# Unified Practice in Grainsize Classification for Civil Engineering Purposes

*by*

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## Introduction

In soil as well as coastal engineering practice, particles right from clay < 0.002 mm to boulders of more than 30 cms are usually encountered. Grainsize characteristics are expressed by numerical values, indicating some characteristics of grainsizes or by names or by symbols, expressing dominent soil fraction. In soil engineering well defined statistical correlations between grainsize and significant properties exhists, which can be used as a basis of judging important soil properties such as internal friction, coefficient of permeability, uniform coefficient etc. The measurement of sediment size particles, helps to understand the process of transportation and deposition of sediments and in the study of contemporary processes and classification of deposits. The ultimate distribution of sediments after transportation and deposition depends on the size of particles and also on conditions of transporting environment. The critical velocity value for entrainment in the transporting environment depends on particle size. Further in beach environment—deposits of coarse size fractions are associated with high energy areas such as breaker zone, berm crest zone and transition zone between surf and swash and fine size fraction deposits are observed with lower energy areas such as deep water and the offshore zone.

## Characteristics of Beach Sediments

(*i*) Littoral materials vary from consolidated rock to clay, but sands with medium diameters between 0.1 to 1.0 mm are most abundant and these are the typical littoral materials mainly considered for shore protection design problems.

(*ii*) Beach sediments usually have a few relatively large particles covering a wide range of diameters and many small particles with a small range of diameters.

(*iii*) Fine grained material at or near surface along the coast is predominent when the annual mean break height is below about one foot and also it depends upon the contribution of fine sediments from rivers.

## Classification Systems

The most commonly used ten classification systems are :

(*i*) U.S. Bureau of soils

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(*ii*) Alterberg Internal standards

(*iii*) M.I.T. system proposed by Gil boy

(*iv*) U.S. Department of Agriculture

(*v*) American Geophysical Union

(*vi*) Classification followed by a majority of Organisation in India

(*vii*) Indian standard Institute 1498-1959

(*viii*) Indian Standard Institute 1498-1970

(*ix*) Unified soil classification based on casegrande classification

(*x*) Wentworth classification system.

In Figure 1, the first seven classification systems are compared. In Figure 2, the last three popular classification systems are examined, and indicated in both wentworth phiscale as well as in millimeters. In majority of cases the bifurcating sizes between clay and silt as well as sand and gravel are 0.002 mm to 2.0 mm respectively. Wentworth classification system only gives clay ranges. The gravel range is common to both wentworth classification and American Geophysical Union namely, 2.0 mm to 64 mm. Further in wentworth classification obsolute differences in the finer sizes namely in sands are exaggerated.

**Wentworth Classification Systems**

In wentworth scale zero phi corresponds 1 mm. On the right side phi scale extends to +12 phi and on the left side to −8 phi covering finer and coarser fractions respectively.

The formula used by wentworth is $\phi = -\log_2 d$ where $d$ is diameter of the particle in millimeters or precisely $d = (\frac{1}{2})\phi$. Most sediments have a log normal size of distribution. If the areas beneath the curve of a normal distribution, as in the case of sediments, is transposed to linear scale, the resulting pattern leads to one in which extreme values are widely spaced and the central values are clustered together, resulting in a symmetrically smooth bell shaped curve. Realising this Krumbein introduced a logarithmic scale of size classes known as phi ($\phi$) scales. The phi ($\phi$) scales give simple scale of measurement already converted to logs. Hence the percentage sediment plots for each class automatically gives a normal distribution. Also $\phi$ units are arranged in arithmatic sequence. Thus $\phi$, $2\phi$ and $3\phi$ are represented by 0.5 mm, 0.25 mm and 0.125 mm respectively, thus simplifying their use. Phi size classes at the coarser and (−2 to −3 $\phi$ equal to 4 to 8 mm in size) of scale are larger, in absolute terms when compared to finer size classes (+2 to $3\phi$ equal to 0.125 mm to 0.25 mm). Thus the difference of 1 mm sand sized material has significant implications to the process of erosion, transportation and deposition than 1 mm difference in coarse gravel. The phi scales groups together particles with similar hydraulic characteristics and separated out particles with dissimilar hpdraulic properties. Thus pebbles of 9 mm and 10 mm diameter behaves similarly in flowing water whereas sands of 0.5 mm to 1.5 mm diameter vary with different hydraulic properties. The phi scale simplifies not only plotting of the distribution of particles but also for the subsequent statistical analysis.

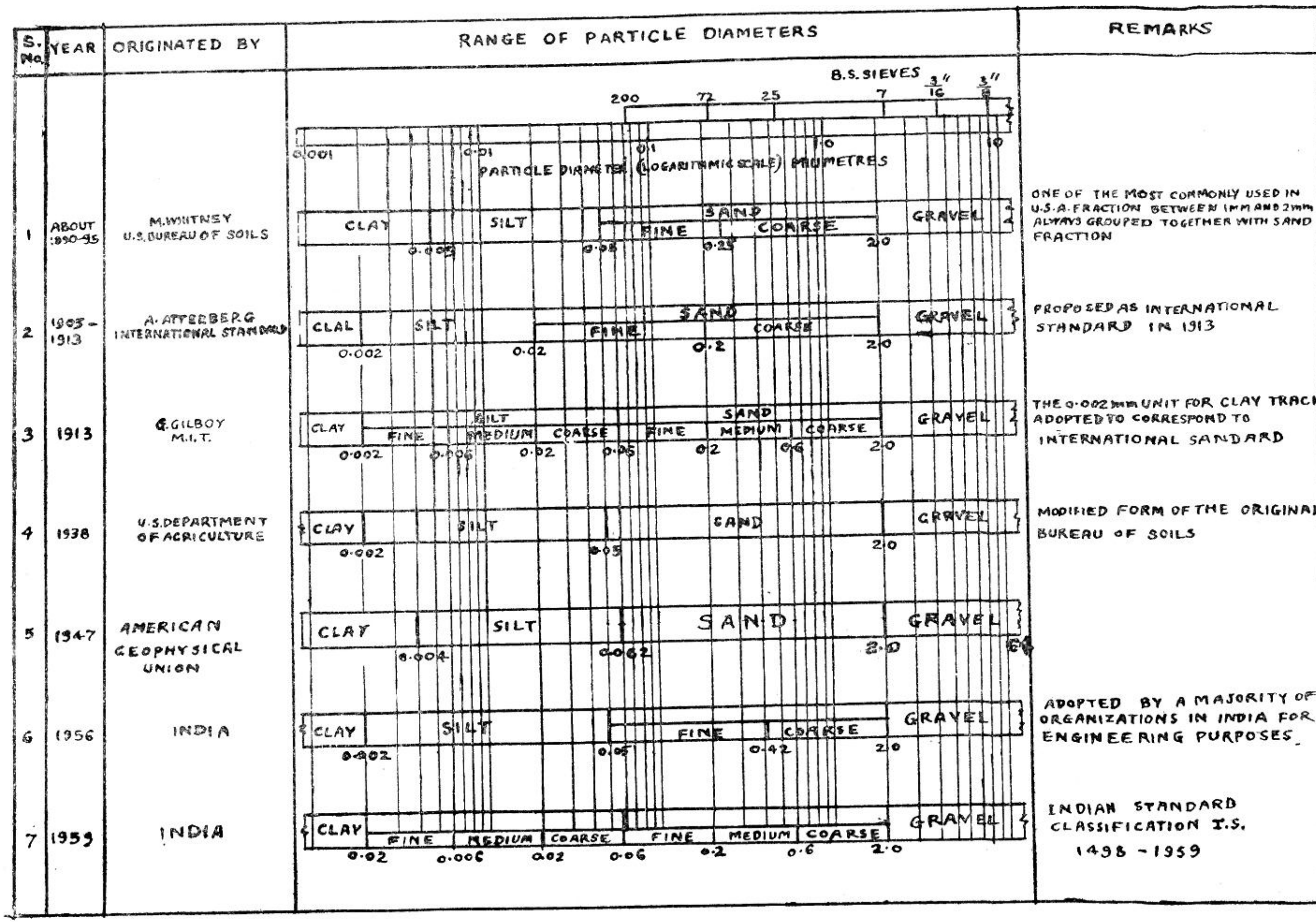


**FIGURE 1** Principal particle size scales (Adopted from I.S. 1498-1959)

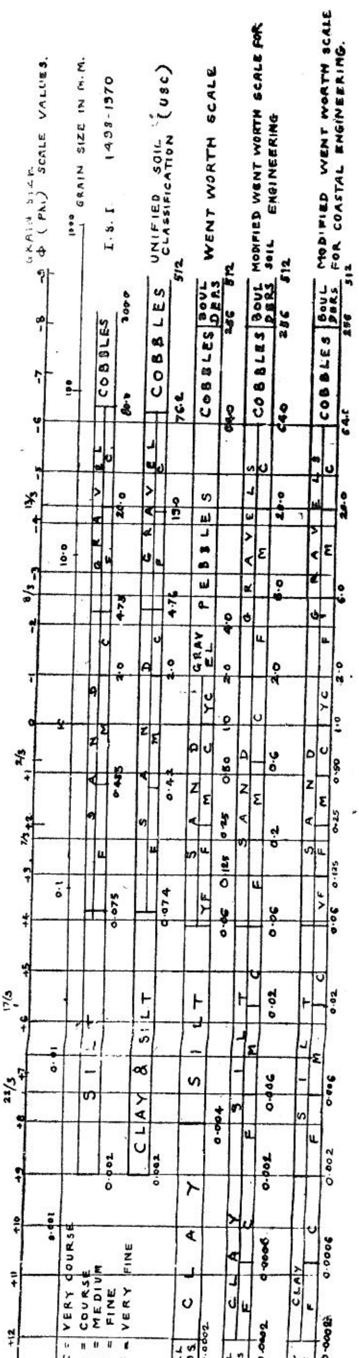


FIGURE 2 Comparison of common textural classification systems

## Modified Wentworth Classifications

After comparing of all these classification systems it is the idea of the author to evolve a classification system, which will have all the advantages of wentworth classification system but also at the same time incorporate the merits of other classification systems. Hence two modified classification systems have been evolved for soil and coastal engineering, which are best suited for soil and coastal engineering practice.

Figure 2 gives two modified wentworth classification systems for soil and coastal engineering along with three other classification systems. In these systems the bifurcating limits between all sizes are defined by whole numbers in phi units. In case of both clay and cobbles sizes the interval is equally divided into half of phi units and designated as fine and coarse fractions. In case silts, sands and gravels each next subfraction is altered by a difference equal to 5/3 phi units. Such of the terms like granules and pebbles, which are not in common use is replaced by popular terms such as fine, medium and coarse gravels. Further the equivalent values of $\phi$ numbers in mm is restricted to first numerical digits only such as 2 and 6. The above system is built upon by the number 2 and 6 altering with decimal point moved one place with each alteration. Each above fractions is subdivided in three equal phi units such as fine, medium and coarse. This classification is simply most logical and easy to remember and can be more popular in use. But one exception is made in case of sands and the same bifurcation is maintained for coastal engineering as given by wentworth.

The ranges of modified wentworth classifications are indicated both in phi units and also in millimeters. This will facilitate appreciation of physically related quantities, which are indicated by units of length such as grainsize, Reynolds number or relative roughness. Percentage of coarser particles coarser than each seive is calculated. This cumulative percentages of coarser material are plotted on the arithmatic probability paper on the y-axis. The size scale in $\phi$ units or mm are arranged in x-axis from coarse at the left hand end and to the finer at the right side end, with an increase of $\phi$ in the right side end. 84th and 16th percentile value is simply the size on the x-axis corresponding to 84th and 16th percentage on the y-axis. The transformed lognormal distribution is then represented by a straight line.

## Application of Wentworth Classification for Planning of Protection of Beach by Artificial Nourishment

In the first place, the grain size analysis of both beach material or natural sand as well as borrow material is carried out. It is further ascertained if there is some borrow material in each size class that comprises the native material. Computation could be made directly by finding phi size class with the maximum ratio of native to borrow weight proportions. This is the critical ratio ($R\phi$ cut) representing the estimated cubic yards of fill material required to produce one cubic yard of material having the desired particle size distribution similar to that of native or stable material. The first graphic moments of each size distribution are computed for less error and these values are substituted within the following equation,

$$R\varphi \text{ critical} = \frac{\sigma\varphi b}{\sigma\varphi n}\, e^{-\left[\frac{(M\varphi n - M\varphi b)}{2(\sigma^2\varphi n - \sigma^2\varphi b)}\right]}$$

where $\sigma\varphi = (\varphi_{84}-\varphi_{16})/2$ which is a measure of sorting

$M\varphi = (\varphi_{84}+\varphi_{16})/2$. phi ($\phi$) means diameter of grain size distribution $-b$ and $-n$ subscripts for borrow material and natural sand respectively.

$\varphi_{84}$—84th percentile in phi units

$\varphi_{16}$—16th percentile in phi units.

By knowing the percentage retained on each sieve, the cumulative $R\phi$ crit gives the best estimate of required overfill ratio when borrow material is finer than the native material ($M\phi b > M\phi n$). But in the other case when borrow material is coarser than the native material ($M\phi b < M\phi n$) then required overfill ratio is probably less than the componitide $R\phi$ crit. However, it is observed that the computed values for critical ratio are in more sensitive to the phi sorting ratio than difference in phi means. This clearly means that, if the borrow material is poorly sorted when compared to native material, the errors during the determination of differences in phi means will not contribute any significant errors in critical ratio computations.

## Conclusions

For soil engineering purposes, the modified wentworth soil classification systems meets all the requirements from clay to boulders and hence adopted with ease.

For coastal engineering purposes, the sand is further divided into five sub-fractions, which clearly meet the required exaggeration in absolute difference in the finer sizes.

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