Sand Sampling for Testing

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Abstract. Fine aggregate (Sand) is a necessary material used in concrete construction purposes, it’s naturally available and it’s widely used around the world for different parts of construction in any building mainly for filling the voids between gravel. Sand gradation is important for different composite materials, and it gives good cohesion when compared with coarse sand that provides strength for the building. Therefore, sand is necessary to be tested before it is used and mixed with other building materials in construction and the specimen must be selected carefully to represent the real material in the field. The specimen weight must be larger than the required weight for test. When the weight of the sand sample increases the approximate precision desired increases. In this study, an approximated multilinear function for Fuller’s curve on the logarithmic scale was used to simulate the fine aggregate (sand) numerically. In order to get the effect of different samples, a stochastic analysis was done by employing 100 realizations of specimens, has been conducted to study the effect of sampling on sieve analysis and the root mean square error (RMSE) for the variation between desired and sampled curves. Then the results were compared with available specifications recommendations.

1. Introduction
Sand (fine aggregate) is the naturally inorganic grainy materials consisting of shells, rock and coral. Sand is mixed with gravel (coarse aggregate), cementing medium and water to form concrete. Its commonly used in construction because of its properties like strength, give volume and its stability when mix with other materials like cement, render and asphalt.

Sand is typically coarser than silt but finer than gravel. Sand composition varies is depended on condition and location where it was found. In the ground of continental regions sand is consist of silica (silicon dioxide). Sand formed and used in construction since millions of years.

Sand is usually separated into five sub-group depended on its size: very fine sand (1/16mm – 1/8 mm diameter), fine sand (1/8 mm-1/4 mm diameter), medium sand (1/4 mm-1/2 mm diameter), coarse sand (1/2mm - 1 mm diameter), and very course sand (1 mm– 2 mm diameter).

One of the main elements that effect on the concrete properties and quality is the quality of sand that used in the mixing process, therefore, its essential that taking sampling process for sand specimen. Sampling is very important issue to ensure that good quality of sand (fine aggregate) before beginning to used it. The degradation of the aggregate sample affects on the behavior of construction materials such as asphalt [1].

A specimen is representing a small part from a big quantity of a material. In addition, it has must represent the specimen of the materials that gets form the testing aim. Sand specimen should be the same sampling materials in the nature and its condition which it illustrate [2].

The specimen take from the site must be suitable to represent a big amount of sand for total representation of the all given sample. The require specifications need a part of the sit specimen for the testing sample.

The specimen gets from site must be minimized. splitting of the specimen size helps being fast and easily tested. There are two different ways to reduce the size of field sand specimen may be used to the suitable test size; quartering mechanical and splitter.
In sand graduation test, a dry specimen of sand is weighed and then separated by used a series of sieves with gradually smaller sieve hole. First divided, the retained particle was weighted for the all sieves amount and compared with the weight of sand specimen. The percentage retained of the specimen by the weight of particle size distinguished by weight on every sieve. Results commonly act in table form or diagram resolve. The diagram shows the use of the classically semi-logarithmic or the standard power graduation diagram.

In this paper sand was numerically simulated using random processes according to prescribed sieve curve, and then sampled for different weights to get the variation between original and sampled curves. A stochastic analysis was conducted to get the statistics for different random trials and weights. After that, the analysis results were compared with available specifications about sand sampling.

The paper is outlined as follows: the process is sand simulation is described in section 2. Then after results of sampling were discussed in section 3, and finally the conclusions are summarized in section 4.

2. Sand simulation

In order to obtain the sand modeling sample statically characteristics was used and the particle size of the sample was get by grading curve. Grading curve means set of sieves with standard opening sample of the sand passing through these sieves. The sample must be regulated depending on the graduation diagram. A graduation diagram can be getting by experimental design from codes or by used clear functions like Fuller’s curve. In this research, we used Fuller’s curve equation as defined below:

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

where $d$: the size of the particle diameter.

d$_{\text{max}}$: the maximum diameter of the sand particle.

Passing \%: the percentage passing of the sand specimen.

$\alpha$: Exponent of Fuller’s curve and it is typically between 0.45 and 0.5 [3,4,5].

Sand particles are modelled as ellipsoids with three radii ($r_1$, $r_2$, and $r_3$), it assumed $r_1 \geq r_2 \geq r_3$. The medium diameter $2r_2$ is the medium diameter and it can be found form the passing specimen through the opening the sieve. $r_1$ and $r_3$ can be obtained from $r_2$ according to the following equations [6,7]:

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

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

where $u_1$ and $u_3$ are observation of independent uniform randomly variables. m is a constant that represent the flatness of the sand specimen. For $m = 1$ that mean the particle of sand specimen be a sphere and where m reach to higher values that mean flatness was increased.

The mass of individual sand particle is $m=4\rho \pi r^3$ where $\rho$ is the density.

$r_2$ must be selected from the line of the grading curve of the cumulative distribution masses of the sand particle. using the logarithmic scale, the graduation curve was approximated to multilinear function. In this problem sand particles were split into classes depending on their medium diameter and every class was simulated individually.

To obtain particles diameter for every class of that linear distribution in logarithmic scale we can use equation (4).

$$d_{\text{eqv}} = 2 \times r_2 = \frac{d_1 \, d_{i+1}}{\sqrt{u_2 d_1^3 + (1-u_2) d_{i+1}^3}}, 0 < u_2 < 1 \quad (4)$$
Where \( u_2 \) is the uniform randomly variable between 0 to 1. \( d_{i+1} \) and \( d_i \) are the diameters boundaries of sand class (i).

The mass of every sand diameters class must be:

\[
m_i = \frac{(d_{i+1})^a - (d_i)^a}{1 - (\frac{d_{min}}{d_{max}})^a} \times m_{total} \tag{5}
\]

Where: \( m_{total} \) is the total sand mass and \( d_{min} \) is the minimum diameter of sand concerned.

The process can be epitomized as: the amount of all the mass is can be obtain form largest diameters class by using Equation (5). After that the individual sands classes are similar and their mass is getting by using Equations (1-4). The operation is return until the desired mass is overtaking. The segregation between the constructed mass and assigned mass is discounted from the mass of the subsequent class of the sand to enclose all the mass is not exceeded. Then the procedure was repeating for the subsequent diameter class.

3. The results simulation and specimen study

3.1. Specimen Simulation

Specimen of fine aggregate (sand) parameters was simulated in Table 1, by using the equations and process that represent previously. The selected parameters were selected according to ISS 45 [8].

| Table 1. Sand parameter (sand) | Parameters | 0.5-5 |
|-------------------------------|------------|-------|
| \( d_{min} \) (mm)           | S          | 0.5   |
| \( d_{max} \) (mm)           | S          | 5     |
| \( \alpha \)                 | S          | 0.45  |
| \( m \)                      | S          | 3     |
| \( \rho \) (g/mm\(^3\))      | S          | 2.6   |
| \( m_{total} \) (kg)         | S          | 10    |

Figure 1 displays the division curves for the approximation multilinear Fuller’s curve (Target Curve) with the simulated curves. It can see good degree of matching.

![Figure 1. Target vs. Simulated Curve for sand specimen.](image-url)
3.2. Study of the Sampling
To see the effect of specimen weight of fine aggregate (sand), the specimen was selected randomly sand particles from the specimen until getting certain specimen weights. The specimen weight is 0.05 kg to 0.5 kg. Figure 2 shows the three trails for modeling 0.05 kg weight sand specimens.

The specimen must represent the real material in the site with acceptable error. The convergent accuracy acceptable in the laboratory for the specimen controls the weights of the sand sample.

Since the storage was sampled and the specimen investigated was represented previously are random processes, it is better to repeat the process many times to obtain the statistics. So, it was repeated 100 realizations and a curve for every. It can be showed in Figure 3 the effect of the weight of the sand specimen with the distribution for three different weights.

Figure 4 shows the difference between the target curve (error) and sand specimen. It can appear that when the weight of the specimen increases causes decrease in the error. Also in the small sieve size the error appears smaller than in the big sieve sizes due to the few numbers of large sand particles.

![Figure 2. Three trails for modeling 0.05 kg weight sand specimens.](image)

![Figure 3. Distribution of the weight of the specimen with three different trails](image)
Figure 4. Distribution and error of the sand specimen

It is illogical to see the 100 realizations and their errors, so it is suitable to distinguish root mean square error (RMSE) between target and the specimen curve. Figure 5 shows RMSE relationship with diameter of the specimen with three different realizations. It can be seen that RMSE increases when specimen as weight decreases and its value decreases with decrease the diameters of the specimen.

Figure 5. RMSE variation with diameter

To illustrate the influence of the specimen weight on RMSE, the specimen weight is drawn versus maximum values of RMSE for each weight can be found in Figure 6. It also shows a regression curve for the results with an exponent of -0.5.
Specifications set different sample minimum weights to be used for sieve analysis. AASHTO T 248[9] suggest using at least 300 gm, while Indian standard [10] recommended at least 200 gm. Both of them have max. RMSE according to Fig. 6 of 0.7% and 0.95%, respectively. Other specifications [11,12] set higher sample weights of 500 gm to get more precision with maximum RMSE equal to 0.55% according to Figure 6.

4. Conclusions
In this study used approximate multilinear function for Fuller equation on logarithmic function was used in a stochastic process to generate sand particles for sieve testing. The particles of the sand assumed ellipsoids and different diameters of the sand particles has been used to represent the desired specimen. The study of the effect of random samples with different weight had shown that samples with larger weight have smaller error while largest deviation happen to appear in higher particles diameters. A comparison with recommended values of minimum samples weights for different specifications suggest a maximum of RMSE of 0.55-0.95% in sieve analysis will occur.

5. References
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