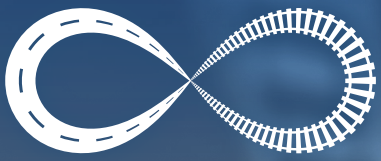

CETRA 2018

5th International Conference on Road and Rail Infrastructure
17–19 May 2018, Zadar, Croatia

Road and Rail Infrastructure V

Stjepan Lakušić – EDITOR

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INTERACTION COEFFICIENT FOR RESISTANCE TO FRAGMENTATION BY GOST AND EN TEST RESULTS

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Abstract

There are many quality tests in Europe for aggregates used nowadays, and a lot tests methodology were used also in Eurasian and post-Soviet states, unfortunately tests results were not comparable and important data cannot be used in investigations and were almost lost. The aim of this research was to elaborate an interaction coefficient between resistance to fragmentation tested by EN standards using Los Angeles test methodology and GOST standard, which use cylindrical testing equipment. Elaboration were held with limestone and dolostone materials used as aggregates for concrete, as unbound and hydraulically bound materials, aggregates for bituminous mixtures and surface treatments for roads, airfields and other trafficked areas, in civil engineering works and road constructions. Requirements and properties of tested aggregates are presented in this paper as well and necessary correlation analysis were held using single factor of statistical possibility. According to this correlation by interaction coefficient, EN test results are interrelated with GOST test results and can be used for new properties investigations and comparison researching of aggregate materials quality. Achieved analytical results can be very useful for road engineers, constructors and geology service.

Keywords: road materials, testing methods, strength parameters, resistance to fragmentation, standardization systems, correlation methodology

1 Introduction

There are many assessment methods of road aggregates quality testing were used. Although at the moment the main strength testing methods are resistance to fragmentation by Los Angeles and resistance to freezing and thawing. Methods for testing are similar, but test results are different in both standardization systems: GOST – developed by the government of the Soviet Union and EN – Estonian and European standard. Unfortunately, there is no methodology to cooperate and compare different test results between mentioned standards. Important parameters what will be compared in this research are resistance to fragmentation by cylinder method using GOST standardization and resistance to fragmentation by Los Angeles method using European standard.
In Estonia and other Baltic states, different data of road aggregate materials were researched during long Soviet Union period. Also, all this data is in GOST standardization system, which is not used in Europe and in all post-Soviet states anymore. The main task of this research is to work out correlation rule between two main testing methods, which allow to use efficiently all previously obtained testing data at present days. In that case, great and informative correlated data can be used for different projects and for next researching as well.

2 The Standardization System and Requirements in Estonia

The Estonian market of construction materials is in need of high quality materials (limestone and dolostone aggregates, sand, gravel) in order to cope with everyday demand. The foundation is to find solutions to improve the sustainability situation in different companies (mining and road-construction). Output aggregates are usually consumed in road, railway and building construction, concrete aggregates and concrete mixtures stuffing, and also for composing unbound mixtures. Each area of usage is followed by the EN (European Normative) standards. Used standards are valid throughout the European Union, [8].
To understand better current situation in whole, it is necessary to describe the existing standards, which are used by Estonian Road Administration for technical requirements and specification definitions in road construction projects. According to the previous decree of the Road Department no. 95 17.04.2006 "The requirement for acceptance of construction and repair of public roads" construction materials for road pavement must meet strict requirements, which are listed below (Table 1). As it can be seen for the crushed materials class II, which is used for constructions of roads with the frequency of motion not more than 6000 vehicles per day, the mandatory testing method was resistance to wear by abrasion from studded tyres – Nordic test. The result of this test must be not more than 14 %, which becomes unbearable obstacle for the main aggregates manufacturers [3].
To assess the quality data of the products in quarries using easiest way and to control the quality of the applicant enterprise level, previous years' data can be applied using GOST standards information and correlations. During Soviet Union time, all quarries in Estonia were particularly investigated. This data is confidential and is very informative. The research results of different quarries and mineral deposits all over Estonia are collected at Geological Survey of Estonia till now. According to that, decisions and conclusions of aggregates quality can be done, [4]. For that purpose, is necessary to investigate and consider dependence of interaction coefficient, analysing GOST and EN standards, and normative documents.

Table 1 Recently Required Tests for Road Construction Aggregates [1]

Testing Method for Quality Control	Road Class I	Road Class II	Road Class III	Road Class IV	Valid EN Standard
	>6000 vehicles per day	3000-6000 vehicles per day	1000-3000 vehicles per day	200-1000 vehicles per day	
Determination of the resistance to wear by abrasion from studded tyres – Nordic test	≤10	≤14	NR*	NR*	EN 1097-9
Resistance to freezing and thawing	≤2	≤2	≤4	≤4	EN 1367-2
Determination of resistance to fragmentation – Los Angeles test	≤20	≤20	≤30	≤35	EN 1097-2
Fines content	≤1	≤1/≤2	≤2/≤3	≤3/≤4	EN 933-1
Determination of particle shape – Flakiness index	≤10	≤20	≤25	≤35	EN 933-3
Radioactivity	-	-	generate natural radioactivity ≤ 85 Bq/kg	Estonian Radiation Law	EN 1744-1

**NR-not required*

3 Strength Classes by GOST 8269-87 Standard

In Russian Federation GOST standardization system is still in use nowadays as a basic one. The resistance to fragmentation by GOST is determined in the cylinder machine (Table 2). It is one of test methods, which corresponds to standard GOST 8269-87. An aggregates compression and resistance to fragmentation defines percent of residuals. The diameter of the cylinder is usually 150 mm. Fractionated aggregates materials is being pressed and crushed by the press of cylinder machine, increasing the pressure by 1-2 kN respectively. After that the residue of aggregates is being screened and weighed. This test can be held in two ways: first one – when the sample is saturated with water or the second one – when the sample is dried. The tests results can be calculated in percent's and represented by classes also. The following table (Table 2) presents the classes of aggregates and relevant percentage [5].

Table 2 Resistance to Fragmentation Test Results by GOST Standard and Appropriate Aggregates Strength Classes

Strength Class by GOST Standard	Test Result by GOST Standard, %
400	20-25
600	15-20
800	12-15
1000	10-12

4 Resistance to fragmentation by EN 1097-2 Standard

To determine resistance to fragmentation by EN Standard the Los Angeles Abrasion Machine drum is in use (Figure 1). The laboratory sample must be large enough: there has to be at least 15 kg of 10 mm to 14 mm grain size. The test must be carried out with material that passes through a sieve of 14 mm and remains on 10 mm sieve. In addition, the sample grades meet one of the following requirements (basic test):

- The particle size of the sieve 12, 5 mm must be from 60 % to 70 %;
- The particle size of the sieve 11, 2 mm must be from 30 % to 40 %.

Both fractions must be washed, and dried in an oven at a temperature of 105 (± 5)°C until constant weight will be achieved. After that must be cooled till constant room temperature. Fractions are mixed together to modify laboratory sample with particle size of 10 mm to 14 mm, the particle size fulfils the above additional requirements. The modified laboratory sample from mixed fractures will be reduced to the sample size. The sample test mass must be at least 5000±5 g. After that the sample will be tested in the Los Angeles Abrasion Machine drum for resistance to fragmentation. The machine consists of control unit and a rolled steel drum (Figure 1). The drum rotates with a constant speed with a steel balls and aggregate inside. Los Angeles coefficient can be calculated as a percentage of the test portion passing a pre-determined sieve after completion of the test [7]. The EN Standard test results are in percentage units and test results by GOST Standard also; due to that results can be simply compared or correlated.

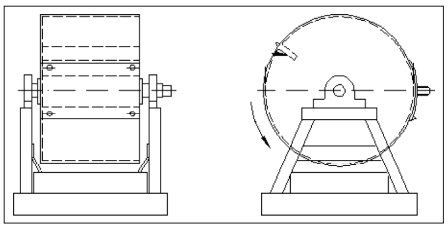

Figure 1 Los Angeles Abrasion Test Machine Drum for Testing by EN 1097-2 Standard [7]

5 Resistance to fragmentation by GOST Standard

Using GOST 8269-87 standardization resistance to fragmentation of limestone or gravel aggregate can be measured by compression of the grains in cylinder machine. Testing machine defines hydraulic jaw crusher (maximum strength 500 kN) with steel cylinders (diameters 75 mm and 105 mm, heights 75 mm and 105 mm) and with removable bottom and plungers as shown in Figure 1. Laboratory scales, drying oven and sieves set (with sieve size 2,25 mm as well) are used to measure aggregate mass loss. Also water vessel is used to irrigate crushed aggregate, [6].
In aggregate testing process, usually mixture consists at least of two contiguous fractions. Basic aggregate mixture is sieved to standard fractions (5-10 mm, 10-20 mm, 20-40 mm) after that they are tested separately. Smaller residue fraction is divided into two testing samples no less than 0,5 kg by mass if 75 mm cylinders will be used and no less than 4 kg if 105 mm cylinders will be used in testing process [6].

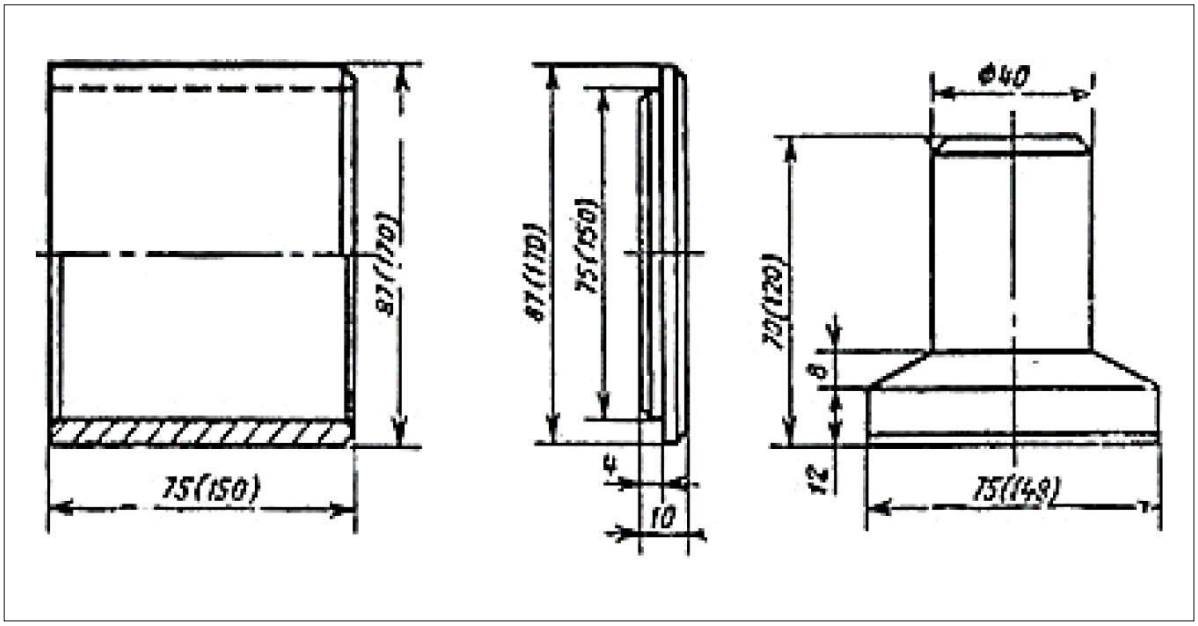

Figure 2 Cylinder testing machine by GOST [6]

Coarse aggregate fractions bigger than 40 mm must be previously crushed, that test could be done with fractions 10-20 mm or 20-40 mm. In case of homogeneous petrographic aggregate mixture, 40-70 mm fraction testing results can be described by fraction 20-40 mm testing results. Aggregates can be tested dried condition or in water saturated condition. Dried aggregate mixtures should be dried till constant mass at the oven. In water saturated conditions testing, aggregates must be set to water for two hours. After water saturating process aggregate grains must be swept by wet fabric material [6].
By GOST Standard for aggregate grading tests must be used cylinder with 150 mm diameter. For approximately quality control for fractions 5-10 mm and 10-20 mm is allowed to use cylinder with 75 mm diameter. Testing aggregate sample must be spread on cylinder from 50 mm altitude, levelled until 15 mm from cylinder edge. After that plunger must be installed into cylinder and plunger plate should be on the same level with cylinder edge. If it is not on the same level, then some aggregate grains should be removed or added into cylinder. Next step in testing process will be setting cylinder on to press surface. Increasing press imprint by 1-2 kN (100-200 kgF) per second until 50 kN (5000 kgF) in 75 mm cylinder testing case and until 200 kN (20000 kgF) using 150 mm cylinder. After compression tested aggregate mixture should be poured out, weighted and sieved through 1,25 mm sieve if 5-10 mm fraction was tested; with 2,5 mm sieve if 10-20 mm fraction tested and 5 mm sieve if 20-40 mm fraction was tested.

Sieve residues also should be weighted after sieving. If water saturated testing were chosen, sieve residues should be washed out and swept by wet fabric material. Results handling for resistance to fragmentation should be measured with 1 % accuracy using next equation:

$$Q = \frac{t - m_1}{t}, \% \quad (1)$$

Where:
t – tested aggregate mass in grams;
m_1 – mass of sieve residues after crushed aggregate sieving in grams.

Average between two similar tests is a final testing result. In case of using different fractures, mixture resistance to fragmentation should be measured differently [6].

6 Aggregates strength properties analysis

Two deposits located in different parts of Estonia were tested for correlations and interaction coefficients by previously mentioned standards: Pudivere dolostone deposit and Nabala limestone deposit (Nõmmevälja claim-field part only).
Pudivere dolostone deposit is located in central Estonia. Its previous post-Soviet geological research results tested by GOST 8269-87 Standard are used and dolostone resistance to fragmentation by EN 1097-2 Standard were determined as well. For Pudivere dolostone deposit totally 13 samples were taken from 13 boreholes for physical-mechanical tests. The following Table 3 shows all test results.
Nabala limestone deposit (Nõmmevälja claim-field) is located in Northern part of Estonia. Nabala deposit test results (Table 4) are shown below, where limestone aggregate test results are studied by two methods of resistance to fragmentation, by GOST and EN Standards. Totally 14 tests were held for results comparison and correlations.

Table 3 Pudivere dolostone deposit resistance to fragmentation tests results

Sample number	Cylinder test result, %	Los Angeles test result, %
1	15,2	37
2	14,9	31
3	16,5	31
4	13,1	32
5	11,5	27
6	14	34
7	12,3	29
8	15,9	31
9	14,2	31
10	14,7	34
11	13,3	31
12	12,9	30
13	15,7	31
Average value	**14,2**	**31,5**

Table 4 Nabala limestone deposit resistance to fragmentation tests results

Sample number	Cylinder test result, %	Los Angeles test result, %
12kT	14,1	31
13kT	13,5	33
14kT	14,5	31
5KL	13,6	31
6KL	15,4	32
7KL	13,1	32
8KL	11,9	28
9KT	15,2	31
10KT	14,5	34
11KT	13,5	30
30KT	13,9	30
31KT	15,2	31
32KT	13,8	29
33KT	12,5	29
Average value	**13,9**	**30,9**

7 Correlations and interactions results

The following graphics (Figure 3 and Figure 4) show that these two testing methods have similar results for dolostone and limestone deposits. When the dependence of these methods was verified (The Single Factor showed the 100 % of probability of dependence), the positive correlation coefficient was found as well. The research showed, that Pudivere and Nabala deposits results gave similar interaction coefficient result: Pudivere – 0,45 and Nabala – 0,45. Average test results by GOST Standard method (cylinder test) are less than EN Standard method (Los Angeles test) than 0,45 when grouped by columns for both deposits, so interaction coefficient is 0,45 irrespective of raw material type. For example, according to this correlation, the Los Angeles test result of 30 complies with cylinder test result of 13 and has the 800 class of aggregate quality (Table 2) by GOST Standardization, which means that the aggregates in Estonian deposits has high quality. All interaction coefficients of investigated deposits can be seen at the Table 5. For interacting tests results can be used simple equation, where 0,45 – interaction coefficient (grouped by columns), CT – cylinder tests average result and LAT – Los Angeles tests average result:

$$0{,}45 = \frac{CT}{LAT} \tag{2}$$

Table 5 Interaction coefficients data depending on raw material type

	Interaction Coefficient	Deposit Name	Raw Material Type
	0,45	Pudivere	dolostone
	0,45	Nõmmevalja	limestone
Average	**0,45**		

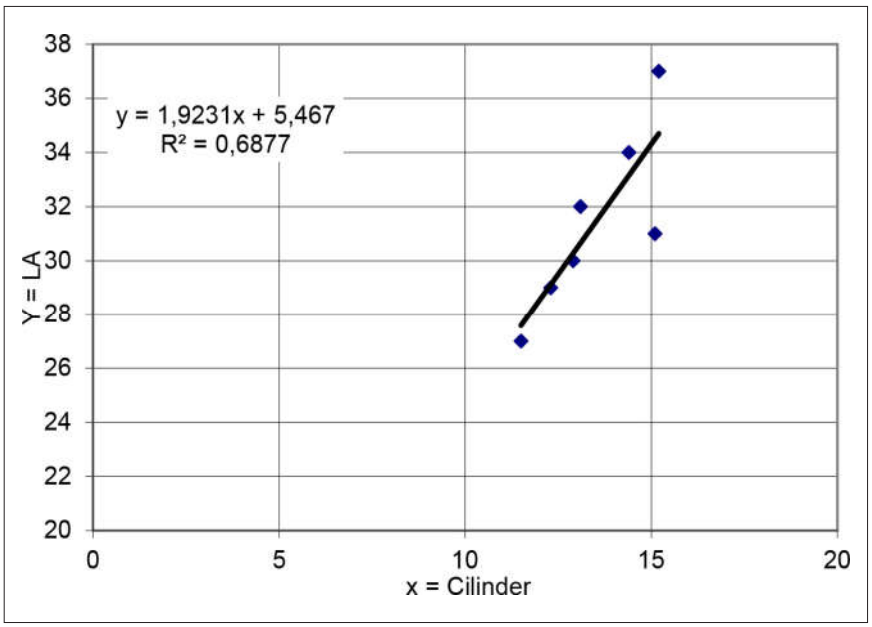

Figure 3 Pudivere dolostone deposit LA and cylinder test results graphic

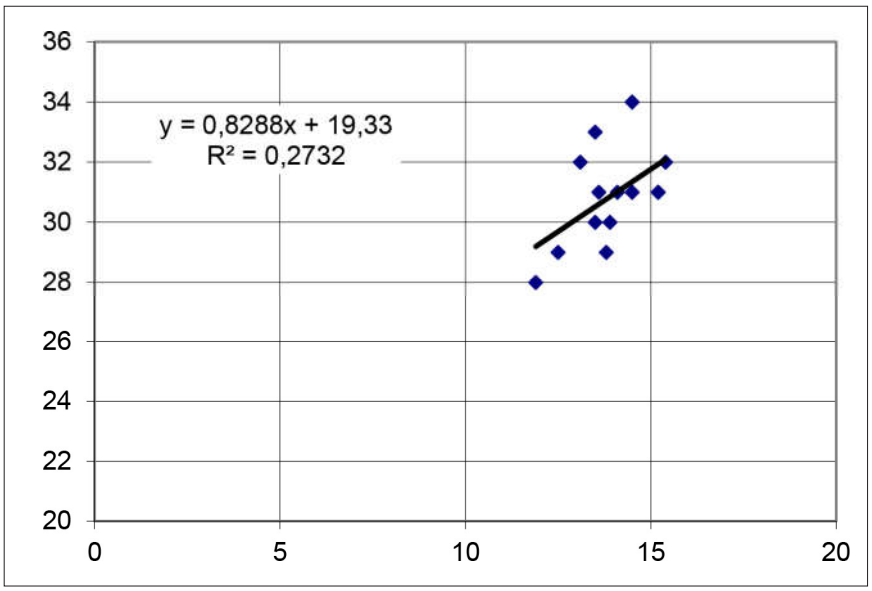

Figure 4 Nabala limestone deposit LA and cylinder tests results graphics

8 Conclusions

The result of this study is the correlation analysis and interaction coefficient. Due to this, it is possible to use previous time data of Soviet Union geological investigations to assess the quality of limestone and dolostone aggregate materials; it is possible to predict the limestone aggregates quality, also to transform the GOST Standard data into EN Standard by equation to get the quick assessment method.

Results show that resistance to fragmentation by EN standard and GOST standard have a definite interaction, and the coefficient of these can be easily calculated. Is possible to use this coefficient in conversion between previous old data to the new standards. It can save costs of supervision and helps to analyse aggregates quality.

It is important to continue the research in same key, correlating the EN and GOST standards. For instance, the resistance to freezing and thawing in different standardization methods has

different results calculations and values, but similar testing conditions. Also, sieve analysis grading (gradation test) of aggregates has different values and particles size distributions, although the preparations and testing conditions are almost the same. Hereafter, the given research will be continued with mentioned tests and will be more significant for aggregates contributors and proprietors.

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