

Gravel Sampling for Testing

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Abstract. Sampling is the selection of a representative portion of a material, and it's as important as testing. The minimum weight of gravel field or lab sample depends on the nominal maximum particle size. The weight of the sample will always be greater than that portion required for testing. The approximate precision desired for the testing will control the weight of the gravel sample. In this study, gravel sample has been simulated by using multilinear approximated function for Fuller's curve on the logarithmic scale. Gravel particles are divided into classes according to their medium diameter and each class was simulated separately. A stochastic analysis, by using 100 realizations in sampling, has been done and the root mean square error for the errors between sampled and target curve has been discussed for two selected samples of coarse aggregate.

1. Introduction

Gravel (coarse aggregate) is the natural or artificial inorganic granular material used with sand (fine aggregate) and a cementing medium to form concrete.

Gravel is a combination of stone particles between a maximum and a minimum sieve size. These sizes are varying in different specifications.

One of the main contributing factors to the quality of concrete is the quality of aggregate used therein. It is, therefore, imperative that due consideration is given to sampling procedures, which will assist in the accurate and objective evaluation of the quality of the sampled aggregate. Sampling is perhaps the most important step in assuring that good quality aggregates are being used.

A sample is a representative small portion from a larger amount of a material. It is essential that a truly representative sample of the material be obtained for testing purposes. Gravel sampling is of equal importance to its testing and a man drawing samples shall use every precaution to obtain a sample that will show the true nature and condition of the gravel, which it represents.

A field sample is supposed to be sufficiently a large amount of gravel for full representation of the whole supply. Specifications require only a portion of the field sample for the test sample.

The field sample should be reduced (split) to a sample size (test sample) that can be quickly tested. Two different methods are used to reduce a field gravel sample to the proper test size; mechanical splitter and quartering.

The test sample size must fall within the minimum and maximum weight limits provided by a specific specification [1].

In a gravel gradation, a sample of weighed dry gravel is separated through a series of sieves with progressively smaller openings. Once separated, the weight of retained particles on each sieve is valued and compared to the weight of gravel sample. Particle size distribution is then expressed as a percent retained by weight on each sieve size. Results are usually expressed in tabular or graphical format. Graphical displays use traditionally semi- logarithmic or the standard power gradation graph.



There is different gravel grading specified by specifications in the world. The adopted gravel grading is based on the uses and the availability. Gradation is measure of size range of gravel in specified range.

Several common terms are used to classify gravel gradation; fine gradation, coarse gradation, uniformly graded, open graded, gap graded and dense or well-graded (preferable for maximum density).

2. Aggregate simulation

In order to get a realistic representation of aggregate sample and confirm a minimum mass of test portion for sieve analysis, it should be simulated according to a grading curve. Grading curves can be either empirical from design codes or explicit functions such as Fuller's curve. In this study Fuller's curve was used with the equation shown below:

$$Passing \% = \left(\frac{d}{d_{max}} \right)^{\alpha} \quad (1)$$

Where Passing % is the passing percentage for (d) sieve size, d_{max} is the maximum aggregate diameter and α is Fuller's curve exponent which can be between 0.45 and 0.5 [2] or may be between 0.33 and 0.5 [3].

In the early 1960s, the American Federal Highway Administration used α equals 0.45 in the standard gradation graph [4].

Aggregate particles are assumed to be ellipsoids with three principal radii (r_1 , r_2 , and r_3) with $r_1 \geq r_2 \geq r_3$. The medium diameter $2 * r_2$ is the main diameter which is determinant for passing the aperture of the sieve. r_1 and r_3 are assumed to be related to r_2 by the following equations [5]:

$$r_1 = \left(1 + u_1 * \frac{m-1}{m+1} \right) * r_2 \quad , \quad 0 < u_1 < 1 \quad (2)$$

$$r_3 = \left(1 - u_3 * \frac{m-1}{m+1} \right) * r_2 \quad , \quad 0 < u_3 < 1 \quad (3)$$

Where u_1 and u_3 are realizations of independent uniform random variables. m is variable that determines the flatness of aggregate particles. If $m=1$ the particles will be spheres and higher values will increase flatness.

The mass of individual aggregate particles is: $m=4\rho\pi r_1 r_2 r_3$, where ρ is the density. r_2 should be chosen so the cumulative distribution for the particle masses follow the grading curve. In order to simplify the problem, the curve is approximated as multilinear function on the logarithmic scale with $2 \times r_2$. In this case, particles are divided into classes according to their medium diameter and each class is simulated separately. Equation (4) is used in order to get linear distribution in logarithmic scale within each diameters class.

$$d_{eqv} = 2 * r_2 = \frac{d_i d_{i+1}}{\sqrt{u_2 d_i^3 + (1-u_2) d_{i+1}^3}} \quad , \quad 0 < u_2 < 1 \quad (4)$$

Where u_2 is the realization of uniform random variable ranging from 0 to 1. d_i and $d_{(i+1)}$ are the boundaries of aggregate diameters class (i).

The mass of each aggregate diameter class should be:

$$m_i = \frac{\left(\frac{d_{i+1}}{d_{max}} \right)^{\alpha} - \left(\frac{d_i}{d_{max}} \right)^{\alpha}}{1 - \left(\frac{d_{min}}{d_{max}} \right)^{\alpha}} * m_{total} \quad (5)$$

where d_{min} is the minimum diameter of aggregate involved and m_{total} is the total mass of aggregate.

The process can be summarized as: The mass proportion is determined for highest diameters class using equation (5). Then individual aggregates are simulated and their mass is computed using equations (1-4). The procedure is repeated until the required mass is exceeded. The difference between the assigned mass and the simulated mass is subtracted from the mass of the next aggregate class to ensure total mass will not exceed. Then the process is repeated for the next diameter class.

3. Simulation results and sampling study

3.1. Sample Simulation

Two samples of coarse aggregate were simulated with the parameters in table 1, by using the method that described earlier. The grading of the selected samples is according to ISS 45 [6].

Table 1. Coarse Aggregate Simulation Parameters.

	5-20 Aggregate	5-40 Aggregate
d_{min} (mm)	5	5
d_{max} (mm)	20	40
α	0.5	0.5
m	3	3
ρ (g/mm^3)	2.6	2.6
m_{total} (kg)	100	100

Figure 1 shows the distribution curves for the multilinear approximation of Fuller's curve (Target Curve) and the simulated curves. It shows high level of matching.

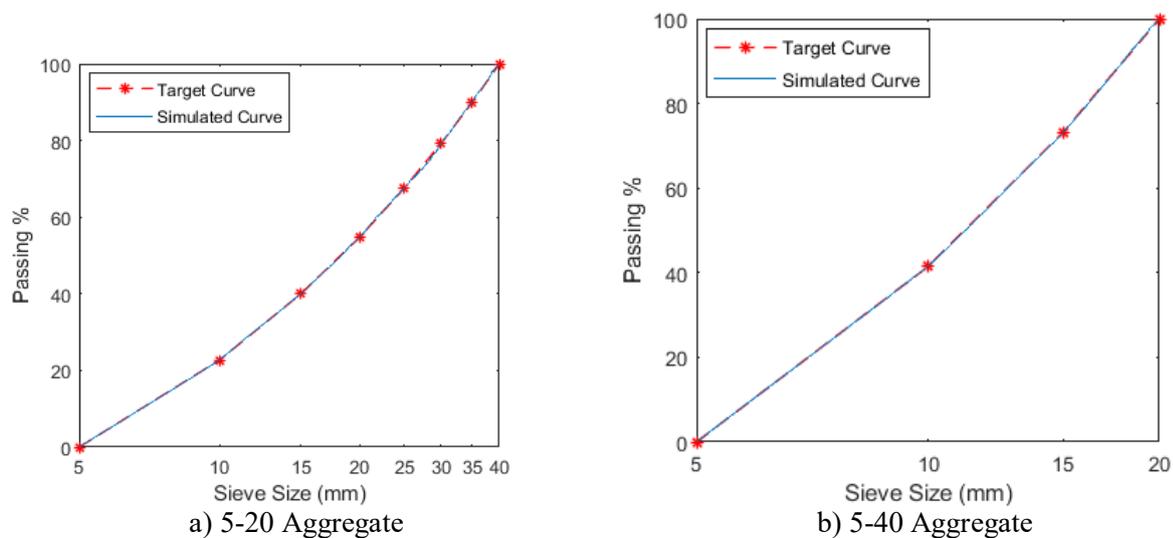


Figure 1. Target vs. Simulated Curve.

3.2. Sampling Study

In order to study the effect of suggested sampling on the distribution of coarse aggregate, the two samples were sampled by taking random gravel particles from the sample till reaching a certain sampling weight. The sampling weights were 0.5 kg, 1 kg,10 kg for 5-20 aggregate and 1 kg, 2 kg, 20 kg for 5-40 aggregate. Figure 2. a) and b) shows the distribution of sampled gravel for some different weights.

Figure 2. c) and d) shows the difference between the sampled and target curve (error). It is clear from the figures that as the sample weight increases the error decreases. Also the error is greater in higher sieve sizes than small sieve size due low number of large gravel particles.

Time will not allow testing the total gravel. The key to sampling is to ensure that the weight of sample taken representative of the material in the stockpile with acceptable error. The approximate precision accepted by the lab for the testing will control determination of the weight of the gravel sample.

3.3. Stochastic Analysis (100 Realizations)

Since the stock pile simulation and sampling study described earlier are random processes, it is important to repeat them many times to get the statistics. So, 100 realizations have been repeated with each realization having curves different than curves in figure 1 and 2 figure 3 shows how distribution of sampled weight can be different for a three realizations for the two samples.

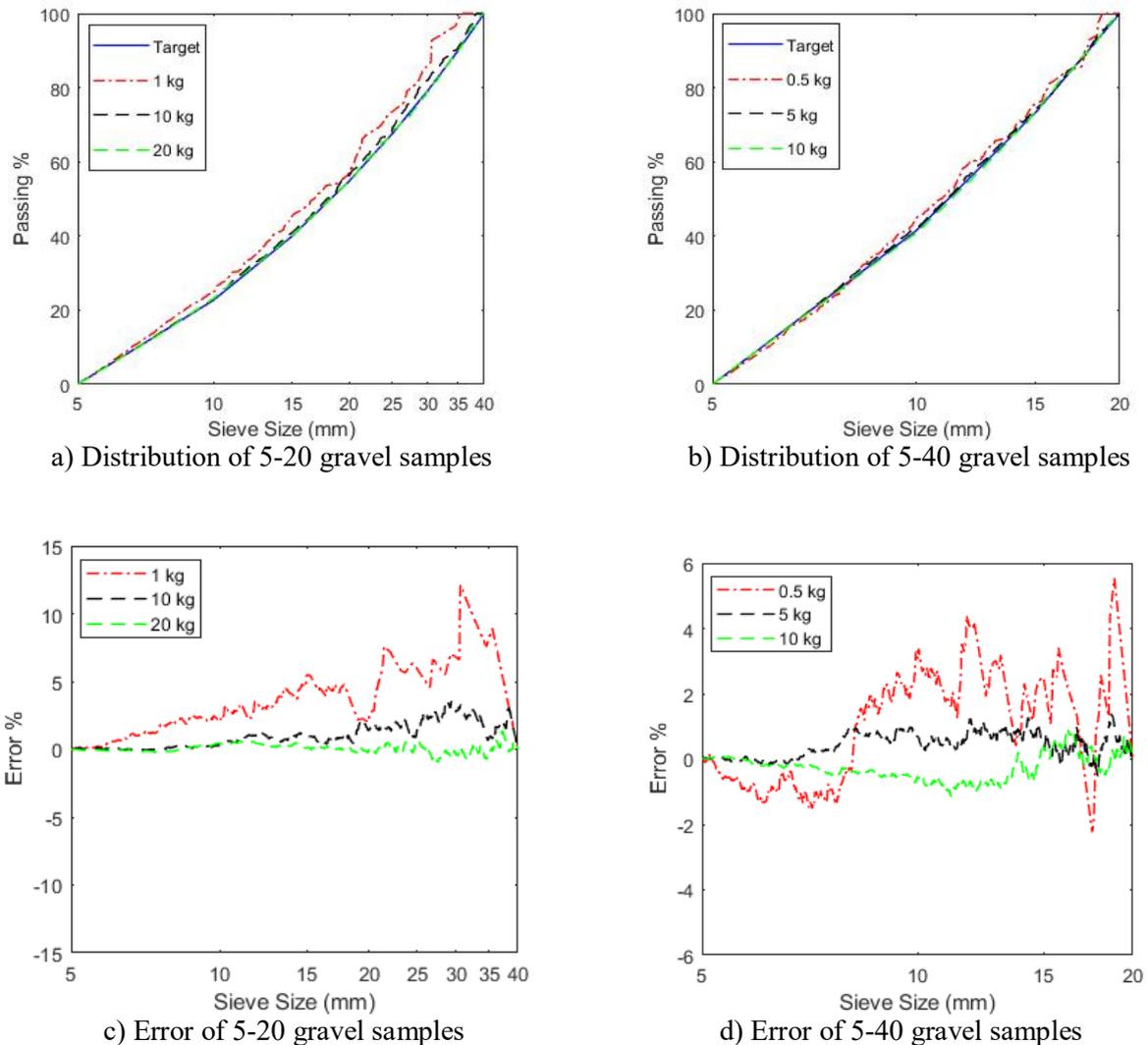


Figure 2. Distribution and error of the sampled gravel.

It is irrational to show all the 100 realizations and their errors, so it is more convenient to find root mean square error (RMSE) for the errors between sampled and target curve. It is clear that RMSE decreases with the increase of sampling weight and it is greater for higher diameters. Figure 4. shows how RMSE changes with diameter can be different for three realizations.

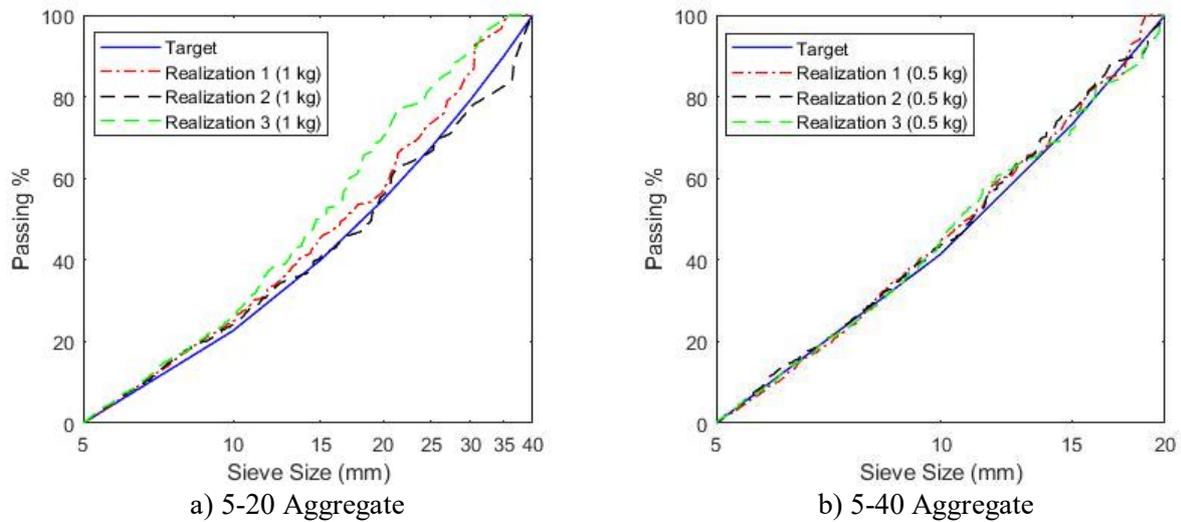


Figure 3. Distribution of sampled weight for three different realizations.

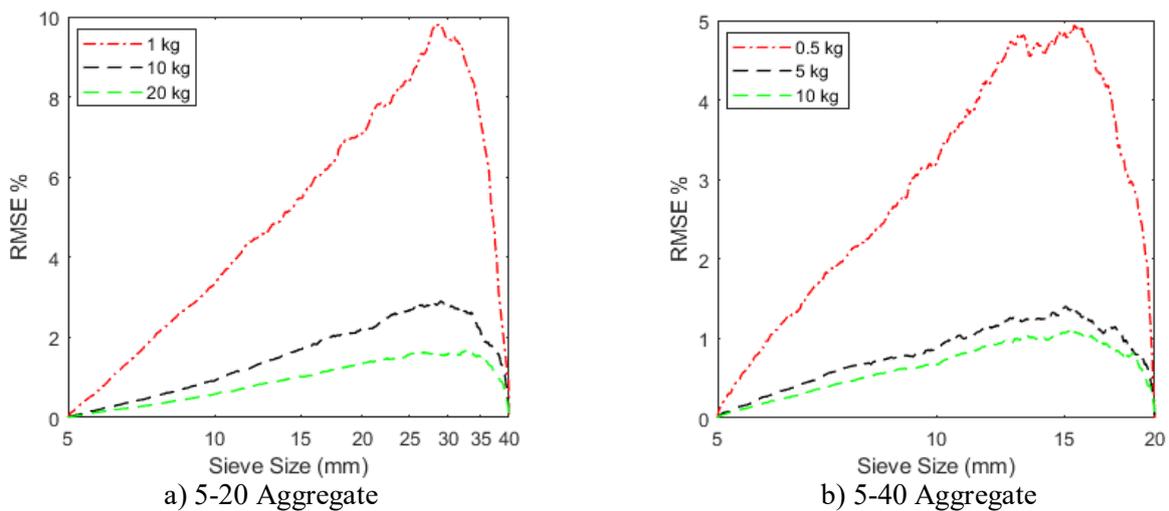


Figure 4. RMSE change with diameter.

To see the effect of sampling weight on RMSE, the sampling weight is plotted against maximum values in RMSE curves as shown in figure 5.

The plotted results show that the proposed multilinear approximated function for Fuller's curve produces a good estimate of gravel sample weights. It achieves a decreasing RMSE for the two samples.

Theoretically, there exists a particular aggregate gradation that, for a given nominal maximum particle size, will yield the maximum material density. This gradation would involve a particle arrangement where successively small particles fill the spaces between the larger particles.

The approximate precision desired for the estimate should be prescribed by the sampler. That is, it must be decided what maximum deviation can be tolerated between the estimate to be made from the sample and the result that would be obtained by measuring every unit in the lot or process.

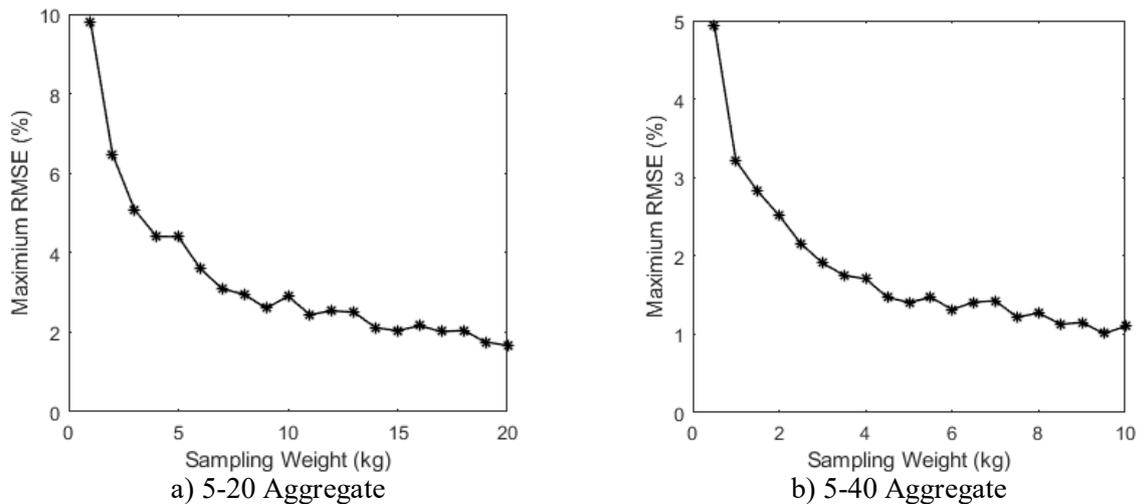


Figure 5. Maximum RMSE change with sampling weight.

4. Conclusions

A multilinear approximated function for Fuller and Thompson's equation on the logarithmic scale has been developed in random processes to simulate gravel test sample for sieve analysis (grading). Gravel particles are assumed to be ellipsoids and the medium diameter of the gravel particles has been employed in the sampling procedure.

The desired precision for the gravel sieve analysis results and the nominal maximum particle size will control the weight of the gravel sample.

References

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