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Screenings from the Soil Research Lab

IOWA ENGINEERING EXPERIMENT STATION
IOWA STATE UNIVERSITY of Science and Technology
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SOIL CLASSIFICATION, II.

'Twas brillig...

Engineers are eminently practical men, and whether they're evaluating something for the job or furnishings for the home, such as a wife, the questions remain basically the same: Will it work, how soon will it wear out, and how much does it cost? Some engineers get on space-age jobs where these particular answers don't seem to make much difference, but practicality also can take other directions.

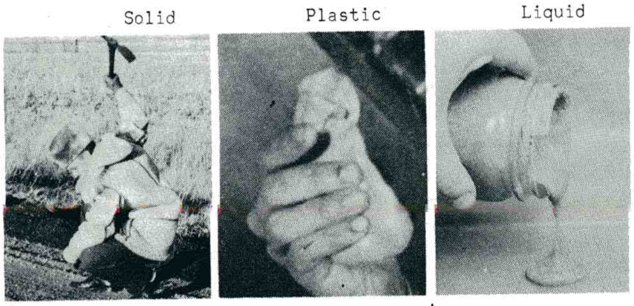
For example, in this outer space mischief you don't find one engineer sending himself up. There's always somebody better qualified, like officers, mice, and chimpanzees. Engineers are no astronuts, and they let the chimps be the chumps who ride the long shots for fleeting fame and speaking engagements. The thinking rocketeer maintains a proper perspective by keeping his feet on the ground, or on the desk if necessary, and letting the chimps fall where they may.

Speaking of on the ground, engineering classifications for soils are sweet and simple as a good night kiss on a lighted porch. That is to say they are usually adequate for the immediate purpose, such as to say good night, but they may leave something to be desired.

And so we present Part II of a II-part parlay on soil classification. The first, presented in the last issue, gave recent thinking of soil scientists, or agronomists. Now we are going to devastate soil engineers.

Three moisture conditions of soil:

Solid | Plastic | Liquid



Plastic limit | Liquid limit

B.P.R. System

In the 1920's the father of soil mechanics, Dr. Karl (or Charles) Terzaghi, came to this country after 10 years at Robert College in Turkey. Soon he met mother Chester Hogentogler, Senior Highway Engineer with the U. S. Bureau of Public Roads, and they became parents to the first and most widely used system of engineering soil classification. It was probably the greatest single advance in highway engineering since free air.

With almost startling insight and perception, Hogentogler and Terzaghi grouped soils according to performance as pavement subgrades, and roughly characterized the soil groups by pertinent engineering tests. _A_ group soils gave uniform support to pavements, whereas _B_ group soils did not. The latter were not very carefully defined and have since gotten lost.

_A_ soils were classified as A-1 through A-8. An A-1 soil is as the tag implies, A-1 for highways, whereas A-8 is at the other extreme, like peat bogs. In-betweens are in between.

This epic classification was published in 1929. Requirements for an A-number-one highway soil had been described a couple years earlier by C. M. Strahan in Georgia, who pointed out that the best is not a gravel or a sand or a silt or a clay, but a graded mixture of all

The plastic limit (left) is the moisture content needed to make a soil plastic. Below the P.L. the soil crumbles when shaped by hand -- unquestionably the simplest and therefore one of the most criticized of all soil lab tests.

On the right, former Robert College soil mechanic Joakim (Jim) Laguros, now at Iowa State, tests for the liquid limit, or moisture content needed to make a soil liquid when tapped on $65 standard machine. That's more like it.

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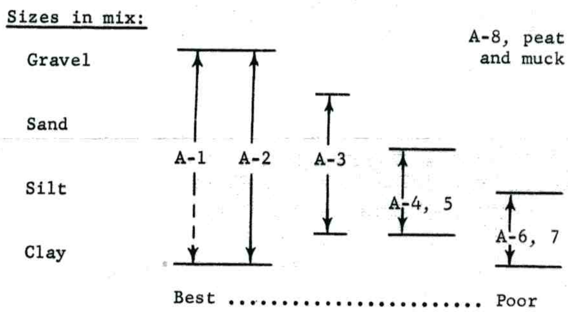
sizes. And so it is with the A-1's in the engineering classification.

A-2 soils are almost like A-1's but they soften in the rain. Too much clay and fines.

A-3 soils are rutty, cohesionless sands, soft when dry. Too little clay.



A-4 soils are very fine sands without much granular interlocking as in A-1, 2, and 3, and without much clay. Not strong, and very susceptible to frost action.

A-5 soils are like A-4 but difficult to compact because of the content of mica or diatoms (Fuller's earth).

A-6 soils are clayey, swelling soils which need a tight roof or they become mud.

A-7 soils are like A-6 but more so. In addition they are spongy and difficult to compact. Much expansive clay mineral.

A-8 soils are utterly ugh. Peat and muck.

Organization Men

In the 1920's as highway engineering blossomed and engineers first became literate, they organized, the better to write things down and talk things over.

As a general rule when a group becomes larger than about 20 the time is right to either disband or break into committees so everybody has a chance. When the committees grow to about 20 or more you will begin to see subcommittees, and when these grow, sub-subcommittees, and sections and subsections, and so on, to the tune of Hi-Ho. Work is then pursued by a few while business is conducted by all the rest.

By the 1940's the Public Roads soil classification system had had extensive trial and was ready for revision. The Highway Research Board

Committee.

Department of Soils Investigations Committee on Classification of Materials for Subgrades and Granular Type Roads Subcommittee Representing Highway Engineers[1] did the job in fast time for a committee. They proved that the committee route is best for widespread acceptance, albeit quite a strain on individuality. D. J. Steele was subcommittee group leader.

The A soil groups remained much the same but were more precisely defined on the basis of sieve analysis and plasticity. By use of a key somebody who knows nothing about soils can now classify and talk knowingly.

% sand + gravel (ret. on 200 sieve)	% fine sand, silt, clay (pass 40 sieve)	% coarse sand + gravel (ret. 40 sieve)	% gravel (ret. on 10 sieve)	Plasticity index	Group
>85	-	>70	>50	6 max	A-1-a
>75	-	>50	-	6 max	A-1-b
>90	>51	-	-	NP	A-3
>65	-	-	-	*	A-2
<65	-	-	-	*	A-4, 5,6,7

*See graph of PI and LL (left column, next page).

The A-1, A-2, and A-7 groups have been subdivided, the subgroup number in most cases suggesting the near intergrade. For example, an A-2-4 is an A-2 with silt, like an A-4, an A-2-6 is an A-2 with clay, like an A-6. The only exception is in A-1; A-1-a contains gravel or stone, whereas A-1-b contains mainly coarse sand.

In the revised system soils also were given a "group index" based on plasticity properties and percent fines, and written in parentheses. The higher the group index the lousier the subgrade. Example: A-7-6(20) is not so good as A-7-6(18), although the difference would be

[1]Because of growing complexity many groups now use abbreviations. For clarity this should be HRBDSICCMSGTRSRHE.

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scarcely distinguishable. When you can split differences to the vanishing point the classification may be considered real fine. Group Index is obtained from liquid and plastic limits and percent fines by means of an horrendous empirical formula, or from two charts, shown at right.

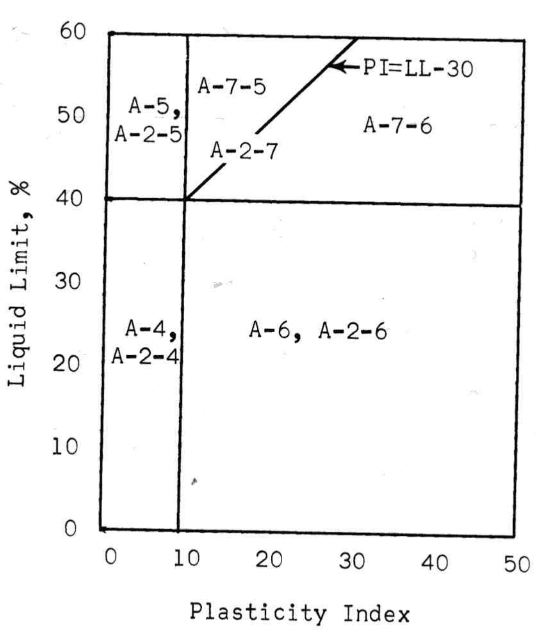
The modified Public Roads classification was subsequently adopted by the American Association of State Highway Officials and dubbed the AASHO (ash-o) system.

Brief problem: My back yard is strewn with boulders from 6 inches to 34 feet in diameter which catch in the lawn mower. Is there any way to correct this? I live at the foot of a cliff. -- Californian.

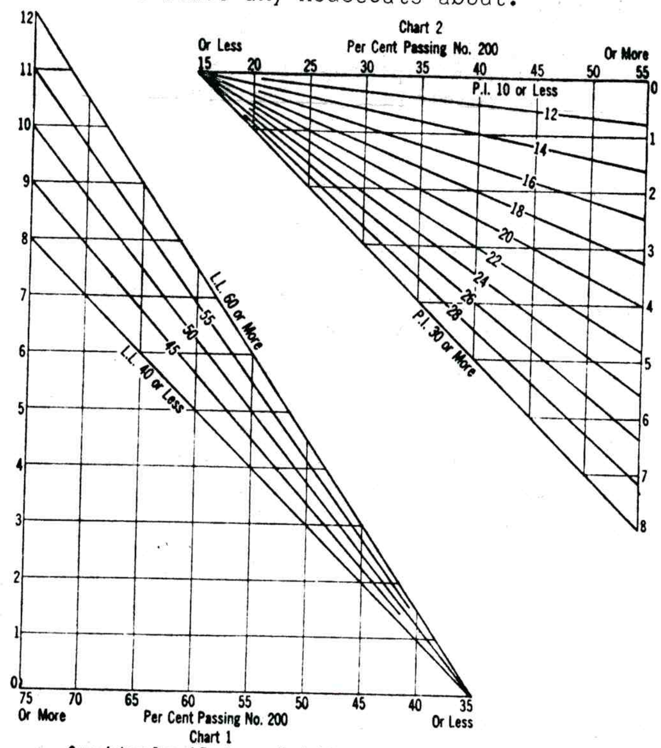
Ans.: According to the AASHO soil classification your back yard is A-1-a soil and you should have no problem; go ahead and build the road. As for the boulder, paint on a door and call it your fallout shelter.

Another problem: My husband tracks mud into the house. Upon drying, smashing and sieving I find that 45 percent passes the No. 200 sieve; the liquid limit is 60 percent water, below which the plastic range is down to 20 percent water. What do you recommend? -- Farm Wife.

AASHO Classification
of Fine-Grained Soils



Ans.: Burial. To further analyze, 45 percent passing the 200 puts it in the A-4, 5, 6, or 7 groups, and as you can see from the diagram at left, an LL of 60 and a plasticity index, or PI, of 60 - 20 = 40, puts this in the A-7-6 subgroup. This is a very sticky clay and may not behave well in the living room, particularly if the roof leaks. We suggest that you remove this clay or at least cover it with several inches of sand before you invite in friends. Don't leave any housecats about.



Group Index = Sum of Readings on Vertical Scale of Charts 1 and 2

Another ans.: The way the population is growing one must never forget the group index! In the example above the group index is 3 from Chart 1 plus 6 from Chart 2, or 9. The full classification is A-7-6(9). You now may intelligently compare notes with your neighbors.

Future Trends

According to Will Rogers a hidden goal of classification is to provide something to revise, and the AASHO classification is again up for grabs. Current thinking based on highway engineering experience in Nebraska, Oklahoma, and Ohio is that group index charts should be extended or revised. Several charts have been offered, and an AASHO committee headed by Preston Smith of the Bureau of Public Roads is up to arbitrate.

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UNIFIED CLASSIFICATION

In the early 1940's came a sudden need for many far-flung airfields, the better to deliver the mail. In the fury and scurry to get things going a visual soil classification appeared the thing, and in those ivyed halls of Harvard a committee of one headed by Dr. Arthur Casagrande[2] found itself in unanimous agreement on a new system.

A committee of one is best for getting the job done with a minimum of static but it is not so good for getting the point across. Casagrande used a professor's prerogative of teaching the new system to classes, primarily U. S. Army Corps of Engineers students.

The AC or Airfield Classification system was used by the Corps in the War, and after modification was adopted for peacetime by both the Corps and the U. S. Bureau of Reclamation in 1952. This singular point of agreement was so noteworthy the system is now called the Unified.

The first step in the Unified Classification is to decide if the soil is predominantly gravel, sand, silt, or clay. Usually this is not a difficult decision unless you are blind and can't feel. The soil is then tagged with the appropriate very difficult symbol:

G . . . . gravel
S . . . . sand
M . . . . silt
C . . . . clay

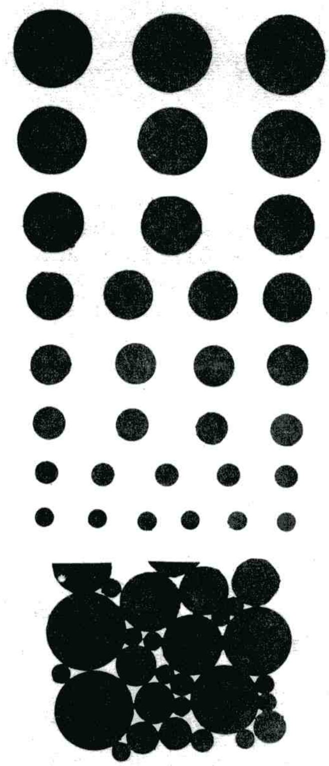
The symbol M for silt is the only one which doesn't seem logical, but S already has been used. M comes from Swedish mo, signifying non-plastic silt or rock flour.

More than half sand and gravel	More than half gravel	Clean (<5% fines)	Well graded	= GW	If between 5% and 12% fines, use dual symbols. Example: GP-GC, poorly graded gravel with plastic fines.
			Poorly graded	= GP	
		Dirty (>12% fines)	Silty (see ML)	= GM	
			Clayey (see CL)	= GC	
	More than half sand	Clean (<5% fines)	Well graded	= SW	Ditto above. Example: SP-SM, poorly graded sand with non-plastic fines.
			Poorly graded	= SP	
		Dirty (>12% fines)	Silty (see ML)	= SM	
			Clayey (see CL)	= SC	
More than half silt and clay	Liquid limit < 50		Silty, low PI (see graph)	= ML	
			Clayey, high PI (see graph)	= CL	
			Organic, in bad odor	= OL	
	Liquid limit > 50		Silty (see graph)	= MH	
			Clayey (see graph)	= CH	
			Organic, bad smellum	= OH	

In addition two other symbols must be committed to memory:

O . . . . organic
Pt . . . . peat

A soil is called O if it stinks; otherwise O soils test out like those in the M group. Peat is peat.



Best for engineering, whether soil, bituminous, or concrete, are granular mixtures of all grain sizes, i.e., "well - graded mixtures." These compact to give high density, many grain contacts, and much intergranular friction. That's life, we guess.

Gravels and Sands. If the soil is either a gravel or a sand, the next step is to determine if it contains appreciable fines. If it does, and the fine fraction is clayey or plastic and gives dry strength, the soil is a GC or SC (gravel-clay or sand-clay). It should be good to excellent as a foundation soil, moderately susceptible to frost action, and poor draining. Approximate AASHO equivalents are GC = A-1-a and SC = A-1-b, although GC and SC tolerate more plasticity.

If the fines are not plastic, the soil is GM or SM, which in general is not quite so good. Approximate AASHO equivalents, A-1 and A-2.

If on the other hand the sand or gravel contains but a mere pittance of fines, the engineer must make another kind of decision: Is the soil well graded? Ordinarily one hands out grades on the basis of tests, and this is still recommended, although those tested perennially take a

[2]Brother of electro-osmotic Leo; see Screenings Vol. 4 No. 1.

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dim view. A well graded soil is like a well rounded personality (not a well rounded person) and is a conglomeration of all sizes or grades. A poorly graded soil is "skip graded;" it skips grades like a village genius. For example, the skip-graded child may have no sand, which eventually gives a problem product. For this description we need two more mysterious symbols:

W . . . . well graded
P . . . . poorly graded

GW soils are tops for subgrades, or road bases; GP and SW are about on a par, OK for subgrades but questionable for bases, and SP is another step down.

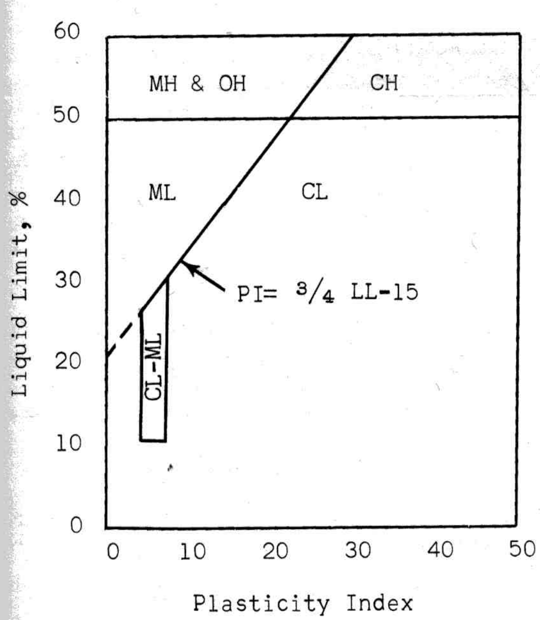
<u>Silts and Clays.</u> If a soil is over half finer than a 200 sieve, the classifying question is the liquid limit, or the moisture content at which the soil becomes liquid as defined by standard test. The dividing point is arbitrarily taken as 50, and we introduce two more secret symbols:

H . . . . high liquid limit
L . . . . low liquid limit

In general high liquid limit soils show high shrinkage and low liquid limit soils show low to medium shrinkage on drying.

The final question is whether it's a silt or clay. Dried just to the point where it crumbles (the plastic limit) a silt (ML or MH) crumbles easily whereas a clay (CL or CH) is tough

UNIFIED Classification
of Fine-Grained Soils



and gummy. Completely air dried, the silt is weak and friable whereas clay forms a hard clod near ideal to bean a neighbor.

A third alternative plain as the nose on your face is highly organic silts and clays, designated OL and OH, depending on their liquid limit.

<u>Problem:</u> My boy friend has been dating me for 27 years but is afraid to ask me to marry him. Instead he goes swimming every day. Please tell me if there's anything I can put in his trunks to make him see things my way. -- Breathless Spinster.

<u>Dear Spinster:</u> Your boy friend obviously has feet of clay with a high liquid limit, or CH. This means that he will firm up if you can keep him out of the water. Another possibility is that the feet are OH, which are as the name implies, and little could be done, <u>O</u> soils being the worst. Romance is dead when one of the party's feet smell ripe. Or perhaps he has a heart of stone, GW or GP. We suggest some classifying tests. Like does he favor pets and children, weep at movies, etc.

CAA CLASSIFICATION

The early 1940's were monumental for engineering soil classifications. In 1944 the youthful and zoot Civil Aeronautics Administration got into the act with the goal that a classification should be more directly applicable to runway design. The CAA system therefore included a popular strength test, the California Bearing Ratio. The ten soil groups were labelled E-1 through E-10.

The number of groups was later increased to 13 and CBR was dropped, and test criteria are therefore the same as for AASHO and Unified--size gradation, liquid limit, and plasticity index. However, the CAA system rates each soil group for either rigid or flexible pavements, taking into account local factors such as drainage and frosty climate.

For example, a fine sand classifies as E-2. With good drainage the flexible pavement rating is Fa, with poor drainage and no frost it is F1, and with poor drainage plus severe frost it is F2. The F class is plugged into the appropriate design chart to give a minimum pavement thickness.

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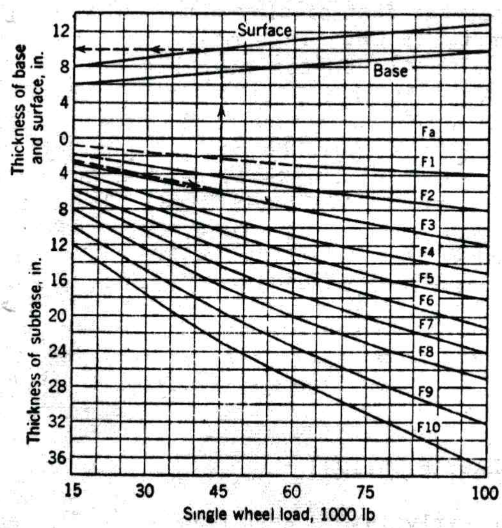
Example: With 60,000 lb single wheel load the F2 condition would require an 8 inch granular base course such as crushed stone, and a 3 inch bituminous surface course for a total of 11 inches, all on top of a 6 inch selected Fa class sand or bank-run gravel subbase.

For rigid base the soil in this example comes out R1a, which referred to another graph says that 12 inches of plain concrete or 11 inches of reinforced concrete should also do the job. (Cookbook engineering.) Other paving cookbooks use the CBR.

FLEXIBLE PAVEMENTS



WHICH?

Like the girl with too many beaus, there eventually comes the day of decision, and regardless of the consequences one must decide. The AASHO system remains the favorite of U. S. highway engineers, whereas the Unified is used by military engineers and the big dam builders. Both are recognized the world over, the Unified being favored in the United Kingdom.

For the serious student of soils, classification is not enough, and a knowledge of the soil structure and minerals may save some grave situations; take Mexico City (Screenings Vol. 2 No. 1). Dominant minerals are most quickly identified by X-ray diffraction, which also gives an oblique look at the clay minerals. Ionic environment of the clay minerals is predictable from X-ray, thermal analysis, presence of carbonate, and chemical tests such as ion exchange and pH. All such should be taken into account if one is to properly manipulate a change.

IN RETROSPECT

As any draft board knows or should know, mere classification at most tells only part of the story, and ultimate behavior of the draftee often depends on more subtle and less readily measurable aspects of his character such as family background, neighborhood, ego, battle jaundice, etc.

Engineering classifications similarly are strictly use classifications which, while necessary, ignore two very pertinent aspects of character: How did it get there and what kind of childhood? -- (1) and (2) below.

The college-educated soil therefore has the following minimum pedigree: (1) Geological parent material (limestone, glacial till, alluvial point bar, etc., plus formation name and age), (2) a pedological classification (A, B, C horizon, soil series, great soil group, and textural class), and (3) an engineering classification (AASHO, Unified, CAA).

Cash & Carry. A cost-cutting advantage of the three-pronged guessification is that many geological materials or soil series which consistently test out the same are more readily mapped by eye than tested by hand. We now are learning that repetition of engineering classifying tests on hundreds of samples from the same deposit may be as reasonable as measuring a thousand rabbits to see if they all have long ears. True, you first have to know what are rabbits. Soil maps are already available for most areas. The geological and pedological approaches tell inherent character, and the engineering classification helps put to use.

REFER AND ACKNOWLEDGE

Classic articles on engineering soil classification may be gleaned from any standard textbook; students shouldn't miss Hogentogler and Terzaghi in Public Roads 10:37-64, 1929; Allen et. comm. in Highway Research Board Proc. 25: 375-392, 1945, and A. Casagrande in A.S.C.E. Trans. 113:901-991, 1948.

Iowa State University research in soil engineering is sponsored under several welcome projects of the Iowa Highway Research Board with funds from the Iowa State Highway Commission.

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