparent from the wide range of weight is the difference in composition of the head of waste also visible in “Figure 7 Head of mixed construction site waste”. The mean density of the waste is about 0,4 g/cm³. The temperature of the head of waste when samples were taken was -0,5 °C.

Table 1 Sample record

<table>
<thead>
<tr>
<th>Sample Nr.</th>
<th>Type of sample [SS/MS/GS]</th>
<th>Specimen cup</th>
<th>Sample volume</th>
<th>Weight without specimen cup</th>
<th>Density [g/cm³]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SS plastic</td>
<td>5</td>
<td>1,8464</td>
<td>0,3693</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>SS plastic</td>
<td>5</td>
<td>1,8020</td>
<td>0,3604</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>SS plastic</td>
<td>5</td>
<td>1,0056</td>
<td>0,2011</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>SS plastic</td>
<td>5</td>
<td>1,9708</td>
<td>0,3942</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>SS plastic</td>
<td>5</td>
<td>2,7100</td>
<td>0,5420</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>SS plastic</td>
<td>5</td>
<td>1,8726</td>
<td>0,3745</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>SS plastic</td>
<td>5</td>
<td>1,4150</td>
<td>0,2830</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>SS plastic</td>
<td>5</td>
<td>2,6106</td>
<td>0,5221</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>MS plastic</td>
<td>5</td>
<td>1,9736</td>
<td>0,3947</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>MS plastic</td>
<td>5</td>
<td>2,3352</td>
<td>0,4670</td>
<td></td>
</tr>
</tbody>
</table>

Figure no. 7 shows the head of mixed construction site waste where samples were obtained. The difference in colours of the waste shows that components are not evenly distributed and mixed waste samples are necessary for reliable results.
In figure no. 8 a mixed waste sample is represented. Clearly recognizable is the big range in sizes and composition. Figure no. 9 exhibits the norm based storage of the waste samples in the refrigerator.
4.2 Dry residue

The following table shows the data recorded for the measurements of dry residue. About 5 g of each sample were used to determine the value. The temperature of 55 °C was used to dry the samples.

<table>
<thead>
<tr>
<th>Sample/crucible</th>
<th>Weight crucible bone-dry [g]</th>
<th>Weighed portion [g]</th>
<th>Weight crucible + waste [g]</th>
<th>Weight crucible + waste bone-dry [g]</th>
<th>Dry residue of sample [%]</th>
<th>Water content of sample [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>52.7205</td>
<td>5.0141</td>
<td>57.7346</td>
<td>56.3993</td>
<td>73.37</td>
<td>26.63</td>
</tr>
<tr>
<td>2</td>
<td>54.0698</td>
<td>5.0318</td>
<td>59.1016</td>
<td>57.7609</td>
<td>73.36</td>
<td>26.64</td>
</tr>
<tr>
<td>3</td>
<td>53.3723</td>
<td>5.0089</td>
<td>58.3812</td>
<td>57.1265</td>
<td>74.95</td>
<td>25.05</td>
</tr>
<tr>
<td>4</td>
<td>56.3589</td>
<td>5.0335</td>
<td>61.3924</td>
<td>60.0145</td>
<td>72.63</td>
<td>27.37</td>
</tr>
<tr>
<td>5</td>
<td>52.1950</td>
<td>5.0219</td>
<td>57.2169</td>
<td>55.9803</td>
<td>75.38</td>
<td>24.62</td>
</tr>
<tr>
<td>6</td>
<td>56.6485</td>
<td>5.0711</td>
<td>61.7196</td>
<td>60.3339</td>
<td>72.67</td>
<td>27.33</td>
</tr>
<tr>
<td>7</td>
<td>54.1144</td>
<td>5.0203</td>
<td>59.1347</td>
<td>57.7263</td>
<td>71.95</td>
<td>28.05</td>
</tr>
<tr>
<td>8</td>
<td>54.1776</td>
<td>5.0054</td>
<td>59.1830</td>
<td>57.9902</td>
<td>76.17</td>
<td>23.83</td>
</tr>
<tr>
<td>9</td>
<td>55.7349</td>
<td>5.0166</td>
<td>60.7515</td>
<td>59.4374</td>
<td>73.80</td>
<td>26.20</td>
</tr>
<tr>
<td>10</td>
<td>51.4789</td>
<td>5.0414</td>
<td>56.5203</td>
<td>55.2024</td>
<td>73.86</td>
<td>26.14</td>
</tr>
</tbody>
</table>

Calculation of dry residue with subsample no. 1:

\[(1) \, w_{dr} = \left( \frac{m_c - m_a}{m_b - m_a} \right) \times f = \left( \frac{56.3993 \, g - 52.7205 \, g}{57.7346 \, g - 52.7205 \, g} \right) \times 100 = 73.37 \% \]
In “Figure 10 Dry Residue of Samples” a mean value of about 74 % dry residue is shown. Nearly the same dry residue is clearly visible for mixed waste samples no. 9 and 10. To rely on those results an additional measurement of the dry residue is done (Figure 11 Dry Residue of Samples over Time).
In due consideration the samples could not dry at the temperature mentioned in the European Standard EN 14346 a reliability measurement of the samples is needed. Therefore around 5 g of mixed waste sample no. 9 are used for each crucible and were dried for a specific time.

Table 3 Dry residue of samples over time

<table>
<thead>
<tr>
<th>Crucible</th>
<th>Time [h]</th>
<th>Weight crucible bone-dry [g]</th>
<th>Weighed portion [g]</th>
<th>Weight crucible + waste [g]</th>
<th>Weight crucible + waste after Δt [g]</th>
<th>Dry residue of sample [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>56,2789</td>
<td>5,0162</td>
<td>61,2951</td>
<td>60,1272</td>
<td>76,72</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>56,0016</td>
<td>5,0139</td>
<td>61,0155</td>
<td>59,7955</td>
<td>75,67</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>52,9441</td>
<td>5,0067</td>
<td>57,9508</td>
<td>56,6394</td>
<td>73,81</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>51,2457</td>
<td>5,0184</td>
<td>56,2641</td>
<td>54,9432</td>
<td>73,68</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>54,1007</td>
<td>5,0028</td>
<td>59,1035</td>
<td>57,7823</td>
<td>73,59</td>
</tr>
<tr>
<td>6</td>
<td>12</td>
<td>54,9096</td>
<td>5,0172</td>
<td>59,9268</td>
<td>58,5873</td>
<td>73,30</td>
</tr>
<tr>
<td>7</td>
<td>14</td>
<td>51,6786</td>
<td>5,0734</td>
<td>56,752</td>
<td>55,4111</td>
<td>73,57</td>
</tr>
<tr>
<td>8</td>
<td>16</td>
<td>54,6988</td>
<td>5,014</td>
<td>59,7128</td>
<td>58,4265</td>
<td>74,35</td>
</tr>
<tr>
<td>9</td>
<td>18</td>
<td>54,2723</td>
<td>5,0017</td>
<td>59,274</td>
<td>57,9512</td>
<td>73,55</td>
</tr>
</tbody>
</table>

Apparent from “Figure 11 Dry residue of samples over time” a drying process of 6 hours is enough to rely on the results shown in “Figure 10 Dry residue of samples”. The samples are not going to dry noticeable anymore after that time. The peak, at the sample taken out of the oven after 16 hours of drying, can be attributed to the fact that only a small amount of waste is allowed for the measurements and the samples are not as homogenous as required for them. A piece of glass for example, what only could bind water on his surface, can increase the weight of the sample by shrinking the loose of water during the drying process.
Figure 11 shows the laboratory furnace used for the analyses of dry residue. The flattened crucibles are suggestive to have a bigger surface of the waste samples. The drying gas can reach more particles what simplifies the drying process.

Figure 11 Dry residue of samples over time

Figure no. 12 shows the laboratory furnace used for the analyses of dry residue. The flattened crucibles are suggestive to have a bigger surface of the waste samples. The drying gas can reach more particles what simplifies the drying process.

Figure 12 Laboratory furnace
4.3 Sieving

To show the particle size distribution 1 kg of the mixed waste sample no. 9 is sieved by the help of laboratory sieves shown in figure no. 13. Mixed sample no. 9 is used to ensure a distribution of any kind of material the waste consists.

Figure 13 Laboratory sieves and sample
The sum of masses in “Table 4 Particle Size Distribution” shows the amount of 998.1 g. The missing 1.9 g of waste are lost during the shaking process and left on the surfaces of the sieves. Furthermore the mass percentage rate, passage and residue are expressed by the Formulas 2-4. Considering Table 4 the mass percentage rate $\Delta Q_{3,i}$ is nearly the same in every size portion.

**Table 4 Particle size distribution after sieving**

<table>
<thead>
<tr>
<th>No.</th>
<th>Mesh-opening</th>
<th>Mass-portion</th>
<th>Mass percentage rate</th>
<th>Interval wideness</th>
<th>Passage</th>
<th>Residue</th>
</tr>
</thead>
<tbody>
<tr>
<td>i,j</td>
<td>$x_i$</td>
<td>$\Delta m$</td>
<td>$\Delta Q_{3,i}$</td>
<td>$\Delta x_i$</td>
<td>$P$</td>
<td>$R$</td>
</tr>
<tr>
<td></td>
<td>[mm]</td>
<td>[g]</td>
<td>[%]</td>
<td>[mm]</td>
<td>[%]</td>
<td>[%]</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0,00</td>
<td>100</td>
<td>00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>231,8</td>
<td>23,22</td>
<td>4,00</td>
<td>23,22</td>
<td>76,78</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>199,6</td>
<td>20,00</td>
<td>4,00</td>
<td>43,22</td>
<td>56,78</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>339,9</td>
<td>34,05</td>
<td>8,00</td>
<td>77,28</td>
<td>22,72</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>226,8</td>
<td>22,72</td>
<td>15,50</td>
<td>100</td>
<td>0,00</td>
<td></td>
</tr>
<tr>
<td></td>
<td>31,50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sum $m = 998.1$ g

Calculation of mass proportion with subsample no.1:

(2) $\Delta Q_{3,i} = \frac{\Delta m}{m} \times f = \frac{231.8 \, g}{998.1 \, g} \times 100 = 23.22 \%$

(3) $P = \sum_i \Delta Q_{3,i} = 23.22 \%$

(4) $R = 100 - P = 100 - 23.22 \% = 76.78 \%$
In “Figure 14 Particle size distribution of mixed waste sample” the passage and residue are plotted against the mesh opening sizes. At that point where curves intersect is a mean particle sizes of approximately 9 mm to read.

![Particle Size Distribution](image)

**Figure 14 Particle size distribution of mixed waste sample**

The residues on the sieves, shown in ”Figure 15 Waste sample in different size classes after sieving” below, are analysed on their contents.

![Waste sample in different size classes after sieving](image)

**Figure 15 Waste sample in different size classes after sieving**
The results of the analyses of contents is recorded in “Table 5 Distribution of Mass Percentage” and represented in the figures 16-19. All of these figures are contrast in “Figure 20 The proportion of the waste components in different size classes”. In that figure is to see that in every size portion the distribution of contents is nearly the same expect parts lower than 4 mm, which is based on the fact that the sorting has to be done by eye therefore not so accurate.

Table 5 Distribution of sieve residues in mass percentage

<table>
<thead>
<tr>
<th>Meshopening</th>
<th>&lt;4 mm</th>
<th>4 mm</th>
<th>8 mm</th>
<th>16 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g</td>
<td>%</td>
<td>g</td>
<td>%</td>
</tr>
<tr>
<td>Residue</td>
<td>231.8</td>
<td>23.2</td>
<td>199.6</td>
<td>20.0</td>
</tr>
<tr>
<td>Wood</td>
<td>12.6</td>
<td>5.5</td>
<td>16.4</td>
<td>8.3</td>
</tr>
<tr>
<td>Polystyrene</td>
<td>0.8</td>
<td>0.3</td>
<td>1.1</td>
<td>0.6</td>
</tr>
<tr>
<td>Paper, Board, etc.</td>
<td>0.7</td>
<td>0.3</td>
<td>6.6</td>
<td>3.3</td>
</tr>
<tr>
<td>Expanding foam etc.</td>
<td>4</td>
<td>1.7</td>
<td>6.9</td>
<td>3.5</td>
</tr>
<tr>
<td>Gypsum</td>
<td>8.1</td>
<td>3.5</td>
<td>76.8</td>
<td>38.5</td>
</tr>
<tr>
<td>Glass</td>
<td>5.3</td>
<td>2.3</td>
<td>9.2</td>
<td>4.6</td>
</tr>
<tr>
<td>Concrete, Bricks, Sand</td>
<td>200.3</td>
<td>86.4</td>
<td>82.3</td>
<td>41.2</td>
</tr>
</tbody>
</table>
Figure 16 Distribution of different waste components in particle size < 4 mm

Figure 17 Distribution of different waste components in particle size 4 mm
Figure 18 Distribution of different waste components in particle size 8 mm

Figure 19 Distribution of different waste components in particle size 16 mm
Figure 20 The proportion of the waste components in different size classes
4.4 Loss on ignition

Table 6 shows the loss on ignition of water-free samples. About 4 g of each sample were used. The samples were dried before in an oven at 55 °C. The results are expressed in percent with a mean value about 29 % (Figure 21 Loss on ignition of water-free samples) of organic material. According to the waste framework directive the value of is high since it have to be assure that the waste is treated as best as possible (EUROPEAN COMMISSION, 2011)

<table>
<thead>
<tr>
<th>Sample</th>
<th>Mass of empty crucible</th>
<th>Mass of crucible containing dried sample</th>
<th>Mass of crucible containing ignition residue</th>
<th>Loss on ignition of water-free samples</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( m_a ) [g]</td>
<td>( m_d ) [g]</td>
<td>( m_c ) [g]</td>
<td>( W_{LOI} ) [%]</td>
</tr>
<tr>
<td>1</td>
<td>39,3587</td>
<td>43,0495 g</td>
<td>42,1632</td>
<td>24,0</td>
</tr>
<tr>
<td>2</td>
<td>39,8397</td>
<td>43,534 g</td>
<td>42,5774</td>
<td>25,9</td>
</tr>
<tr>
<td>3</td>
<td>40,1078</td>
<td>43,9774 g</td>
<td>42,7209</td>
<td>32,5</td>
</tr>
<tr>
<td>4</td>
<td>39,3952</td>
<td>43,0637 g</td>
<td>42,0208</td>
<td>28,4</td>
</tr>
<tr>
<td>5</td>
<td>41,0361</td>
<td>44,817 g</td>
<td>43,8792</td>
<td>24,8</td>
</tr>
<tr>
<td>6</td>
<td>37,9185</td>
<td>41,6116 g</td>
<td>40,1855</td>
<td>38,6</td>
</tr>
<tr>
<td>7</td>
<td>38,4464</td>
<td>42,0701 g</td>
<td>40,6732</td>
<td>38,5</td>
</tr>
<tr>
<td>8</td>
<td>37,6861</td>
<td>41,508 g</td>
<td>40,6606</td>
<td>22,2</td>
</tr>
<tr>
<td>9</td>
<td>40,7738</td>
<td>44,4513 g</td>
<td>43,2881</td>
<td>31,6</td>
</tr>
<tr>
<td>10</td>
<td>36,6753</td>
<td>40,4838 g</td>
<td>39,5137</td>
<td>25,5</td>
</tr>
</tbody>
</table>

Calculation of loss on ignition wit subsample no. 1:

\[
(5) W_{LOI} = \left( \frac{m_d - m_c}{m_d - m_a} \right) \times 100 = \left( \frac{43,0495 \text{ g} - 42,1632 \text{ g}}{43,0495 \text{ g} - 39,3587 \text{ g}} \right) \times 100 = 24 \% 
\]
The results in “Figure 21 Loss on ignition of water-free samples” vary a lot. This is based on the different composition of the waste samples. Samples with a high value of loss on ignition (sample no. 6 and 7) comprised more organic material than others.
4.5 Gross calorific value

Based on the high amount of organic material the gross calorific value is measured to take a look if an implementation in incinerating plants is possible.

Table no. 7 and Figure no. 22 show the temperature record of the samples during the tests. For the measurements 3 samples of each mixed waste sample were evaluated. Each sample placed in the combustion bomb had a weight about 0,7 g.

<table>
<thead>
<tr>
<th>sample</th>
<th>9.1</th>
<th>9.2</th>
<th>9.3</th>
<th>10.1</th>
<th>10.2</th>
<th>10.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>mass</td>
<td>0,685</td>
<td>0,667</td>
<td>0,704</td>
<td>0,666</td>
<td>0,706</td>
<td>0,683</td>
</tr>
<tr>
<td>0</td>
<td>21,428</td>
<td>21,929</td>
<td>21,69</td>
<td>21,321</td>
<td>21,532</td>
<td>21,236</td>
</tr>
<tr>
<td>1</td>
<td>21,426</td>
<td>21,931</td>
<td>21,69</td>
<td>21,324</td>
<td>21,534</td>
<td>21,237</td>
</tr>
<tr>
<td>2</td>
<td>21,417</td>
<td>21,953</td>
<td>21,691</td>
<td>21,324</td>
<td>21,535</td>
<td>21,238</td>
</tr>
<tr>
<td>3</td>
<td>21,413</td>
<td>21,964</td>
<td>21,692</td>
<td>21,325</td>
<td>21,535</td>
<td>21,238</td>
</tr>
<tr>
<td>4</td>
<td>21,405</td>
<td>21,97</td>
<td>21,692</td>
<td>21,326</td>
<td>21,536</td>
<td>21,239</td>
</tr>
<tr>
<td>5</td>
<td>21,397</td>
<td>21,97</td>
<td>21,692</td>
<td>21,326</td>
<td>21,536</td>
<td>21,239</td>
</tr>
<tr>
<td>6</td>
<td>21,444</td>
<td>22,137</td>
<td>21,831</td>
<td>21,422</td>
<td>21,653</td>
<td>21,367</td>
</tr>
<tr>
<td>7</td>
<td>21,579</td>
<td>22,233</td>
<td>21,97</td>
<td>21,543</td>
<td>21,787</td>
<td>21,483</td>
</tr>
<tr>
<td>8</td>
<td>21,624</td>
<td>22,241</td>
<td>22,02</td>
<td>21,547</td>
<td>21,862</td>
<td>21,494</td>
</tr>
<tr>
<td>9</td>
<td>21,643</td>
<td>22,252</td>
<td>22,043</td>
<td>21,553</td>
<td>21,876</td>
<td>21,506</td>
</tr>
<tr>
<td>10</td>
<td>21,647</td>
<td>22,259</td>
<td>22,051</td>
<td>21,555</td>
<td>21,877</td>
<td>21,509</td>
</tr>
<tr>
<td>11</td>
<td>21,647</td>
<td>22,262</td>
<td>22,056</td>
<td>21,558</td>
<td>21,889</td>
<td>21,51</td>
</tr>
<tr>
<td>12</td>
<td>21,639</td>
<td>22,263</td>
<td>22,058</td>
<td>21,559</td>
<td>21,889</td>
<td>21,51</td>
</tr>
<tr>
<td>13</td>
<td>21,637</td>
<td>22,264</td>
<td>22,059</td>
<td>21,56</td>
<td>21,889</td>
<td>21,509</td>
</tr>
<tr>
<td>14</td>
<td>21,633</td>
<td>22,263</td>
<td>22,059</td>
<td>21,562</td>
<td>21,888</td>
<td>21,509</td>
</tr>
<tr>
<td>15</td>
<td>21,632</td>
<td>22,262</td>
<td>22,059</td>
<td>21,562</td>
<td>21,888</td>
<td>21,509</td>
</tr>
</tbody>
</table>
Figure 22 Gross calorific value (temperature record)

Calculation for standardization:

\[(8) \epsilon = \frac{m_{ba}q_{v,ba}}{\Delta T} = \frac{1.033 \, g \cdot 6318 \, \text{cal} \, g}{(23.527^\circ C - 20.858^\circ C)} = 2445.3 \, \text{cal} \, ^\circ C\]

Calculation for gross calorific value with subsample 9.1:

\[(7) \Delta T = T_F - T_I = 21.647^\circ C - 21.397^\circ C = 0.25^\circ C\]

\[(9) q_{v,gr} = \frac{\epsilon \Delta T}{m_1} = \frac{2445.3 \, \text{cal} \, ^\circ C \cdot 0.25^\circ C}{0.685 \, g} = 892.45 \, \text{cal} \, g = 3.74 \, \text{Mj} \, \text{kg}^{-1}\]

\[(10) q_{v,gr,d} = q_{v,gr} \cdot \frac{100}{100 - M_{ad}} = 3.74 \, \text{Mj} \, \text{kg}^{-1} \cdot \frac{100}{100 - 26.19} = 5.067 \, \text{Mj} \, \text{kg}^{-1}\]
The mean value of the dry samples, shown in Table 8, is about 6 MJ/kg which is a low amount compared to wastes from other sources like household wastes, which consist of a higher amount of organic material (Rand, et al., 2000, p. 6). The lower the gross calorific value is, the lower the efficiency of the combustion process. Consequently the producing costs of energy are higher for the companies (Rand, et al., 2000, p. 29). For an implementation the lower calorific is important to know. The calculation is not done at this point because in case of mixed waste samples the annex of the standard is too vague with moisture content (CEN/TS 16023, 2013, p. 24).

Table 8 Gross calorific value

<table>
<thead>
<tr>
<th></th>
<th>9.1</th>
<th>9.2</th>
<th>9.3</th>
<th>10.1</th>
<th>10.2</th>
<th>10.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>qv,gr</td>
<td>3.74</td>
<td>4.51</td>
<td>5.34</td>
<td>3.61</td>
<td>5.12</td>
<td>4.06</td>
</tr>
<tr>
<td>qv,gr,d</td>
<td>5.06</td>
<td>6.11</td>
<td>7.23</td>
<td>4.92</td>
<td>6.94</td>
<td>5.50</td>
</tr>
</tbody>
</table>

Mean value 4.40 MJ/kg
Mean value dry 5.96 MJ/kg

Figure 23 Calorimeter  Figure 24 Oxygen combustion bomb

Figure no. 23 shows the dewar vessel with the engine on the left side which moves the stirrer. The oxygen combustion bomb with a placed mixed waste sample is visible in figure no. 24.
5 DISCUSSION

The water content of 26 % is considering the high amount of organic material (29 %), determined in “4.4 Loss on ignition analyses”, an acceptable value. Just a sieving process would not bring any benefits, since in every particle size nearly the same mass percentage rates are existent. To separate the material in the single components would be an inefficient process. The energy amount needed would be higher than the benefits of reuse single components in this particle size. That is the reason an implementation in an incinerating power plant is advisable.

In this process the organic components basically combust to produce energy. The inorganic left over can be reused in road works or implemented in cement industries (“1.3 Management options”). Regarding the gypsum the waste contains, state-of-the-art technology with a flue gas desulfurization plant is needed. The research resulted in that most of the Finnish companies are equipped with those. In view of the gross calorific value, an important data for the implementation in incinerating power plants is to say that about 6 MJ/kg is compared with other types of waste, for example household wastes, a relatively low amount (Rand, et al., 2000, p. 6). That is the reason information was sought from the “Westenergy” company in Vaasa. In general the amount organic material and the gross calorific value are high enough to implement the mixed waste in an incinerating power plant a responsible of the company assured. Unfortunately the “Westenergy” plant only is allowed to burn waste from their own company group. Moreover, a grade firing as a combustion technique is necessary since the inorganic material would afford abrasion in a fluidized firing process.

To raise the low energy content, which is based on a high inorganic amount, it is either possible to mix it with higher energetic waste or to differ the organic and inorganic matter beforehand. This can be achieved by a sieving and air separation machine. The air separation differs by the help of different flow resistances and densities.

By mixing the waste with higher energetic waste the company could get rid of the whole waste but most companies obviously do not like a high inorganic content because it reduce the efficiency of their process and increase the amount of hot bottom slag. If a previous sieving and air separation would be used, a higher gross calorific value can be achieved and a grade firing is not needed anymore what opens more application possibilities.
In conclusion an investment in a wind shifter would bring many benefits. In appendix 2 an offer of the Dutch company “Redox Recycling Systems” is available. They told that, by the help of their equipment, the separation of concretes and gypsum is also possible whether they can have nearly the same density. In case it is inoperative, an attrition drum can be added afterwards. The drum is comparable with a washing machine. The material will scrub on each other and the surface of the drum and will chop to smaller parts. This basically works due to different shredding resistances.

The dual lane wind shifter RSB 1600/2 (Appendix 2. Dual lane wind shifter information) with a 10 m feeding belt can manufacture a volume of 30 T/h. So when we assume a 5 days week, with 8 hours per day, the equipment can manage 57600 T/a (calculation no. 11).

\[
\dot{m} = 30 \frac{T}{h} \times 8 \frac{h}{d} \times 5 \frac{d}{week} \times 4 \frac{weeks}{month} \times 12 \frac{months}{a} = 57600 \frac{T}{a}
\]

Even the description say that it is dimensioned for an input material of wood, paper and cardboard and the material size should be in between 3/4” – 6” the company (p.p. Peter Verstraaten; Sales Support) assured that the current waste can be utilized. The dual lane wind shifter separates, by use of a sieve, the material in two size portions and wind shift them afterwards. The previous sieving is necessary due to the wide range of particle sizes.

The aboriginal costs of this device would be 130.500 €, precise commercial details are available in “Appendix 2 Dual lane wind shifter information”. The running costs of the device are mainly energy costs about 3500 €/a (calculation no. 12). For the calculation the costs of 0,066 €/kWh (Statistics Estonia, 2015) and the details of one 4 kW, two 11 kW and one 1,5 kW engine (Appendix 2 Dual lane wind shifter information) were used.

The maintenance costs are low, further particulars the company could not state.
The investment costs are comparatively small considering there is annually about 20,000 T of waste to be treated, and to bring it to landfill costs them about 136 €/T (Pirkanmaan Jätehuolto Oy, 2015).

(13) \[ 20,000 \frac{T}{a} \times 136 \frac{€}{T} = 2,720,000 \frac{€}{a} \]

Furthermore the transportation of the waste has to be dissected. If a separation of organic and inorganic material is fulfilled the transport costs would not differ from the current ones of about 17,000 €/a (calculation no. 13). This based on the fact that road works are everywhere ubiquitous local customers can be found for the inorganic material of 14,200 T/a (71 % of 20,000 T/a), the other option is cement industry. For the organic material of 5,800 T/a (29 % of 20,000 T/a) the incinerating plant in Tampere can be a costumer. The factory is at the moment in building phase (Waste Management World, 2015). Even the fact grade firing will be available, where the complete mixed waste could be implemented, they not stated at the moment if they are allowed to take the waste from this sources. A separation is suggestive in any case. The transportation ways should be as short as possible, not only because of the costs also from environmental point of view to save fossil fuels and decrease the CO2 emission. The costs are calculated by the help of the mean density of 400 kg/m³, a distance of about 15 km to landfill, the amount of 20,000 T/a of waste, assuming that a 40 m³ container is used for transportation and the costs are about 0,90 €/km (Hovila, 2015).

(14) \[ 400 \frac{kg}{m^3} \times 40 \frac{m^3}{Container} = 16,000 \frac{kg}{Container} \]

\[ \frac{20,000,000 \frac{kg}{a}}{16,000 \frac{kg}{Container}} = 1.250 \frac{Container}{a} \]

\[ 15 \frac{km}{Container} \times 0.90 \frac{€}{km} \times 1250 \frac{Container}{a} = 16,875 \frac{€}{a} \]
In comparison the investment and running costs in the first year of about 134,000 € are incommensurate with the current costs of 2,720,000 € annually to bring it to landfill. The running costs do not include the sale of organic and inorganic material. Advisable for the company DELETE at this point is to ask several potential customers about prices for taking the waste and if there are specific requirements needed. These prices have to be added to the running costs and afterwards compared with the 2,720,000€, if the costs are lower than this value a purchase of the recommended equipment should be definite follow.
6 REFERENCES


FRANCE ETUVES SARL, 2010. *FRANCE ETUVES SARL Designer and Manufacturer of Laboratory and Industrial Ovens.* [Online]


APPENDICES

Appendix 1. Sample record

<table>
<thead>
<tr>
<th>Sampling Record</th>
<th></th>
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<tbody>
<tr>
<td>Sample Code: 11/2/15</td>
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</tr>
<tr>
<td>General Information</td>
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</tr>
<tr>
<td>Waste producer:</td>
<td>DELETE CONSTRUCTION SITE</td>
</tr>
<tr>
<td>Contact:</td>
<td></td>
</tr>
<tr>
<td>Location of sampling:</td>
<td>DELETE BILLYARD</td>
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<tr>
<td>Reason of sampling:</td>
<td>ANALYSES OF CONTENTS</td>
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<tr>
<td>Source of waste:</td>
<td>CONSTRUCTION SITE</td>
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<tr>
<td>Assumed pollutants:</td>
<td>GYPSUM</td>
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<td>Sampling Objective</td>
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<td>Material</td>
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</tr>
<tr>
<td>Type of material:</td>
<td>MIXED WASTE FROM CONSTRUCTION SITE</td>
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<td>Description:</td>
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<td>Duration of storage:</td>
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<td>Volume of waste:</td>
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<td>Amount of single samples (SS):</td>
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</tr>
<tr>
<td>Amount of mixed samples (MS):</td>
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<tr>
<td>Amount of gross samples (GS):</td>
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</tr>
<tr>
<td>Amount of single samples per mixed sample:</td>
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<td>Sampling Methodology</td>
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<td>Place and point of sampling:</td>
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<td>Access problems that affected areas or volumes of material sampled:</td>
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</tr>
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<td>Date and time of sampling:</td>
<td>19/02/15 9:22</td>
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<tr>
<td>Persons present:</td>
<td>GELA ROSS VISEKLE, GEORGUS KROHMANN</td>
</tr>
<tr>
<td>Procedure:</td>
<td>DIGGING SLIT</td>
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<td>Equipment used:</td>
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<td>Number of samples collected:</td>
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<td>Increment size/sample size:</td>
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<td>Observations during sampling:</td>
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<td>Packaging, Preservation, Storage and Transport details</td>
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<td>Packaging:</td>
<td>PLASTIC CUP</td>
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<td>Preservation:</td>
<td>AIR-TIGHT STORAGE</td>
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<td>Storage:</td>
<td>REFRIGERATION +1°C, DARK</td>
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<tr>
<td>Transport:</td>
<td>CO2</td>
</tr>
<tr>
<td>Deviations from Sampling plan</td>
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<tr>
<td>Detail:</td>
<td></td>
</tr>
<tr>
<td>Location drawing</td>
<td></td>
</tr>
</tbody>
</table>

Location drawing:

- DIGGING SLITS

Location: Temple
Date: 19/02/15
Signature: Sampler: Signature: Witness:
Appendix 2. Dual lane windshifter information

Our ref. : 14R075.0
Subject : RSB 1600/2 and 10m feeding belt

Pag. : 11 + 8

Tel. :
E-mail :

Winterswijk, October 13th 2014

Dear ..., 

Herewith our quotation for the dual lane windshifter RSB 1600/2 with 10m feeding belt.

If you have any questions after reading this proposal, do not hesitate to contact us.

Kind regards,

REDOX WASTE RECYCLING B.V.

Peter Verstraaten
Sales Support
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CHAPTER 0 INPUT DATA

The following input figures are made up:

- Input material: wood, paper and cardboard
- Material density: 20 – 25 pcf ~ 0,32 – 0,40 T/m³
- Material Size: ½" – 6"
- Volume: 30 T/h

Redox Waste Recycling B.V. shall not be held responsible for the performance should the process data differ from the values given above.

Assuming an equal divided flow over dual lanes for the two streams ½"-3" & 3"-6", we recommend our dual lane windshifter with a working width of 1800mm.
CHAPTER 1  SCOPE OF SUPPLY

1. FEEDING CONVEYOR TO DUAL LANE WINDSHIFTER

![Rubber belt conveyor](image1.png)  ![Rubber belt conveyor with safety protection on return rollers](image2.png)

**General**
The rubber belt conveyor consists of a stable open frame construction of profiled steel and sheet metal work and a drive and tensioning part. The conveyor belt is of such a design that ensures the highest reliability, limited pollution of the belt and its surroundings and minimal maintenance requirements.

**Drive pulley and tensioning pulley**
The drive pulley and the tensioning pulley are both a welded steel drum and are curved and finished with a diamond profile cladding.

**Return rollers**
The return rollers are equipped with distance rings. Return rollers within reach are protected with a special safety construction to prevent access to this area. The safety construction is easy to remove for maintenance purposes.

**Belt cleaning**
A scraper ensures that the belt is constantly cleaned from contamination to prevent misalignment and damage of the belt. The scraper at the front end is made from hard metal plate and is equipped with automatic spring tensioning. The second scraper is a V-scaper positioned at the inside of the conveyor belt.
Technical data

Length : 10000 mm
Width  : 1600 mm
Angle  : Max. 19° (last part horizontal)
Drive  : 4 kW
Rubber belt type : EP 400/3 4+2
Including : steel support structure
Heavy impact section : 1000 mm
Dual lane

2. DUAL LANE WINDSHIFTER RSB1600/2
General
The REDOX windshifter is designed to separate waste based on the material weight and size. The windshifter of type RSB is built up out of the following main parts:

- Infeed conveyor (executed with belt division)
- Ventilator
- Air nozzle
- Separation drum
- Discharge hood for light fraction

The material is transported to the separation section by means of a rubber belt conveyor. This conveyor is divided in two, so that the two different material flows can be separated in one windshifter. At the end of the conveyor the material is dropped. The ventilator situated below the conveyor belt creates an air flow. This air flow is directed to the end of the rubber belt conveyor by means of a nozzle. The light material falling from the conveyor is blown across the rotating drum. The heavy material is too heavy for the air flow and falls down in front of the drum or bounces against the drum and then falls down.

The parameter settings determine the classification of the material in a light and heavy fraction.

The parameters that can be set
- Conveyor speed (frequency controlled)
- Air speed (frequency controlled)
- Air direction
- Drum speed (frequency controlled)
- Drum rotation direction
- Drum position (both horizontal and vertical)

The advantages of the REDOX windshifter
- Flexibility: parameter settings can be adapted based on the changing incoming material or market demands
- High capacity, able to treat high volumes of material
- Low energy consumption
- Low noise level
- Low maintenance costs

Technical details
- Drive fan: 2 x 11 kW
- Drive drum: 1.5 kW
- Position drum: manually adjustable, horizontal and vertical
- Discharge hood: fixed
- Platform: included
- Compressed air: fan prepared for compressed air cleaning, including compressor
- Support construction: steel frame for mounting on mega-blocks, excluding supports
3. GENERAL SUPPLY

ENGINEERING, START-UP

We will deliver a complete drawing of our scope of supply.

The installation will be delivered with the following documents:

- floor loading plan
- motor list
- cabling scheme
- operation- and maintenance manual in two-fold, in English
- CE-certificate
- electrical scheme of control unit
- list of recommended spare parts

The start-up will be organized after the installation works have been finished. You will assure that the main electricity is connected to the central electrical control cabinet and that sufficient material is available to do the start-up.

Customer will provide to us a correct drawing of the yard and or building (preferably in digital format ME.10 / A-cad).

All machines will be installed at one level on sufficient concrete support.

MECHANICAL AND ELECTRICAL INSTALLATION

Redox will send 1 supervisor for 5 days. XXXXX will arrange the complete installation by experienced people for the total mechanical installation work and electrical cabling work according Redox standards, of the offered scope of supply. XXXXX will supply the tools to mount the installation.

You will connect the main power supply to the control cabinet. Power supply needs to be available directly when the cabling works start.

The maintenance and electrical engineer of the customer, who will maintain the installation later on, will assist during the complete time of the mounting, cabling works, testing and start-up for customers own costs, so they know the installation after commissioning.

Installation works can only start when all concrete foundations and power supply are ready.
FINISH

Coated with a two-component primer and finish in Redox RAL 5015 (sky blue), motors, sorting cabin, railings and platforms in RAL 9002 (grey white) / 9010. Different or multiple RAL-numbers are possible, on request. Different RAL numbers are to be specified by customer within one week after placing the order, different colours will have no price consequence.
CHAPTER 2  COMMERCIAL DETAILS

2.1  PROJECT PRICE

Dual lane windshifter plus 10m. feeding belt  €107,000.00
Control cabinet  €11,800.00
Transport costs DAP Cleveland Ohio  €11,700.00

Project price:  €130,500.00

2.2  PAYMENT

Payment

35% down payment at order, payable within 14 days

The remaining 65% to be covered by an irrevocable Letter of Credit to be accepted by our financial department and the Rabobank Holland and to be paid in three instalments:

35% at presenting the first set of two (2) CMR-bill of loading for the Dutch scope of supply, issued by Redox and signed by the transport company

20% at presenting the second set of two (2) CMR-bill of loading for the Dutch scope of supply, issued by Redox and signed by the transport company

10% at presenting the commissioning report or provisional commissioning report, signed by customer.
2.3 DELIVERY CONDITION

DAP Cleveland, Ohio (according Incoterms 2010).

2.4 DELIVERY TIME

The equipment will be released for transport within 16 to 18 working weeks after signing the contract, receipt of the down-payment and clarification of all technical details within 14 days after signing the contract.

During the production and before transport you are welcome to check the equipment in our company.

We will supply you with our planning scheme for this project during the production / installation period.

2.5 GUARANTEE

The guarantee for the Redox equipment is one (1) year or 2 000 production hours, depending on what is reached first.

The guarantee period starts immediately after the start up.

Wear and tear parts are excluded in the guarantee conditions.
Delivery condition: All tenders and contracts for the performance of deliveries by us outside the Netherlands are governed by the ORGALIME General Conditions for the supply and erection of mechanical, electrical and electronic products (ORGALIME S 2012) of March 2012. A copy of these conditions is enclosed. Any other conditions are herewith explicitly rejected by us.

Excluded are: All grounding connections of machinery and electrical panels; Any civil works, like changes to buildings, site etc; Main power supply to the central electrical panel; Containers or steel cladding of the bays below the equipment; Tools for installation; Mechanical, electrical workforce; All required concrete bays and supports; VAT and other taxes; Spare parts; Items not specified in this order confirmation;

Technical specifications: Redox reserves the right to modify the technical specifications and/or equipment during the production process to improve the operating of the sorting line.

This quotation is not valid in case Orgalime conditions are not included or do not accompany this document. In all other cases the quotation expires 30 days after the date the document was submitted.

REDOX Waste Recycling B.V.

Appendix A: Orgalime delivery conditions