Sustainable development of Estonian mineral resources for economical usage in roads construction

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Abstract

Today the situation has been sharply changed in the production and use of construction materials in Estonia compared with the needs of a decade ago. This fact is explained mainly by Estonia’s entry into the European Union community. This has led to new demands and constraints associated with the extraction of minerals and their further use. Doubtless, it is important to consider the impact on the environment, as well as new technological opportunities in this sector that is growing and changing rapidly. The situation could not affect the construction of roads, which is quite costly procedure. The idea of this paper is to analyse possible ways for sustainable mining of local minerals resources for national roads construction without importing expensive materials from abroad.

Keywords

Sustainable extraction of minerals, roads construction, base course, surface course, aggregates, construction regulation documents, EVS standards

1 Introduction

The debate surrounding sustainable development in the mining industry is a drawn-out one, which has long gained considerable attention from a wide range of parties. The Brundtland Commission, in its landmark report Our Common Future, defined sustainable development as “meeting the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, 1987). This definition, however, fails to outline an effective sustainability framework for any industry to follow. The Brundtland Report emphasizes that no single blueprint for sustainability exists and that the ways in which countries achieve sustainable development will vary among the different economic and political systems around the world (NRC, 1995), prompting a number of academics, industrialists and government employees to provide personal viewpoints on the applicability of sustainable development to mining. Surely, sustainable mining could be perceived as a paradox—minerals are widely held to be finite resources with rising consumption causing pressure on known resources. The true sustainability of mineral resources, however, is a much more complex picture and involves exploration, technology, economics, social and environmental issues, and advancing scientific knowledge—predicting future sustainability is therefore not a simple task. [1]. Estonia is on way to sustainable use of its mineral resources and over the past few years there is uncertain situation in the field of standardization of road construction materials in our country. During this time, there have been several researches commissioned by Estonian Road Administration. One of these studies was to examine the influence of road salt on the levelling course compaction and fracture processes of construction grain. More than 30 samples of the 15 open-pits were taken for the determination of frost resistance in salt water 1% NaCl according to the European system of standardization and testing, and more precisely in accordance with the standard EVS-EN 1367-1:2007. The results of this research were staggeringly unsuccessful, what forced the government to begin the revision of norms and standards for Estonian Road Administration. Some sceptics declared local materials such as gravel; limestone and dolomite are improper for the construction of high-ways and tended to use imported granite. Of course, this case has raised the resonance in the relations between manufacturer and the customer, who was primarily a government, but rather the Estonian Road Administration. The article
raises issues of this situation as a whole, describes the possible solutions and gives a slight description of the previous experimental results.

### 1.1. Standardization system in Estonia

In order to better understand the current situation as a whole, it is necessary to describe the existing standards, which are used by the Estonian Road Administration for technical requirements and specifications definition in road construction projects. According to the decree of the head of the Department of Road no. 95 17.04.2006 "The requirement for acceptance of construction and repair of public roads” construction material for road pavement must meet strict requirements, which are listed below in table 1.

As it can be seen from the table 1 for the crushed stone class II, which is used for construction of roads with the frequency of motion more than 6000 vehicles per day, the mandatory method is abrasive resistance upon the Nordic test. The result of this test might not be higher than 14 per cent, becomes unbearable obstacle for the main manufacturers of aggregates production.

### 1.2. Geological conditions and use of mineral resources in Estonia

The Pleistocene deposits are the majority form of the Quaternary section in Estonia [3]. It is described mostly by glaciofluvial and coastal gravel and sand (about 2.5 billion m³). The composition of the latter depends on the relief and the underlying sedimentary bedrock. For example, if the glacier was moving through the Silurian and Ordovician limestone to southeast, the deposits have dominantly a gray colour. If the glacial movement was southwest across the Devonian dolostones, the gravel and the sand have the brown tone. In the North of Estonia the composition of the gravel deposits may consist of 75 % igneous rocks, mostly the granite, feldspar and quartz. Because of its northern location the Tallinn suburb is rich for open pits of gravel, sand (the Tallinn-Saku sandur) and other aggregates. At the moment the 109 mln m³ are being registered in Estonia, for the Harjumaa (Tallinn) this number is 8.8 mln m³. It is interesting that the gravel aggregates are being used in road construction for a long time. It is a reason to reduce the usage of gravel recourses to save the high qualified material and research the worthy way of its consumption. It is left only 2.3 mln m³ active field of gravel on Harjumaa nad 21.4 mln m³ in Estonia for the end of the year 2008.

### 2 Features of mining legislation of Estonia

Since 2005, the Ministry of Environment of Estonia is actively developing a strategy and development program for extraction of construction materials in period 2010 - 2030. It includes a collection of various documents in other departments such as „Transport Development 2006-2013”, “Managing Government Waste 2008 - 2013 “, “Protection of the Environment of Estonia until 2020”, the whole package consists of 7 strategies for development of completely different directions. The principal criterion is the development of more efficient, cost-conscious and environmentally friendly methods of extraction of natural resources of Estonian Republic. A special feature of the development of aggregates recourses is to obtain the permission for extraction in Estonia. By 07.08.2009 there were issued 347 permits. The process of obtaining the required document is quite complicated and takes about 4-6 years. In addition, it affects the overall demand for materials and consequently their extraction. For example, until now the legislation is not including the operating income from the developing state-owned deposits of construction materials. Such issues will be resolved in the new concept.

### 2.1. The results of previous researches

The use of gravel increases for road construction, because the method of extraction and processing is

<table>
<thead>
<tr>
<th>Sample</th>
<th>Class I</th>
<th>Class II</th>
<th>Class III</th>
<th>Class IV</th>
<th>Norms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abrasive resistance upon the Nordic test</td>
<td>≤10</td>
<td>≤14</td>
<td>PN</td>
<td>PN</td>
<td>EVS-EN 1097-9</td>
</tr>
<tr>
<td>Frost-resistance upon direct freezing</td>
<td>≤2</td>
<td>≤2</td>
<td>≤4</td>
<td>≤4</td>
<td>EVS-EN 1367-2</td>
</tr>
<tr>
<td>Crushing strength upon the Los Angeles test</td>
<td>≤20</td>
<td>≤20</td>
<td>≤30</td>
<td>≤35</td>
<td>EVS-EN 1097-2</td>
</tr>
<tr>
<td>Fine particle content</td>
<td>≤1</td>
<td>≤1/≤2</td>
<td>≤2/≤3</td>
<td>≤3/≤4</td>
<td>EVS-EN 933-1</td>
</tr>
<tr>
<td>Grain shape by the flatness factor</td>
<td>≤10</td>
<td>≤20</td>
<td>≤25</td>
<td>≤35</td>
<td>EVS-EN 933-3</td>
</tr>
<tr>
<td>Radioactivity</td>
<td>shows that generate natural radioactivity not more than 85 Bq / kg</td>
<td>Estonian Radiation Law</td>
<td>EVS EN 1744-1 p.15.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
relatively easy. This article explores some possible areas of gravel use and gives a description of new methods for production. Is the Estonian gravel appropriate for the aggregates production of class II (according to Asphalt specifications 2007)? For example, the gravel from Kalda pit meets the following quality characteristics:

<table>
<thead>
<tr>
<th>Description of method</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine particle content</td>
<td>2 %</td>
</tr>
<tr>
<td>Crushing strength upon the Los Angeles test</td>
<td>25 %</td>
</tr>
<tr>
<td>Frost-resistance</td>
<td>1 %</td>
</tr>
<tr>
<td>Radioactivity index</td>
<td>0,05</td>
</tr>
<tr>
<td>Abrasive resistance upon the Nordic test</td>
<td>23,4%</td>
</tr>
</tbody>
</table>

Table 2. Average quality values of gravel in Kalda pit

As it seen from Table 2 gravel meets almost all requirements except the Nordic-test method. Also, crushed gravel is more cubic-shaped (the declared category 10%), in contrast with the same from limestone. As it is well known cube-shaped grain forms have a stable three-dimensional structure, which helps to reduce the cement and bitumen contend in surface courses of pavement. The freezing tests of gravel from Kalda (on freeze in brine) (1%) have also showed one of the best result up to 12% of the destruction that, in comparison with limestone gravel (40% and above), is a good indicator.

The high content of flakiness negatively impacts the workability and the density of asphalt mix. They have lower mechanical strength compared with the cube, and therefore destroyed in the process of construction and operation of roads, which may lead to the formation of surfaces, not covered with bitumen. These sites are the primary fracture of asphalt concrete with water penetration and the action then alternate freezing and thawing. Regarding this, the existing regulatory and technical documentation restricts content in the mixtures of grain flakiness forms: 15% - for the roads with density from 8000 cars per day, 20% - up to 2500, 25% - for up to 500 [4]. The roads constructed by using cube-shaped gravel will need at least 2 times less exploitation costs than same roads with lamellar shape aggregates. Plateness factor influences to the process of compression, and forms “islands” of grain flakiness, what is causing the local pavement failure.

2.2. The effects of material extraction procedure for the quality of stone

The choice of technology and specific models of equipment for the production of aggregates depends on the type of recyclable material, its abrasiveness, quality and purpose of the finished product, the required percentage of cube-shaped grains, the expected performance, capacity to bear the costs of restoring efficiency of working bodies. The seeming simplicity of the production of gravel (breaking rocks) is misleading, because the modern technology of producing aggregates has to meet high standards for quality of gravel, used mostly as a filler in the manufacture of concrete, asphalt and road surfaces. During the production of cube-shaped gravel must be taken into account the form of grains of crushed material, what is determined by the textural and structural features of the original rock, used equipment and processing technology. Grains form also depends on the principle of the crushing procedure. Optimal isometric cube-shaped form is created in the following crushers, impact-centrifugal and pneumatic-centrifugal. From the stone crushing units (crushers, roller, standard cone crushers) are crushed with a high content of grain flakiness. As practice showed medium fractions (12-16, 4-16, 8-12) have more strength features than gravel fractions 16-32. Part of the reason may in a double crushing process for the production of small gravel fractions. The Warrior screen complex was used for Kalda quarry. The system worked according to the next process: first of all it was been sorted the little and a big stuff. Because sometimes the number of large grain content (over 70 mm) can reach 40-50 per cent or more, the material was separated by the screen and was forwarded to the crusher. The next step is a jaw crusher complex. The crusher is processing the overall fractions, which are forwarded from the screen. To achieve the highest quality of aggregate it is supposed to lead the material to cone crusher additionally. It will help to reduce the weak grain content.

2.3. Kunda Nordic Cement Ltd new crushing – sorting complex

Another technical solution for aggregates production will show AS Kunda Nordic Tsement factory processing complex where the quality rises with reduction of 0-4 material. AS Kunda Nordic Tsement supplies almost all the cement used in Estonia. In total, company sells almost one million tons of cement per year. Around three-quarters of the cement are sold into the domestic market. Also KNC produces limestone aggregates in all fractions. Limestone aggregates are used for producing concrete, as filler in road construction, and for performing various subsoil filling works at construction sites. The main goals of KNC are highly connected with CO2 emissions reduction from production and development of sustainable mining. The figures are following:

- Reduce specific net CO2 emissions (CO2/ton of cement) by 15 percent compared to 1990;
- Decrease absolute net CO2 emissions (CO2/million tons).

In this paper, one of the possible ways to meet these goals is described. What is also important the new crushing – sorting complex is working with zero waste. All fractions what can not be sold for
construction purposes are going to cement production. Technology of limestone and gravel aggregates production is very similar. Different approaches will be considered for the excavation of limestone in Aru and gravel Kalda pits. Mainly, there are some processing series using jaw and cone crusher units in Estonia. AS Kunda Nordic Tsement has opened a new crushing - sorting complex in the pit of Aru, in March 2009. This industrial park for the production of limestone can produce maximum 300 - 350 tons / per hour. It has replaced 3 crushing units used in the past decade. The new approach for limestone treatment is used in cone crusher. This is the main difference between limestone and gravel aggregates production. The cost of project was about 30 mln Estonian krones.

When the research was started, two different scenarios had been analysed in cooperation with Kunda Nordic Tsement top managers and Metso Minerals professionals with idea to satisfy both: cement production and limestone excavation. The main supplier of needed equipment is Metso Minerals. This company offers the simulation software Bruno. Both scenarios were analysed by Bruno. The process layout is shown at fig. 1. The Scenario I was elected due to:

The second scenario was more primitive and less effective;

Rotor Crusher used in the second scenario is producing more aggregates in fractions of 0…2 mm, 0…4 mm (11-13%), what can not be sold. It means the difference in net price of end-product about 30-40 Estonian krones if 800 000 tons are produced; [5].

Fig. 1. Scenario 1 simulation layout by Bruno

The process itself is simple, divided into 3 levels. In the beginning, the crushed material is going from feeder to jaw crusher. This is the I level of the process. When the first screening is done, the material pieces what are greater than the upper screen mesh are going further into cone crusher. The II level is fulfilled with this procedure. If material is smaller than the lower screen mesh it will be forwarded to the second screen where the second screening takes place and the smallest fractions are done. For example, from the first screen the fractions 8-16 mm and 16-32 mm are taken. The material pieces what are greater than 32 mm are going to III level crusher and smaller than 16 mm are going to back screen for 2-4 mm and 4-8 mm fractions.
The crushing - sorting complex consists of next units: basic module, feeder, feed hopper, by-pass arrangements, side and main conveyors. The technical data is following.

Nordberg NW116 is a wheel mounted, electric powered primary crushing unit.

Performance when crushing is as follows:
- feed size up to 610 mm
- capacity up to 174 Mtph...425 Mtph

Main dimensions of basic module in crushing position:
- length 15 200 mm
- width 4 700 mm
- height 5 400 mm

Basic module

Basic module includes standard equipment of frame, electrification, control panels, service platform, rails and ladders. The wheel-mounted chassis gives the Nordberg NW high mobility between crushing sites. Main control panel is mounted on the side of Nordberg NW frame including the following functions:

Feeder

Vibrating grizzly feeder TK11-48-2V has grizzly spacing 70 mm + screen deck. Vibrating feeder has to maximize the overall production through the efficient removal of fines from the feed material. The feeder is equipped with 2 grizzly sections.
- length 4 800 mm
- width 1 100 mm

Mesh size 25 mm

By-pass arrangement

By-pass chute

Side conveyor H6, 5-5

Belt conveyor is used for transporting the fine material to the side of the NW. The side conveyor is equipped with electric drive and emergency stop switches on both sides of the conveyor.
- discharge height 1 635 mm
- length 5 000 mm
- belt width 6 500 mm
- belt quality Y650EP400/3-3/1
- electric motor 5,5 kW
- dust cover

Crusher

Jaw crusher Nordberg C116 is a single toggle primary crusher with non-welded construction. The crusher is mounted without a bolted connection. The setting is easy to adjust with both mechanically and hydraulically operated wedges.
- intake width 1 150 mm
- intake depth 800 mm
- fixed jaw length 1 600 mm
- setting c.s.s. 60...175 mm
- rotation speed 280 mm
- inclination -6 degrees
- electric motor 132 kW squirrel cage
- V-belts 10 x SPC length 6 000 mm

STD jaw dies

Hydraulic setting adjustment

Main conveyor H12-9

Belt conveyor is used for transporting the crushed material from the crusher to the discharge point. The conveyor is equipped with electric drive and emergency stop wires on both sides of the conveyor.
- length 9 000 mm
- belt width 1 200 mm
- belt quality Y1200EP500/3-5/1,5
- electric motor 18,5 kW
- dust cover

The freshness of the process is hidden in work of cone crushers. The new generation of cone crushers is not working only on pressing method, but also the impacts are added into process. The whole procedure is controlled by special sensors, what are keeping the cone feeding rate on the same level, about 80%. These all help to keep material pieces from crushing by each other. For quality reasons the needed parameters can be changed just by pushing a button. The process is automated.

3 The issue of research, hypothesis and possible outcomes

This article describes the quality characteristics of the gravel aggregate from the Kalda pit and gives some technical characteristics of the limestone aggregates production using an example from Aru open pit. It is assumed that the gravel aggregates could be used in the highroad construction precisely in surface courses of pavement. The limestone production in Aru pit has proved that there is a possibility to produce 2 main streams of product: cement limestone and aggregates. The processing complex is able to produce limestone for construction without quality losses. And the good result is that the production outcome has been risen. Now there are some researching started to examine the indispensability of abrasive resistance upon the Nordic test using the limestone and gravel aggregates and the influence of the salt on the grains.
destruction (the processes in the base course). Another research will give some answers to processing problems: are there some correlations between crushing type and the product quality, are there some hidden consequences which can appear after using the aggregates in construction. As well as being a study on the actual processes in the road base courses in Estonian climatic conditions. If the results are successful, then the usage of gravel deposits could be more profitable and with less impact on the environment.

4 Conclusions
As a result good technological solution can improve the quality of excavated aggregates depending on type and needs. The new research will show if there some possibilities in technological ways for wide use of the Estonian gravel and limestone in highway construction as base and binder courses. No doubt, sustainable mining will be the creed of the global mining industry in the near future and beyond, reliant on clean, bulk mining systems with ICT as the underpinning. Shored up by innovative technology configurations, mining industry will be sustainable and hopefully meet the global minerals hunger with responsible resource stewardship.

5 Acknowledge
This research succeeded thanks to cooperation of different institutions of Tallinn University of Technology. The Mining Institution is represented by Julia Gulevich and Riho Iskyl. Machinery Institution is represented by Viktoria Bashkite and was added to the research as partner. The main goal was to analyze the implemented technical equipment in Aru pit. The idea of this collaboration is to use optimal technological solutions in order to achieve the highest level of sustainable development in Estonian mining facilities. The research was supported by Estonian Science Foundation (ETF 8123 и ETF 7499) and Doctoral School of Energy and Geotechnology II.

References
4. The regulation project of Economic-and Communication Ministry of Estonia according to Road Regulation act, Tallinn march, 2010