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Note

Utilization of unbound aggregates for road construction

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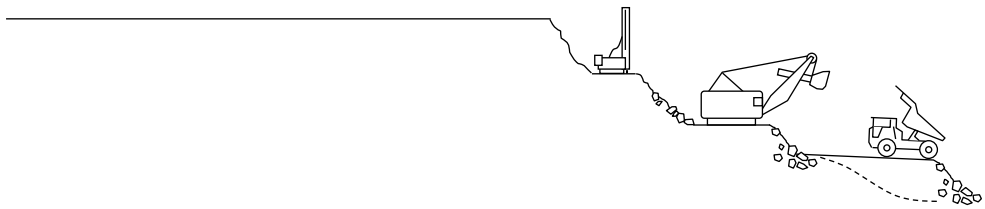
Crushed rock aggregate is a non-renewable resource of great interest in road construction and other branches of the construction industry. To prevent resource scarcity, utilization of aggregates should be considered carefully.



1. BACKGROUND

Crushed rock is the most important raw material for road construction in Norway. The Norwegian Public Roads Administration (NPRA) has initiated a PhD study in cooperation with the Department of Geoscience and Petroleum at NTNU to gain more knowledge about enhancing aggregate utilization through optimizing the production process. The focus of the study will be aggregate crushing processes and its effect on aggregate quality.

A normal road construction following current design requirements from the NPRA contains aggregates in all layers of the pavement structure; surface, base, subbase and frost protection layers (Statens vegvesen Vegdirektoratet 2014). Subbase and frost protection layers are the parts of the road construction where the majority of aggregates are used, due to large required layer thicknesses. Despite being subject to notably dissimilar quality requirements, these two layers can consist of the same materials. While the subbase also has requirements regarding mechanical properties, the frost protection material is only bound by grading requirements. Within the new requirements for frost protection materials from 2014, new opportunities for the use of aggregates are given which has not yet been explored fully.

Aasly and Erichsen (2016) provide statistics for the Norwegian mineral industry for the year 2015: The Norwegian aggregate industry sold 82 million tonnes of aggregates, at a value of 6 billion NOK. Of the total 82 million tonnes, 67 million tonnes are crushed rock aggregates. More detailed information about the use of aggregates can be found in the mineral statistics for 2014 (Neeb 2015): About half of the produced amount of aggregates was used in road construction, and one third in concrete production. In total, nearly 36 million tonnes crushed rock aggregates were used for road construction purposes in 2014, of which 26.5 million tonnes in unbound form.

Initial investigations show that a normal two-lane road construction following current design requirements from the NPRA typically can consist of 51 tonnes of crushed rock aggregates per metre. Although aggregates represent the largest contribution to the construction in terms of both volume and mass, the cost of aggregates only represents 7-8 % of the total construction cost per metre for a new road.

The Norwegian practice for aggregate use, with grain sizes up towards 200 mm in the pavement structure is uncommon compared to many other countries. In the literature, the term coarse aggregates can be used to refer to aggregates of the size range 4 mm to 63 or 75 mm (Ekblad and Isacsson 2008, Xiao et al. 2012). Information about practice for aggregate use from several countries is gathered in Fladvad et al. (2017, in press). Among the 18 participating countries, five restrict aggregate sizes in their pavement constructions to sizes smaller than 50 mm. The differences in this practice have created a need for verification of international research in a Norwegian context.

2. SCOPE

The main scope of the project is crushed aggregates used in unbound form in the main layers of a pavement structure: base, subbase, and frost protection layer.

CEN (2009) defines aggregates as “granular material of natural, manufactured or recycled origin used in construction”. Within this research project, the definition of aggregates is additionally confined to “granular material of crushed rock used in road construction”. The aggregates investigated will mainly be coarse aggregates, with upper sieve sizes in the range of 63-120 mm. In the production of these coarse aggregates, fine aggregates and fines are also produced, and the properties of the complete grain size distribution are an important part of the research scope.

The study will include a comprehensive view of aggregate production – planning for the best possible utilization of available materials for use in different layers using one single production line.

The research is limited to aggregates produced by blasting, crushing and screening bedrock, and does not cover recycled aggregates, natural uncrushed aggregates or aggregates for use in bound forms like asphalt or concrete.

3. AIM OF THE RESEARCH

A main aim of the research is to show that methods for producing aggregates have impact on the aggregate properties as a raw material for road construction. The currently accepted laboratory tests for mechanical aggregate properties are based on standardized fractions and laboratory crushed material. This practice implies the assumption that aggregate properties are predominantly determined by the resource, and only negligibly influenced by the production, e.g. crushing. The research aims to be able to test materials after full-scale crushing, using test fractions relevant to those used in road construction.

The specified aims of the research are:

- Establishing a knowledge base for the impact of gradation, grain size distribution, grain shape and other physical properties on mechanic properties for coarse aggregates
- Developing and improving existing methods for characterization of crushed aggregates
- Associating variations in material characteristics for aggregates with variations in the production conditions
- Evaluating whether established knowledge on aggregate properties from research on fine aggregates is valid for coarse aggregates with upper sieve size in the range 63-120 mm.
- Assessing sustainability issues for various aggregate choices using life cycle analysis.

4. RESEARCH METHOD

An initial literature review and examination of current best practice in the aggregate production business will form the basis for the research. The PhD research will consist of a combination of field studies and laboratory work.

Los Angeles (LA) and MicroDeval test are the standardized tests that will provide information about mechanical aggregate properties. Materials with different properties due to production conditions will be tested to evaluate whether the standardized test is able to identify these differences. Tests will be conducted to assess the applicability of the Los Angeles test on coarser materials compared to what is specified in the current standardized testing procedure. Both the regular LA test and the LA test for railway ballast (aggregate size 11-14 mm vs. 31.5-50 mm, respectively) will be used to continue previous work by i.e. Nålsund (2010), Erichsen et al. (2011), Erichsen (2014), and Benediktsson and Wigum (2015).

Thin section analysis will be conducted to quantify the amount of micro-cracks in the material after blasting, and after one or more crushing steps. Thin section analysis will also be used to collect information about the petrographic properties of the materials in the research.

Full-scale testing will be arranged to find vital correlations between full-scale and lab-scale conditions. The possibility of using Heavy Vehicle Simulator (HVS) on a full-depth pavement structure is being considered for this purpose. The HVS equipment is able to simulate accelerated deterioration of a pavement construction by running a heavy wheel load over the pavement over a concentrated period of time (Hellman et al. 2013). The equipment will be considered to test several subbase materials, e.g.:

- Varying gradation, while mechanical properties and upper/lower sieve size are kept constant
- Varying amount of micro cracks, resulting from varied production conditions, while other petrographic properties and gradation are constant
- Different size fractions screened from a production line, where mechanical and petrographic properties are constant
- During testing rutting and stress/strain levels will be measured. After testing, the material will be analysed for degradation in terms of wear and crushing.

The field studies will consist of full-scale production tests conducted at ongoing road building or aggregate production sites. Testing combinations of crushing and screening equipment and the various settings of the equipment will produce aggregates for further analysis in laboratory and full-scale testing. Gradation tests will be an important tool to assess the crushing results.

An established method for life cycle assessment will be used to analyse the sustainability of road construction using different aggregate choices based on the research results.

5. EXPECTED RESULTS

The research is expected to result in new knowledge regarding the importance of aggregate production methods for the quality of aggregates for use in road construction. Knowing how blasting and crushing affect the quality will give the possibility to differentiate quality demands more widely than in the current practice.

Research results are expected to show significant differences in terms of degradation in aggregate materials that the current pavement design requirements fails to distinguish. Results of this kind can constitute basis for changes in the system for aggregate classification used in pavement design.

Through increased knowledge about aggregate production processes and its effect on pavement strength and life span, aggregate production planning can be improved and more efficient, and a more sustainable production can be achieved. Improvements of this sort will be of advantage for aggregate producers, contractors, construction clients and the environment. By more efficient production, a larger proportion of the blasted rock volume can be used in construction.

The results are expected to show that the current quality demands for aggregates in road construction based on laboratory crushed samples in standard fractions does not have satisfactory validity for all variations of aggregate size and gradation used in road construction in Norway. By obtaining increased knowledge on how to use the appropriate aggregate quality for different purposes, aggregate resources can be utilized in a better way, and a potential for more use of local aggregates can be realized.

Although the research aims to encourage the use of local aggregates, the results will be applicable for both mobile and permanent quarry crushing processes.

6. PARTNERS AND COOPERATION

The Norwegian Public Roads Administration (NPRA) is funding the PhD study on the subject “Optimal utilization of unbound crushed aggregates for road construction”. The study commenced in January 2016, and is funded for a period of three years.

The PhD study will also be a part of the business innovation project Kortreist stein (English title: Use of local materials) financed by the Norwegian research council. SINTEF is chairing the project, in cooperation with Veidekke Entreprenør, Veidekke Industri, Metso Norway, Multiconsult, Asplan Viak, NPRA, Norwegian National Rail Administration, Hordaland fylkeskommune, Bergen kommune, the Norwegian Geological Survey (NGU) and NTNU.

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