Embedded Empiricisms in Soft Soil Technology

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Abstract. Civil engineers of today are continuously challenged by innovative projects that push further the knowledge boundaries with conceptual and/or ingenious solutions leading to the realization of that once was considered impossible in the realms of geotechnology. Some of the forward developments rely on empirical methods embedded within soft soil technology and the spectral realms of engineering in its entirety. Empiricisms unlike folklore are not always shrouded in mysticism but can find scientific reasoning to justify them being adopted in design and tangible construction projects. This lecture therefore is an outline exposition of how empiricism has been integrally embedded in total empirical beginnings in the evolution of soft soil technology from the Renaissance time, through the developments of soil mechanics in the 19th century which in turn has paved the way to the rise of computational soil mechanics. Developments in computational soil mechanics has always embraced and are founded on a wide backdrop of empirical geoenvironment simulations. However, it is imperative that a competent geotechnical engineer needs postgraduate training combined with empiricism that is based on years of well-winnowed practical experience to fathom the diverseness and complexity of nature. However, experience being regarded more highly than expertise can, perhaps inadvertently, inhibit development and innovation.

Keywords: Soft soil, geotechnology, geoenvironment.

1. Introduction

Collin's English Dictionary definition of empiricism is 'the doctrine that all knowledge of "matters of fact" derives from experience and that the mind is not furnished with a set of concepts in advance of experience'. The adjective empirical is derived from or relating to experiment and observation rather than theory, and particularly in the medical field, it relates to treatment based on experience rather than theory.

Over the last century, geotechnicians have been consistently made aware of the rigours of ever increasing complexity and uncertainty in the dynamisms within the lacustrine geo environment. The ever increasing technical impositions from the pace of development of infrastructure and construction are jettisoned by the increasingly volatile and often ambiguous societal, ecological, economic and political constraints. Such developments, progressive though may be, are ever attempting to embrace a wide backdrop of empirical geo environment simulations. Thesaurus claims empiricism to encompass pragmatism, experimentation, observation and practicality while a dictionary definition is the philosophical belief that all knowledge is derived from the experience of the senses. Thus empiricism may suggest that one can only have knowledge acquired through physically observable (empirical) evidence, but interestingly it is self-refuting that there is no empirical evidence that empiricism is true!! For instance, the Ptolemaic model of an earth centred solar system remained unchallenged for over 1300 years until 1543 when Nicholas Copernicus published the then controversial theory, without sufficient "scientific evidence" and "practice" on "the revolutions of the heavenly spheres" which stated that the sun is at rest and the earth is in rotation around the sun. Charles Morris, an author of the Encyclopaedia and Unified Science, specialised in scientific empiricism. He appreciated the continuous progress of scientific empiricism through the use of powerful tools of logical analysis which has been the underlying factor in much scientific advancement as that of Newton.

Geotechnology comprises of a combined application of soil and rock mechanics, engineering geology and other disciplines that bear on civil engineering construction and the geo environmental activities of extraction and use of geo materials with the conscious preservation and enhancement of the environment. Moreover, since all construction is necessarily built on or in the ground, geotechnical engineering plays a latent but key role in all civil engineering projects. The spectrum of geotechnical engineering challenges has grown immensely over the last century with the need to use ground that is naturally complex with the uncertainties of the current and future built environment. The complexity of the site geology often drives the geotechnical engineer to deal with variable materials, whose mechanical properties are usually dynamically degrading (such as that in peat) being affected critically by the local water chemistry and water pressures in the ground that change with rainfall and tidal / groundwater level effects.

Soft soil engineering problems find an appropriate solution through the adoption of the state of the art theoretical framework in the planning, design and construction phases. Present day design practice uses software models that are fast outdating spreadsheet calculations which in turn have superseded the practice of relying on design charts and tables. In the absence of established computational software models, designing turns to the adoption of rational empirical and observational methods such as full scale field or laboratory scale model load testing. Such practice not only provides circumstantial evidence to form the basis to review and endorse the design process, but its empiricism embeds itself to further develop theoretical frameworks through correlations established with data gathering. In the construction practice, engineers have recognised and used empirical phenomena such as Newtonian gravity, much the same way as the practice of alternative medicine.

Though geotechnical engineers do not possess a freehand in prescribing / specifying certain desirable properties or treatment of soils such as those of fills, they themselves are potentially complex by virtue of its nature and potential to change and degrade during its design life. All too often lessons are learnt from the extremely expensive consequences of inadequate and/or even lack of appropriate site investigation. Thorough ground investigation and site characterisation solicits the involvement of experienced geotechnical engineers that possess a good understanding of the geology, as well as the applied mechanics of the behaviour of soil and rock.

Additionally, in this era of technological innovation, with increasing and volatile ambiguity of the societal, ecological, economic and political constraints, there is an urgent need to harmonise with the typical life cycle of civil engineering project implementations. Most importantly this understanding must be combined with empiricism based on well-winnowed experience. In the early nineteenth century, civil engineering was not a highly specialised profession as it is today. The outstanding pioneering civil engineers such as William Smith, an active pioneering geologist; Robert Stephenson of railway construction eminence etc., relied on the observational geological science and empiricism to effectively complete major transportation projects during that time. It is inconceivable that civil engineers can be oblivious to the nature of the materials on which or in which they construct. This paper (and lecture) strives to trace the evolution of this integral discipline of geotechnology within constructional civil engineering from its ancient and empirically based beginnings, through the early

20th century developments of conceptual theories of mechanics of soils and rocks to the rise of modern computational geomechanics with multi physics simulation.

2. Folklores, Legends, Superstitions and Myths

Almost all aspects of our daily living are shrouded by superstitions with unknown origins. While some of them are logical, most of them are often silly. Human (and /or animal) minds extend beyond the anatomical brain to space and time consciousness that sensitively lead to telepathy where the mind acts like a magnetic field; images are not inside the brain but are a perception. Thus superstitions develop as empiricisms that are embedded in the mind and forebear on almost all aspects of daily living and most may have neither an origin nor a scientific justification. "Do not walk under a ladder" is such a superstition that is logical but often they sound just silly. Some sayings are unhealthily deemed superstitious and are most of the time not based on reason or a database of knowledge. Accordingly in a lighter vein, empiricism is also found within; superstitions, myths, legends, folklores, omens, old wives' tales, luck, sayings. There exists considerable intertwining and interchanging between these, that the Table 1 is an attempt to define and categorise them topically.

Table 1. Definitions of Superstitions, Myths, Legends, Folklore, Omens, Old Wives' tales, Sayings [1]

Term	Definition
Superstition	A belief or notion, not based on reason or knowledge, in or of the ominous significance of a particular thing, circumstance, occurrence, proceeding, or the like.
Myth	A popular belief or story that has become associated with a person, institution, or occurrence, especially one considered to illustrate a cultural ideal.
Legend	A non-historical or unverifiable story handed down by tradition from earlier times and popularly accepted as historical.
Folklore	The traditional beliefs, legends, customs etc., of a people; lore of a people
Omen	Anything perceived or happening that is believed to pretend a good or evil event or circumstance in the future.
Old wives' tale	A belief, usually superstitious or erroneous, passed on by word of mouth as a piece of traditional wisdom
Luck	The force that seems to operate for good or ill in a person's life, as in shaping circumstances, events , or opportunities
Saying	Something said, especially a proverb or apothegm

Folklore and legends are similarly non-historical, unverifiable stories and customs that are traditionally handed down through generations and sometimes even referred to as old wives' tales (notionally traditional wisdom). Myths and sayings (proverb or apothegm) illustrate cultural ideals matured from folklores and legends. All these form the hidden layer of neurons within the human mind (in the brain) to predict or predestine and perceive omens of good or ill luck as the outcome of the interaction between circumstances, events and opportunities.

Collin's English Dictionary definition of empiricism is 'the doctrine that all knowledge of matters of fact derives from experience and that the mind is not furnished with a set of concepts in advance of experience'. The adjective empirical is derived from or relating to experiment and observation rather than theory and particularly in the medical field, it relates to treatment based on experience rather than theory. Thesaurus claims empiricism to encompass pragmatism, experimentation, observation and practicality while the dictionary definition is the philosophical belief that all knowledge is derived from the experience of the senses. "Experimental data (empiricism) are believed by everyone but not necessarily by the one who did the experiment; while as a theory needs convincing, it is believed by nobody, excepting the one who developed it". Successful and pragmatic design needs to be based on scientifically sound conceptual models, supported by deduced empirical parameters that are substantiated by a sufficient data base of evidence, and can also be extrapolated outside the database.

3. Success (stability) and Failure (instability)

"Success" and "failure" are deemed through human perception of the eventless meeting of the circumstantial needs. In general terms, success and failure are at times considered to follow as a matter of fate (good luck/fortune or ill-luck). Superstition and culture shrouds this perception. As an example, there are cultural differences of opinion as to what numbers to avoid, or what are the acceptable and lucky colours. The particular superstition in the unlucky number 13 is well known. Notably, however, in the Chinese tradition the unlucky number is 4; Romans believed 13 to be symbol of death and destruction while Chinese traditionally consider number 4 as unlucky as its pronunciation can mean "to die". Hence, many apartment buildings do not have a 13th (or 4th) floor; therefore houses and apartments will not be so numbered; some people do not fly or buy things on the 13th; restaurants and homes will not favour 13 guests in a group to come or sit at a table. Moreover, Friday the 13th is considered as a day that attracts potential disasters. Contrastingly, seeing a new moon for the first time on a Monday will bring the observer good luck.

Lessons learned from both successes and failures necessarily enlarge the database and contribute to advances in all types of engineering. Emerging design standards and codes of practice have developed through the evolutionary process based on experience. Failures lead to new understandings of reviewing the empirically assumed / ignored soft soil properties. Construction industry lags behind other industries in the readiness and preparedness to systematically organise and disseminate failure information. Regardless of the size, all construction projects can benefit from the experience-based judgement of a competent geotechnical engineer.

4. Embedded empiricisms within "colour"

At the core of all good engineering science is the careful and diligent treatment of data; of particular significance is how the human visual system processes colour information in the data or its derivatives.

Eyes are the 'windows of the soul' and the colour leads one to differing beliefs;

- Dark blue eyes = delicate and refined souls.
- Light blue or grey eyes = strong and healthy ones;
- Green eyes = hardy souls;
- Hazel eyes = vigorous, deep thinking eyes.

Metaphorically speaking lawyers, like painters can convincingly change and manipulate the factual evidence of a case from "white to black" and vice-versa. If a black cat walks towards you, it means that good fortune is on its way to you. However, if it walks away, it takes the good luck away with it. From the perspective of weather predictions, it is empirically assumed that a red sky at night is a sailor's delight, while they brace themselves with cautious warning when they see a red sky in the morning.

Furthermore, colour has three perceptual dimensions of how bright it appears; luminance, saturation and hue. Colours can be scientifically coded (as exemplified in Table 2) using either HSB (Hue-Saturation-Brightness) followed by RGB (Red-Green-Blue) or a hexa alpha numeric code. Colour name is linked to one of the main colour hues; red, orange, yellow, green, blue, violet, brown, black, grey and white. Colour, lustre and streak are used to help identify rock forming minerals that give colour to the earthen materials (soils, rocks and their mixtures). Gold is the dust that blinds all eyes, but all that glitters is not gold.

Green depicts freshness in nature, and when it degenerates to brown and black it signify natural decay. Table 2 illustrates the colours associated with a range of typically met soils. HSB, RGB, and the hexa-alpha numeric code are also given beneath each colour as a more rigorous, scientific way of describing each colour. The soil characteristics described in the Table 2 gives a geo environmental dimension to its properties.

Table 2. Characteristics of soil based on colours

Image	Soil colour	Soil characteristics
	Black 7,28,0 0,50,0 000000	These soils are often associated with high levels of organic matter (peats).
	Brown 46,100,17 43,32,00 2B2100	Soils associated with moderate organic matter level and iron oxide
	Red 4,100,90 229,15,00 E50F00	This colour indicates good drainage. Iron found within the soil is oxidised more readily due to the higher oxygen content. This causes the soil to develop a 'rusty' colour. The colour can be darker due to organic matter. Blue London clay underlies the environmentally weathered brown London clay.
	Grey/Green 64,100,48 114,122,0 727A00	These soils are associated with very poor drainage or waterlogging. The lack of air in these soils provides conditions for iron and manganese to form compounds that give these soils their colour.
	Yellow to brown 58,100,97 247,239,0 F7EF00	These soils often have poorer drainage than red soils. The iron compounds in these soils are in a hydrated form and therefore do not produce the 'rusty' colour.
	White/ bleached 60,4,100 255,255,244 FFFFFF	These soils are often referred to as being bleached or 'washed out'. The iron and manganese particles have been leached out due to excessive amounts of rainfall or drainage.

5. Manufacture of Kaolin (English China Clay)

Kaolinite is a common clay mineral with a general chemical composition of $2SiO_2Al_2O_32H_2O$ and is the consequence of weathering of the orthoclase feldspar in the parent igneous rock (granite). English China Clay, which is uniquely wash quarried (see Figure 1) extensively in the South West of England, is desirably pure and brilliant white in colour and is therefore a principal raw material used in the ceramic industry.

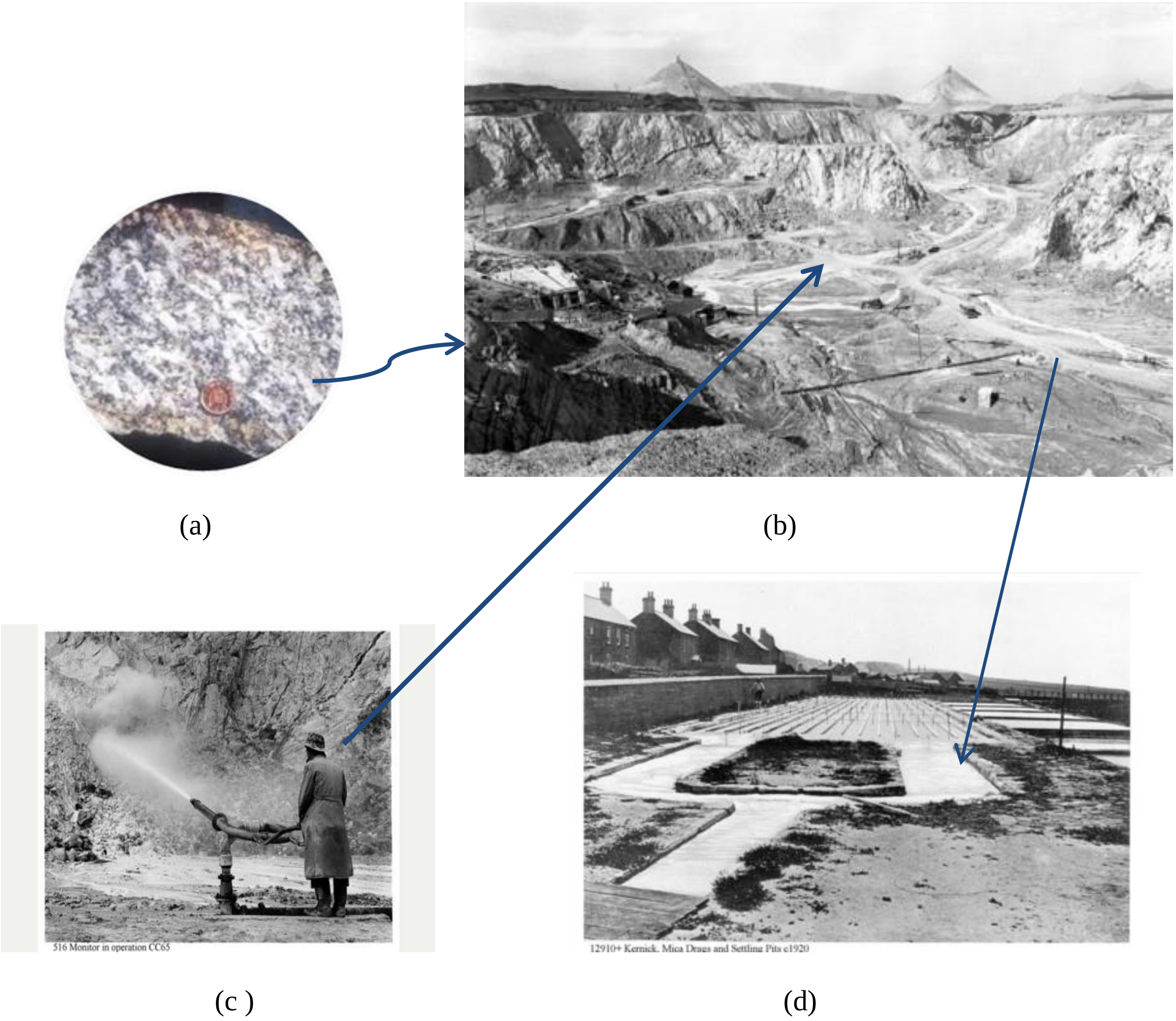

Figure 1. An English China Clay Quarry in St. Austell, Cornwall, UK

The uniquely elongated and white coloured orthoclase feldspar crystals (Figure. 1a) are readily identifiable with the unaided eye in the fresh Dartmoor Granite massif. Kaolinite quarrying using high pressure jet washing (Figure. 1c) of the hydrothermally weathered granite quarries have rivers of white kaolinite slurry directed to settling ponds (Figure. 1d) where the soft kaolinite sludge is separated and collected for further industrial treatment.

Intricate colour enhancement and image analysis can be effected using software PICASA 3 and analySIS@ package. The authors found this technique useful to assess or describe the fabric of peat samples to ascertain its composition. Figure 2 shows the typical images, normal and enhanced colour of undisturbed wet peat sample. The colour manipulation / image enhancement helps to show more clearly the fabric (a 2 dimensional fibre arrangement and orientation) in the fibrous peat composition.

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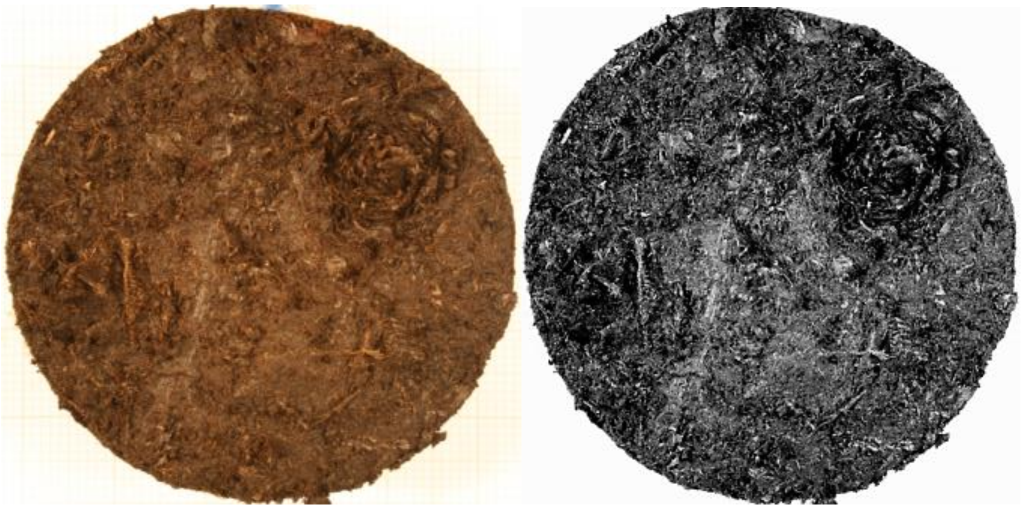
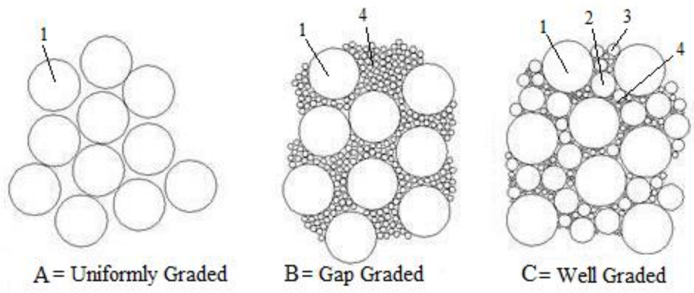


Figure 2. An image of wet fibrous peat enhanced through Picassa 3 to facilitate image analysis

6. Empiricisms embedded in particle morphology

Particle morphology (size and shape) in geotechnics, can be related through topographic features to its genesis or the development of erosional forms. Morphology characterise the soil particles and help define the type of soil; from the rugged and massive boulders to platy clay particles. Soil mass classifications based on particle size distribution are adopted in various standards (BSCS, ASTM, USDS and AASHTO), particle shape, however has not been accounted for in these conventional soil classification systems [2]. Despite the many classification systems that are now in use, not one is totally definitive of any soil for all possible applications because of the wide diversity of soil properties [3]. The particle size distribution curve gives not only the range and distribution of particle sizes but from it, the uniformity coefficient and coefficient of gradation can be determined to class them as uniform (poorly graded), well graded or gap graded as illustrated in Table 3. These gradings influence the fabric of the soil. Table 3 further illustrates empirically typical ranges of angle of friction and permeability coefficient for the three different types of graded soils.

Table 3. The empirical deductions from the grading differences in particle size distributions

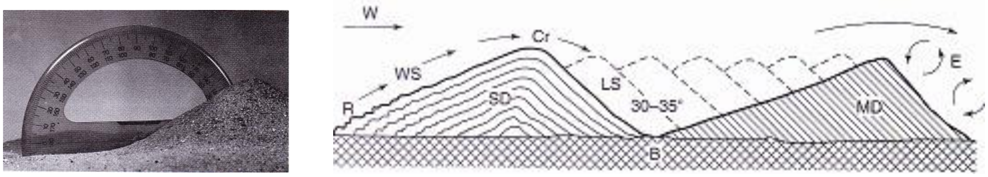


Note: The numbers indicates the scale of the particles

Increase in Shear Strength →

← Increase in Permeability

Type	Uniformly graded	Gap graded	Well graded
Typical Friction Angle values ϕ^0	40 – 45	35 - 40	30 – 35
Typical Permeability Values k m/s	$4.00x10^{-5} – 4.00x10^{-3}$	$2.55x10^{-5} – 5.35x10^{-4}$	$2.23x10^{-3}$

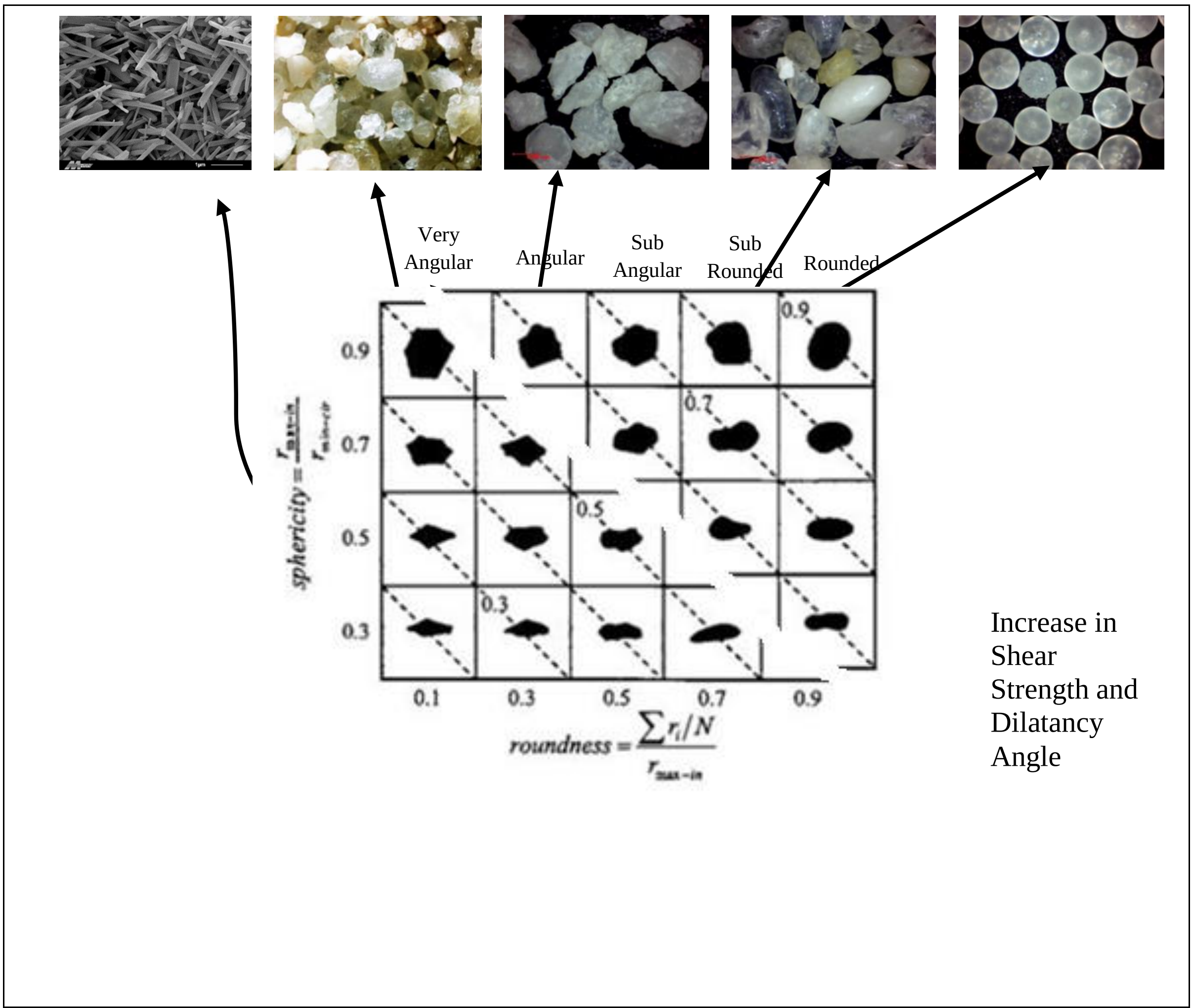


(a) (b)

Figure 3. a) An empirical method of illustrating angle of repose (angle of friction) [4], b) Formation of sand dunes and illustration of the angle of repose [4] Stationary Dune (SD), Migrating live dunes (MD), arrows indicate direction of air (W) and eddies(E) Windward slope (WS) Leeward slope (LS), Ripple marks (R), Crest of dune (Cr)

Sand dunes are so "soft" that they are often migratory landforms resulting from the wind as a geological process. Figures 3 a) and 3 b) show how sand dunes are nature's example of the angle of repose , which being the steepest slope for very loosely packed sands, it represents the angle of friction for grannular materials at its loosest state[4].

Table 4. Classification of particle shapes



Type	Very Angular	Angular	Sub Angular	Sub Rounded	Rounded
Typical Friction Angle values ϕ	40 - 45	35 - 38		27 - 30	
	← Increase in friction angle value				
Typical Dilatancy angle	13.01 – 21.542	9.271 – 11.46		7.734 – 10.322	
	← Increase in dilatancy angle value				

As illustrated in Tables 3 and 4, the changes in the intrinsic angle of particulate friction can be made intuitively empirical. Particle aspect ratio further influences its development. The rare clay mineral, halloysite, has a tubular morphology akin to the decaying and contrastingly cellular morphology of roots in fibrous peat, which negates any empirical predictions. The latter microstructural feature in fibrous peat contradicts one of the founding assumptions in soil mechanics in that the “individual particles are incompressible”. In a cohesionless soil, it was found that for a different types of sand based on its particle shape characteristics, not only the friction angle changes but the dilatancy angle also increases as the shape of the particle changes from rounded to very angular [5].

7. Empiricism in soil classification

In 1911, Atterberg, a Swedish soil physicist (and / agricultural engineer) recognised the four consistency states of liquid, plastic, semi solid, and solid that a fine grained soil can take as it interacts with water. The water content boundaries between these consistency states have been semi empirically assigned as liquid limit, plastic limit and shrinkage limit respectively. Soil classification systems provide, though empirical it may be, a universally accepted communication language to avert lengthy description of the soil. Many researchers have further established correlations between the consistency limits and strength characteristics of fine grained soils.

Soil investigations have then widely adopted these limits to classify soils using the charts as that of Casagrande. The chart displays empirically two boundary lines; the U line and the A line as shown in Figure.4. The corresponding equations for these lines are as follows;

U-Line; $PI = 0.9 (LL-8)$ (1)
A -Line; $PI = 0.73 (LL-20)$ (2)

Some of the AASHTO Soil classes [3] have also been embedded into the Casagrande Chart as included in the Figure. 4. The combination of these information enables further to present a “traffic light – red amber - green” zoning of the chart to obtain a perception of weak (challenging) to good (desirable) soils for construction purposes.

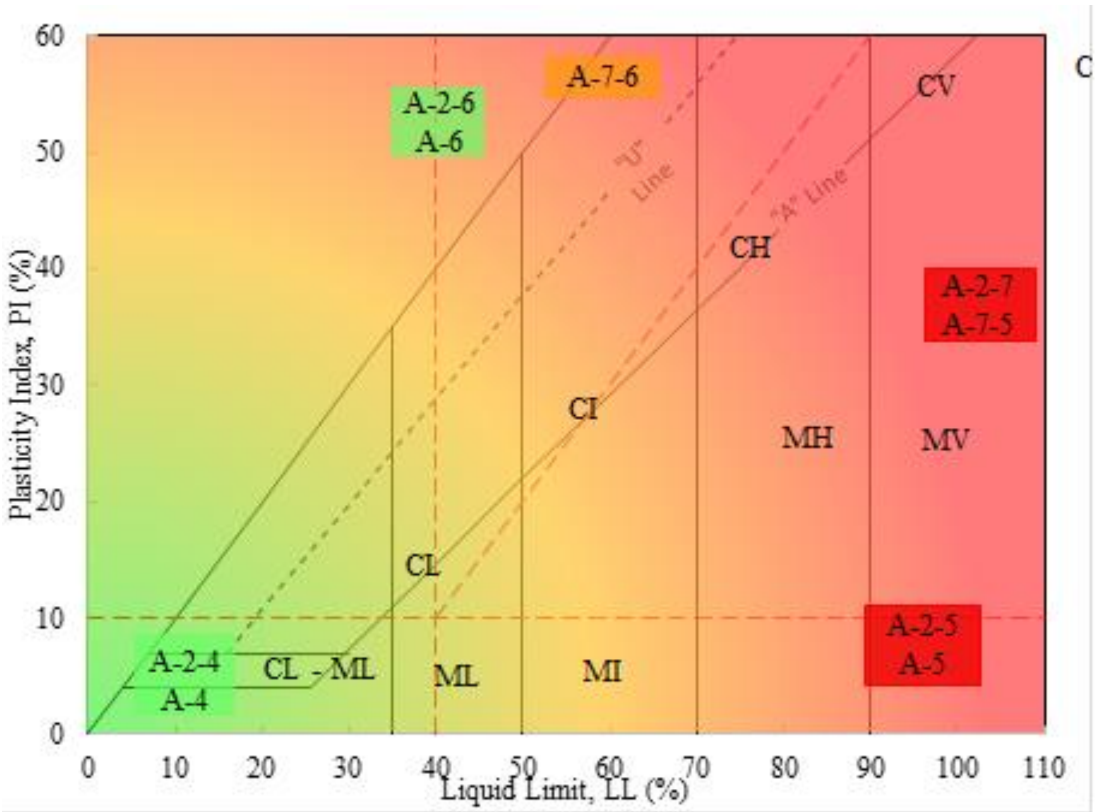


Figure 4. “Traffic light” zoned Casagrande chart with some embedded AASHTO soil classes

The effectiveness of a soil stabilisation technique can now be assessed through the locus of the "consistency state" of the unstabilised soil to that of the stabilised soil. As illustrated in Figure. 5, a locus towards the origin (downward and towards the left) conceptually signifies an improvement in the soil condition and vice versa. A vertical downward locus (an increase in PL with no change in LL) represents the effect of agglomeration due to the stabilisation process. A lateral locus towards the left of the Casagrande Chart (decrease in LL with no change in PI) suggests an increase in soil stiffness through cementation.

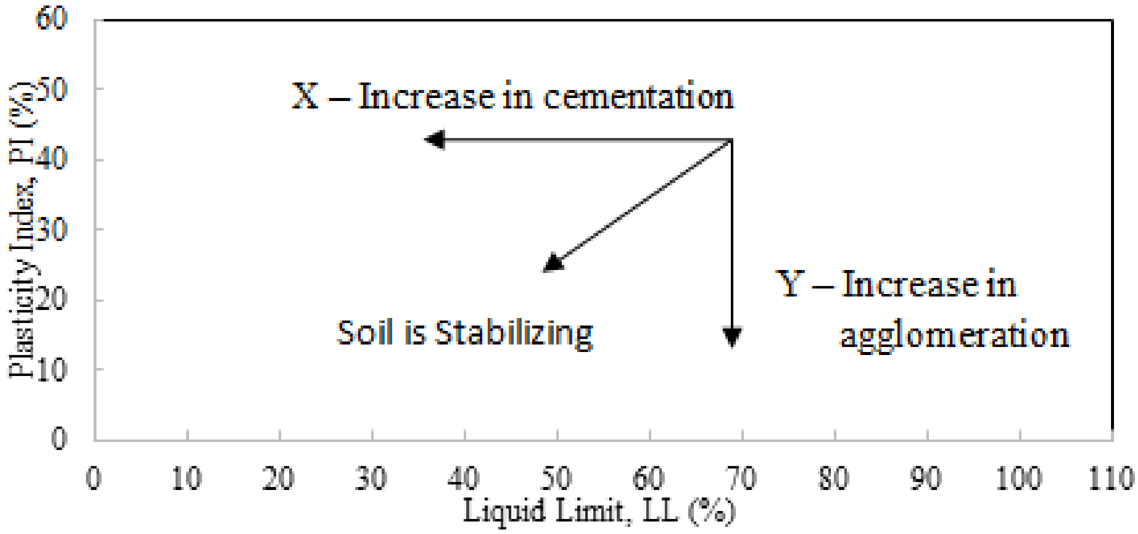


Figure 5. Soil stabilisation mechanisms explained through Casagrande Chart

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8. Empiricism within Von Post Classification of Peat Soils

Table 5. Von Post Classification for Peat Soils and Squeeze Test (modified from [6])

Degree of Humification	Description	Squeeze test
H1	Completely undecomposed peat which releases almost clear water. Plant remains easily identifiable. No amorphous material present.	
H2	Almost completely undecomposed peat which releases clear or yellowish water. Plant remains still easily identifiable. No amorphous material present.	
H3	Very slightly decomposed peat which releases muddy brown water but for which no peat passes between the fingers. Plant remains still identifiable and no amorphous material present	
H4	Slightly decomposed peat which, when squeezed, releases very muddy dark water. No peat is passed between the fingers but the plant remains are slightly pasty and have lost some of their identifiable features.	
H5	Moderately decomposed peat which, when squeezed, releases very “muddy” water with a very small amount of amorphous granular peat escaping between the fingers. The structure of the plant remains is quite indistinct although it is still possible to recognize certain features. The residue is very pasty.	
H6	Moderately decomposed peat which a very indistinct plant structure. When squeezed, about one-third of the peat escapes between the fingers. The structure more distinctly than before squeezing.	
H7	Highly decomposed peat. Contains a lot of amorphous material with very faintly recognizable plant structure. When sequeezed, about one – half of the peat escapes between the fingers. The water, if any is released, is very dark and almost pasty.	
H8	Very highly decomposed peat with large quantity of amorphous material with very indistinct plant structure. When squeezed, about two thirds of the peat escapes between the fingers. A small quantity of pasty water may be released. The plant material remaining in the hand consists of residues such as roots and fibers that resist decomposition.	
H9	Practically fully decomposed peat in which there is hardly any recognizable plant structure. Fairly uniform paste when squeezed.	
H10	Completely decomposed peat with no discernible plant structure. When squeezed, all the wet peat escapes between the fingers.	

Table 6. Systematic outline of Von Post Classification

Degree of Humification (VON POST)	Decomposition	Plant structure	Amorphous material	Colour of released water	Escape of material on squeezing	Nature of residue
H1	None	Easily identified	None	Clear	None	
H2	Insignificant	Easily identified	None	Clear or yellowish	~	
H3	Very slight	Still identifiable	~	Muddy brown	~	Not pasty
H4	Slight	Not easily identifiable	Very slight amount	~	None	Somewhat pasty
H5	Moderate	Recognizable but vague	~	~	Very small amount	~
H6	Moderately strong	Indistinct	~	~	About one third escapes	
H7	Strong	Very faintly recognizable	Lots	Very dark and almost pasty	About one half escapes	Fibres and roots more resistant to decomposition remain in hand
H8	Very strong	Very indistinct	Large quantity	~	About two thirds escape;	
H9	Nearly complete	Almost undiscernable	~	~	~	
H10	Complete	Not discernable	~	~	All the wet peat escapes	

Table 7. Summary of Published Geotechnical Properties for Peats

Degree of Humification (VON POST)	Natural Moisture content (%)	Specific gravity	Organic content (%)	Fiber Content (%)	Liquid Limit (%)	Cc, Virgin compression	Cr, Re-compression ratio
H1							
H2				93[12]		0.021[12]	0.0025[12]
				40[12]			
H3	670(±20) [9]	1.30[9]	92[9]	75[9]			
	708(±10) [10]	1.49[10]	98[10]	74[11]	267[10]		
H4	480(±10) [10]	1.56[10]	92[10]	63[10]	162[10]		
	555[11]	1.24[11]	96.4[11]	90[11]			
H5	544(±10) [9]	1.40[9]	96[9]	63[9]	224[9]		
H6	472(±10) [9]	1.14[9]	92[9]	43[9]	137.2[9]		
H7	605[11]	1.82[11]	42.5[11]	31.98[11]			
H8				53[12]		0.012[12]	0.0030[12]
H9				48[12]		0.0030[12]	0.0020[12]
H10							

Table 5 shows an empirical visual assessment coupled with human subjectivity of a squeeze test that forms the basis of the Von Post classification of Peat into ten different "H" classes depending on the degree of humification [6]. The description of each Von Post class has been outlined systematically in Table 6 to delineate the differences between them, and thereby a logical transition between classes becomes apparent. Von Post's classification categorized peat into 10 "H" classes and this has now been further extended into 16 classes [7]. However these classes are empirical and do not provide an engineering perspective to its characteristics. Shear strength of peat is dependent on its moisture content, degree of humification and mineral content (higher the moisture content and humification, lower will be the shear strength; higher the mineral content, higher will be the shear strength [8] [9]. Table 7 presents geotechnical information from some research available in the public domain, on some peats described as H2 to H9. Some of the geotechnical parameters show appropriate changes with increasing Degree of Humification.

9. Empiricism observed through Animal Senses and Behaviour

Animals can sense disaster; they have a sixth sense. Many animals escaped the great 2004 Asian Tsunami. Elephants, Donkeys and dogs in Sri Lanka and Sumatra moved to higher ground before the giant waves struck. Similar peculiar behaviour of Elephants on that day was reported from Thailand; in that they even were trumpeting before they moved to higher ground. Reports from villagers in Bang Koey, Thailand gave the account of a herd of buffalo were grazing by the beach when "they suddenly lifted their heads and looked out to sea, ears standing upright"; They turned and stampeded up the hill, followed by bewildered villagers whose lives were thereby saved. At Ao Sane beach, near Phuket, dogs ran up to the hill tops, and at Galle in Sri Lanka, dog owners were puzzled by the fact that their pet animals refused to go for their usual morning walks on the beach. Similar reports from Cuddalore District in South India where buffalos, goats and dogs escaped and in addition a nesting colony of flamingos flew to a higher ground. In the "Andaman Islands "stone age" tribal groups moved away from the coast before the disaster, alerted by the behavior of the animals. Similar stories of animals "freaking out" and behaving in unusual manner long before (even up to 12 hours – early warning signal) are also reported from other past earthquakes (1995 Kobe, Japan; Assisi, Italy) Dogs have a remarkable sense of smell, birds can migrate using celestial cues and bats can locate food with echoes. Animals may sense unusual vibrations or changes in air pressure coming from one direction that suggest they should move in the opposite direction.

10. Empiricism in Ground Investigation

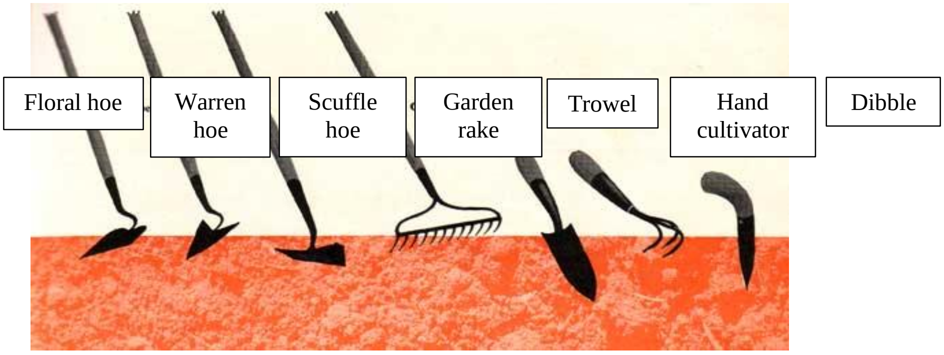
Ground investigation is a prerequisite to site characterization, which in itself needs to extract representative and reliable information from the earth which hosts a complex three dimensional distribution of (often non uniform) rocks/soils with its associated numerous structures and hydro-geomorphologies. A primary objective of site characterization is based on an empirical approach of acquiring a simplistic two dimensional (or 3D block) spatial arrangement description of topographical, hydro-geological, geotechnical, seismological and geo-environmental information that is relevant to the requirement of the particular project. This challenge needs to be approached by a coalition of hybrid disciplines [13] [14]. It has been said that, "one test result is worth a hundred expert opinions", but this is only true if such tests and their analysis are truly accurate, representative and relevant for the application [15].

Agricultural Engineers and Geotechnical Engineers can be found working on the same ground but with differing scopes and objectives. It is noteworthy, that one's gain may often be another's loss. While peat is considered a challenging problematic material to Geotechnical engineers, it is a material of prime importance to Agricultural engineers [16]. For instance, for the same amount of suction, tropical peat holds more water. The soil moisture at permanent wilting point (150 kPa matric suction) for Sapric / Hemic peat is reportedly still relatively high and prevalent at about 50 to 60% volumetric water content, which makes the ground to be still visually wet but lacks available water for plant use. This will necessitate maintaining the field water table optimally high to facilitate irrigation through capillary rise [17]. Such a requirement is met with mixed reception from a geotechnical perspective. The presence of a high water table reduces the permissible bearing capacity on one hand, while on the other hand, maintaining the water table constant will minimise shrinkage induced structural distress.

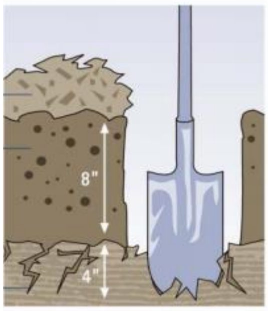
The most common problem that engineers face is whether the methods are appropriately suitable or not before carrying out the test. The selection of test method should be based on the information gathered from the site reconnaissance. Pioneering ground investigation methods used simple instruments such as pocket penetrometers etc. to solely identify and characterise the soil. Different equipment with varied appearances, shapes and purposes (such as the hoe, trowel and dibble etc. – Figure. 6 a) have been used in small scale farming. While some of these manual hand tools are intended for specific uses such as soil moving and soil conditioning, others can perform multiple functions. Figures 6b and 6c are an extension to the farming equipment that enable a ground investigator to help determine the depth of soft soil / depth to bedrock and obtain to study disturbed / in situ soil samples from a test pit. A rod penetrometer has dimensions which are approximately 1.2m long, 10 mm diameter and is a stainless steel rod with a 90 degree bend, 120 mm at the top to form a handle. Figures 5e and 5d are views of similar but empirical site investigation tools, Mackintosh probe and its modified JKR probe used to characterise the soil. Figure 5f illustrates the commonly used Standard Penetration Test (SPT). When the borehole is advanced to the desired depth, the drilling tools are removed and a split spoon sampler attached. A standard hammer weighing 623N is dropped through a distance of 0.762m to the top of the drilling rod. The number of blows required for driving the sampler through three 152.4 mm intervals is recorded. The sum of the number of blows required for driving the last two 152.4mm intervals is referred to as the standard penetration Number, N. This N value is very popularly used in design and has been empirically correlated by various researchers to give strength and stiffness parameters. The SPT has been further developed with electronic instrumentation to form the basis of Cone Penetration test and even further to the Piezo Cone test.

11. Empirical 45^0 Engineering Thumb Rule

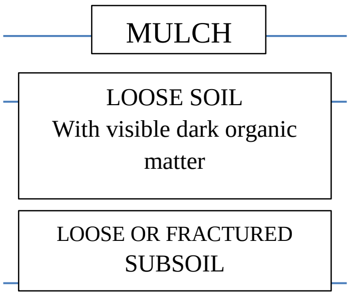
A thumb rule is a principle with broad application, and by virtue of its empiricism, it is neither intended to be strictly accurate nor universally reliable. However its simplicity enables it to be easily remembered as well as learned and to be applied as a procedure for estimation or recalling some value for determination with first order accuracy. Table 8 outlines the empirical together with the conceptual failure surface inclinations for a variety of materials and situations. Ductile materials subjected to tension fail at 45^0 to the tensile stress direction. Brittle materials such as concrete, when subjected to unconfined compression fail at 45^0 and sometimes multiple parallel sets are visible. This as illustrated in the table is due to the failure along the plane of maximum shear stress. In the case of particulate soil samples, Mohr Coulomb failure criterion applies and the inclination of the failure surface will be greater than the 45^0 by an amount equal to one half of the angle of friction, φ. As the soil becomes softer, the failure mode changes from brittle to ductile, giving no well-defined failure surface but bulging. In both laboratory testing and field loading of foundations, a triangular wedge shaped zone of unfailed and passive soil mass moves monolithically. The angle of this wedge deviates from the 45^0 depending on factors such as the type of failure (ductile / brittle) and the roughness of the interface between the loading surface and the soil. Active and intermediate zones develop to various degrees depending on whether it is a general failure or local failure. These failure trajectories are associated with the heave of the soil at the ground surface. The failure surface in highly deformable soils such as soft peat occur with localised settlement followed by punching shear with no bearing on the 45^0 thumb rule.

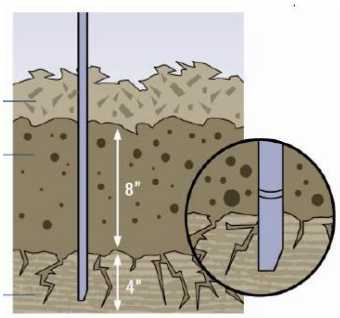


a) Types of Arable Agricultural Farming Equipment [18]

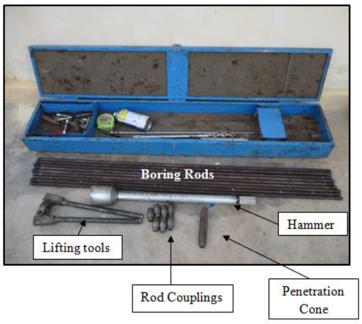


b) Use of shovel for topsoil



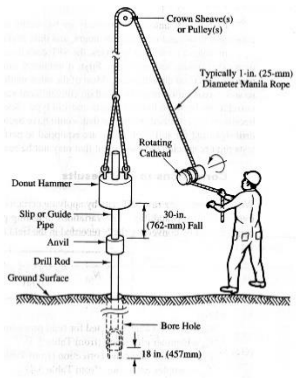


c) Rod penetrometer for soil investigation



d) JKR probe

e) Mackintosh Probe



(f) Standard Penetration Test (SPT)

Figure 6. Some soil investigation tools [15]

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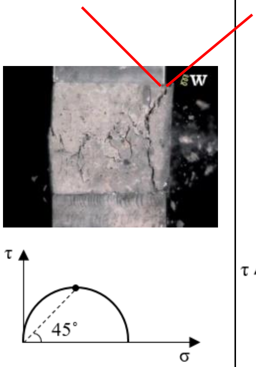
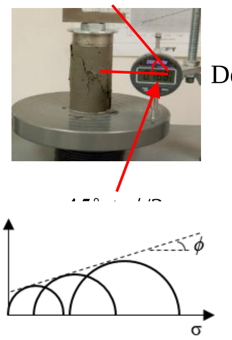
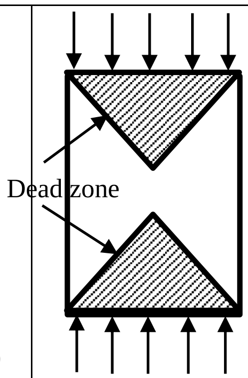
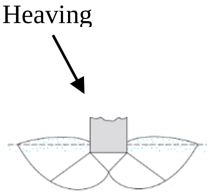
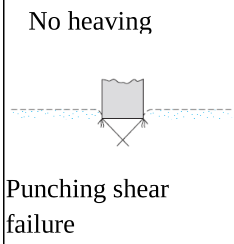
Table 8. 45˚ Thumb Rule

				
Concrete materials which are brittle	Particulate soil materials	Loading produces Triangular wedge shape zone (Dead zone)	Occurs on dense or medium dense soil	Highly deformable occurs on soft soil (Peat)

12. Empiricism through Experience

Experience based knowledge is not very common and "practical experience" does not always necessarily lead to sound intuitive judgement. A "practical person" is one who practices the theories developed at least thirty years ago or more. For every new project, civil engineer relies initially on some first-hand knowledge of the site that point through empiricism, experience of the senses to the need for site investigations which forms the basis for the complete contract drawings and specifications. Field investigations are based entirely on a systematic collation of prudent observations, ably coupled to deduce empirically may be to the presence and orientation of three-dimensional geologic structures from the limited facts explored. On the other hand the civil engineer through training, views the project three dimensionally to the all so important visible end product of the superstructure, but equally important, if not more so, is the knowledge leading to visualize the spatial character of the unseen subsurface geologic conditions. By virtue of the differences in their training, regretfully, geotechnical engineers and engineering geologists think differently; engineering science seeks a prediction for the future while geologists observe the present to interpret the past. These tabled predictions of the subsurface conditions affect, and often govern, the engineer's decisions in design, and also the construction technology to be adopted by the contractor. This empiricism needs to be continuously verified during the project construction stage and periodically inspected even thereafter to ensure safety of its function to be maintained in good order. Such documented records prove to be of inestimable value as a check on the assumptions made in the empirical predictions made at the onset and also as factual records for post construction contract litigations.

13. Empiricism and Public Safety

Historically, professional engineering has been established in response to threats to public safety. Empiricism is embedded into the public safety of modern structures such as bridges; however, in the 1860s American bridges were collapsing at the rate of 25 or more per year. Bridge failure and the associated loss of life precipitated the need for a stricter engineering approach to bridge design and construction. In Canada, engineering folklore holds that the collapse of the Quebec City Bridge in 1907 catalysed the establishment of higher standards in all branches of Canadian Engineering, which is symbolized today in the iron ring ceremony.

Engineering differs from other professions in that doctors, dentists, public accountants and lawyers generally provide their services to specific individuals / or defined corporations. Engineers design things with responsibility for specific societies rather than provide services to individuals. Engineering use of mathematics and science exposes it to the criticism that it is dry and it has sapped the artistic elements out of engineered structures. Art without engineering may be impossible, but engineering without art can be mundane and ugly. 13th century Reims Cathedral may lack art but 13th century builders were able to construct it. The Australian Sydney Opera House has its art dependent heavily upon engineering, as much that a 13th century builder would not be able to construct it. The first century Roman civil engineering of aquaducts and bridge construction was essentially a craft discipline. Arthur C. Clarke said that “any sufficiently advanced technology is indistinguishable from magic”.

14. Experience & Empiricism, Expertise & Zeitgeist

Valuing experience (even though it be through empirical folklore or routine practice based on early theories and practice) more than expertise (innovative, sophisticated and the zeitgeist – the spirit of the age and adopting its novelties) is playing safe and being conservative though it can be considered to be unsustainable in wasting natural resources and overcharging the client. Professionals should not work beyond their own expertise, and must be considered competent and experienced only when they are chartered. Emeritus Professor John Atkinson rightly believes that geotechnical engineers should seek dual chartership from both a geological body and an engineering body. He also argues that the young tigers (new age students who can demonstrate and adopt the zeitgeist of geotechnical engineering, and also have been properly educated in engineering fundamentals) should be valued more than the experienced (the old heads) educated and trained in the 1960s and 70s have done the same thing slightly wrongly using old theories for a long time and have been lucky.

15. Conclusions

Geotechnical engineering that now encompass soil-water-environment phenomena and soil-structure interaction face challenges that necessitate the adoption of a multidisciplinary approach that are developed through embedded empiricisms. The occurrence of many progressive failures cannot be fully explained by classical soil mechanics concepts, but other factors such as chemical, physicochemical, micromechanical, and microbiological factors need to be considered, even though it may be empirically. The heterogeneous nature of both the soil and the prevailing environmental conditions make the engineering solutions at best to be an approximation.

Empiricism, as the name implies, lacks theoretical underpinnings; requiring as a dire necessity that the database of the relevant empirical relationships and assumptions be made explicit and be alerted to the instances where such proposed empirical relationships are at variance with the observed response. Professional engineers base their valued judgements in design on approximations, introduced and implied by these empiricism and/or experiential assumptions. From a solely practical viewpoint, in certain scenarios, applications based on such implications of empiricism and assumptions are inappropriate and inapplicable. On the other hand, in some other situations, one can ignore the distorted inaccuracies imposed by them to be negligible as they are of no practical significance. Caution needs to be therefore exercised in being one step away from reality, as the response evaluations are indirectly inferred.

Soft soils that embrace a wide variety of both mineral and organic soils, demand appropriately relevant empirical assumptions to be accommodated in order that the individual soil types can be appropriately assessed as an engineering material. Assumptions necessarily introduce approximations which in certain situations can distort the reality to an extent that the application of established theories may even produce unacceptable results.

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