CHAPTER TWO

LITARAURE REVIEW

PART ONE: SOIL STABLIZATION

2.1.1 Introduction:

As defined by Murthy (2005) [51] the word 'soil' has different meanings for different professions. To the agriculturist, soil is the top thin layer of earth within which organic forces are predominant and which is responsible for the support of plant life. To the geologist, soil is the material in the top thin zone within which roots occur. From the point of view of an engineer, soil includes all earth materials, organic and inorganic, occurring in the zone overlying the rock crust.

The word 'clay' is generally understood to refer to a material composed of a mass of small mineral particles which, in association with certain quantities of water, exhibits the property of plasticity. Clay materials are essentially composed of extremely small crystalline particles of one or more members of a small group of minerals that are commonly known as clay minerals. These minerals are essentially hydrous aluminum silicates, with magnesium or iron replacing wholly or in part for the aluminum, in some minerals. Many clay materials may contain organic material and water-soluble salts. Organic materials occur either as discrete particles of wood, leaf matter, spores, or they may be present as organic molecules adsorbed on the surface of the clay mineral particles. The water-soluble salts that are present in clay materials must have been entrapped in the clay at the time of accumulation or may have developed subsequently as a consequence of ground water movement and weathering or alteration processes.

Another definition by Olufowobi *(2014)* [62] Clay minerals are typically formed over long periods of time by the gradual chemical weathering of rocks (usually silicate-bearing) by low concentrations of carbonic acid and other diluted solvents. These solvents are usually acidic and migrate through the weathering rock after leaching through upper weathered layers. In addition to the weathering process, some clay minerals are formed by hydrothermal activity.

Clay deposits may be formed in places such as residual deposits in soil but thick deposits usually are formed as the result of a secondary sedimentary deposition process after they have been eroded and transported from their original location of formation. Generally, clay soils have poor drainage characteristics which are largely dependent on the infiltration rate, which can be changed by adding larger particles of organic matter or pea gravel to the soil.

The AASHTO (1914) (M 145) [1] soil classification system differentiates soils, first based on particle size and secondly based on Atterburg limits. If 35 percent or more of the mass of the soil is smaller than 75 μm in diameter, then the soil is considered either a silt or clay and if less than 35 percent of particles are smaller than 75 *micron sieve*, then the soil is considered to be coarse-grained, either a sand or gravel. For stabilization purposes, soils can be classified into subgrade and base materials based on fractions passing No. 200 sieve. If 25 percent or more passes through the no. 200 sieve the soil can be considered as a subgrade and if not they may be classified as a base material. In order to be termed a base material, the material in question must also be targeted for use as a base layer from a structural perspective. On the other hand, an in situ coarse-grained soil with less than 25 percent fines, may be, by definition a native subgrade even though it may achieve the required classification of a base. [38]

2.1.2 Definition of Soil Stabilization

According to Mandeep and Mittal (2014) [42] Soil stabilization is the process of altering some soil properties by different methods, mechanical or chemical in order to produce an improved soil material which has all the desired engineering properties.

Also Olufowobi et al (2014) [62] defined soil stabilization as the process of improving the soil aggregate properties by blending in materials that increase the load bearing capacity, firmness and resistance to weathering or displacement. It can be defined as the process of altering the soil properties by mechanical or chemical means thereby improving the desired engineering properties of such soils. Thus, there are three purposes for soil stabilization namely strength improvement, permeability control and enhancement of soil durability and resistance to weathering.

2.1.3 Mechanisms of Stabilization

As out lined by Little and Nair (2009) [38] the stabilization mechanism may vary widely from the formation of new compounds binding the finer soil particles to coating particle surfaces by the additive to limit the moisture sensitivity. Therefore, a basic understanding of the stabilization mechanisms involved with each additive is required before selecting an effective stabilizer suited for a specific application.

Chemical stabilization involves mixing or injecting the soil with chemically active compounds such as Portland cement, lime, fly ash, calcium or sodium chloride or with viscoelastic materials such as bitumen. Chemical stabilizers can be broadly divided in to three groups: Traditional stabilizers such as hydrated lime, Portland cement and Fly ash; Non-traditional stabilizers comprised of sulfonated oils, ammonium chloride, enzymes, polymers, and potassium compounds; and By-product stabilizers which include cement kiln dust, lime kiln dust. [62]

Among these, the most widely used chemical additives are lime, Portland cement and fly ash [68]. Although stabilization with fly ash may be more economical when compared to the other two, the composition of fly ash can be highly variable. The mechanisms of stabilization of the traditional stabilizers are detailed below.

2.1.3.1 Traditional Stabilizers

Traditional stabilizers generally rely on pozzolanic reactions and cation exchange to modify and/or stabilize. Among all traditional stabilizers, lime probably is the most routinely used. Lime is prepared by decomposing limestone at elevated temperatures. Lime-soil reactions are complex and primarily involve a two step process. The primary reaction involves cation exchange and flocculation/agglomeration that bring about rapid textural and plasticity changes [95]. The altered clay structure, as a result of flocculation of clay particles due to cation exchange and short-term pozzolanic reactions, results in larger particle agglomerates and more workable soils.

Although pozzolanic reaction processes are slow, some amount of pozzolanic strength gain may occur during the primary reactions, cation exchange and flocculation/agglomeration. Extent of this strength gain may vary with soils depending on differences in their mineralogical composition. Therefore, mellowing periods, normally about one-day in length but ranging up to about *4-days*, can be prescribed to maximize the effect of short term reactions in reducing plasticity, increasing workability, and providing some initial strength improvement prior to compaction. The second step, a longer-term pozzolanic based cementing process among flocculates and agglomerates of particles, results in strength increase which can be considerable depending on the amount of pozzolanic product that develops, and this, in turn depends on the reactivity of the soil minerals with the lime or other additives used in stabilization [74]

The pozzolanic reaction process, which can either be modest or quite substantial depending on the mineralogy of the soil, is a long term process. This is because the process can continue as long as a sufficiently high pH is maintained to solubilize silicates and aluminates from the clay matrix, and in some cases from the fine silt soil. These solubilized silicates and aluminates then react with calcium from the free lime and water to form calcium-silicate-hydrates and calciumaluminate- hydrates, which are the same type of compounds that produce strength development in the hydration of Portland cement. However, the pozzolanic reaction process is not limited to long term effects. The pozzolanic reaction progresses relatively quickly in some soils 4depending on the rate of dissolution from the soil matrix. In fact, physio-chemical changes at the surface of soil particles due to pozzolanic reactions result in changes in plasticity, which are reflected in textural changes that may be observed relatively rapidly just as cation exchange reactions are:

Portland cement is comprised of calcium-silicates and calcium-aluminates that hydrate to form cementitious products. Cement hydration is relatively fast and causes immediate strength gain in stabilized layers [40]. Therefore, a mellowing period is not typically allowed between mixing of the components (soil, cement, and water) and compaction. In fact it is general practice to compact soil cement before or shortly after initial set, usually within about 2 hours. Unless compaction is achieved within this period traditional compaction energy may not be capable of developing target density. However, Portland cement has been successfully used in certain situations with extended mellowing periods, well beyond 2 to 4 hours. Generally, the soil is remixed after the mellowing periods to achieve a homogeneous mixture before compaction. Although the ultimate strength of a soil cement product with an extended mellowing period may be lower than one in which compaction is achieved before initial set, the strength achieved over time in the soil with the extended mellowing period may be acceptable and the extended mellowing may enhance the ultimate product by producing improved uniformity. Nevertheless, the conventional practice is to compact soil cement within 2 hours of initial mixing [38]. During the hydration process, free lime, $Ca(OH)_2$ is produced. In fact up to about 25 percent of the cement paste (cement and water mix) on a weight basis is lime. This free lime in the high pH environment has the ability to react pozzolanically with soil, just as lime does and this reaction continues as long as the *pH* is high enough, generally above about 10.5

Fly ash is also generally considered as a traditional stabilizer. While lime and Portland cement are manufactured materials, fly ash is a by-product from burning coal during power generation. As with other by-products, the properties of fly ash can vary significantly depending on the source of the coal and the steps followed in the coal burning process. These by-products can broadly be classified into class C (self-cementing) and class F (non-self cementing) fly ash based on AASHTO M 295[1] (ASTM C 618)[12]. Class C fly ash contains a substantial amount of lime, CaO, but almost all of it is combined with glassy silicates and aluminates. Therefore upon mixing with water, a hydration reaction similar to that which occurs in the hydration of Portland cement occurs. As with Portland cement, this hydration reaction produces free lime. This free lime can react with other unreacted pozzolans, silicates and aluminates, available within the fly ash to produce a pozzolanic reaction, or the free lime may react pozzolanically with soil silica and/or alumina. Class F ash, on the other hand, contains very little lime and the glassy silica and/or alumina exists almost exclusively as pozzolans. Therefore, activation of these pozzolans requires additives such as Portland cement or lime, which provide a ready source of free lime. The hydration or "cementitious" reactions and the pozzolanic reactions that occur when fly ash is blended with water from the products that bond soil grains or agglomerates together to develop strength within the soil matrix. Maintenance of a high system pH is required for long term strength gain in fly ash-soil mixtures. [71]

The kinetics of the cementitious reactions and pozzolanic reactions that occur in fly ash stabilized soils vary widely depending on the type of ash and its composition. Normally, class C ashes react rapidly upon hydration. However, class F ashes activated with lime or even Portland cement produce substantially slower reactions than Portland cement – soil blends. Generally compaction practice of fly ash - soil blends varies depending on the type of ash used or whether or not an activator is used, but the standard practice is to compact within 6 hours of initial mixing [38].

2.1.3.2 By-product Stabilizers

Like traditional stabilizers, pozzolanic reactions and cation exchange are the primary stabilization mechanisms for many of the by-product stabilizers. Lime kiln dust (LKD) and cement kiln dust (CKD) are by-products of the production of lime and Portland cement, respectively. [38]

Lime kiln dust (LKD) normally contains between about 30 to 40 percent lime. The lime may be free lime or combined with pozzolans in the kiln.

The source of these pozzolans is most likely the fuel used to provide the energy source. LKDs may be somewhat pozzolanically reactive because of the presence of pozzolans or they may be altogether non reactive due to the absence of pozzolans or the low quality of the pozzolans contained in the LKD. Cement kiln dust (CKD) The fines captured in the exhaust gases of the production of Portland cement are more likely ‘than LKD’ to contain reactive pozzolans and therefore, to support some level of pozzolanic reactivity. CKD generally contains between about 30 and 40 percent CaO and about 20 to 25 percent pozzolanic material [74]

2.1.3.3Non Traditional Stabilizers:

The mechanism of stabilization for non-traditional stabilizers varies greatly among the stabilizers. Asphalt may or may not be grouped as a traditional stabilizer depending on perspective. Asphalt is not a “chemical” stabilizer in the sense that it does not react chemically with the soil to produce a product that alters surface chemistry of the soil particles or that binds particles together. Instead asphalt waterproofs aggregate and soil particles by coating them and developing an adhesive bond among the particles and the asphalt binder [38]. The process is dependent on the surface energies of the aggregate or soil and the asphalt binder. Consequently, since this mechanism is more physical than chemical, soils with very high surface areas are not amenable to asphalt stabilization and such stabilization is normally limited to granular materials such as gravels or sands, and perhaps some silty sands. As a visco-elastic, visco-plastic material, temperature and/or dilution methods are required to make asphalt stabilization effective in soils. Either lower viscosity liquid asphalts (normally developed by mixing bitumen with diluents) or emulsified asphalts are used in soil stabilization.

2.1.4 Guidelines for Stabilizer Selection:

Soil characteristics including mineralogy, gradation and physical-chemical properties of fine grained soils influence the soil-additive interaction. Hence stabilizer selection should be based on the effectiveness of a given stabilizer to improve the physical-chemical properties of the selected soil. The preliminary selection of the appropriate additive(s) for soil stabilization should consider:

- Soil consistency and gradation
- Soil mineralogy and composition
- Desired engineering properties
- Purpose of treatment
- Mechanisms of stabilization
- Environmental conditions and engineering economics

Soil index properties (i.g, sieve analysis, Atterberg limit testing, and moisture density testing) should be determined based on laboratory testing of field samples. Soil samples should be prepared following AASHTO T 87[1]. The initial processing of most soils involves thorough air drying or assisted drying at a temperature not to exceed $60^{o}C$. Aggregations of soil particles should be broken down into individual grains to the extent possible. A representative soil fraction should be selected for testing following AASTHO T 248[1]. The required quantity of soil smaller than 0.425 mm (No. 40 sieve) should be used to determine the soil index properties. Liquid limit testing should be performed following AASHTO T 89 and plastic limit and plasticity index testing should be measured following AASHTO T 90[1].[80]

2.1.5 Techniques for Stabilizer Selection:

A range of options are available for selecting soil stabilizers most of which are based on the soil classification following either the AASHTO or Unified classification system. A simple, but well accepted methodology by which to select the appropriate stabilizer is the Soil Stabilization Index System (SSIS). The methodology was developed by U.S Air Force, and is based on soil index properties: plasticity index and percent passing the no. 200 sieve [16].These laboratory tests are easy to perform and are necessary inputs for AASHTO and Unified systems. Both these characteristics can be effectively correlated to the engineering properties of the soil and therefore can be used to differentiate engineering applicability. Figures 2.1 (for soils) and 2.2 (for base materials) use these two index properties, PI and percent passing the no. 200 sieve (percent smaller than 75 μm), to identify the appropriate stabilizer [80].

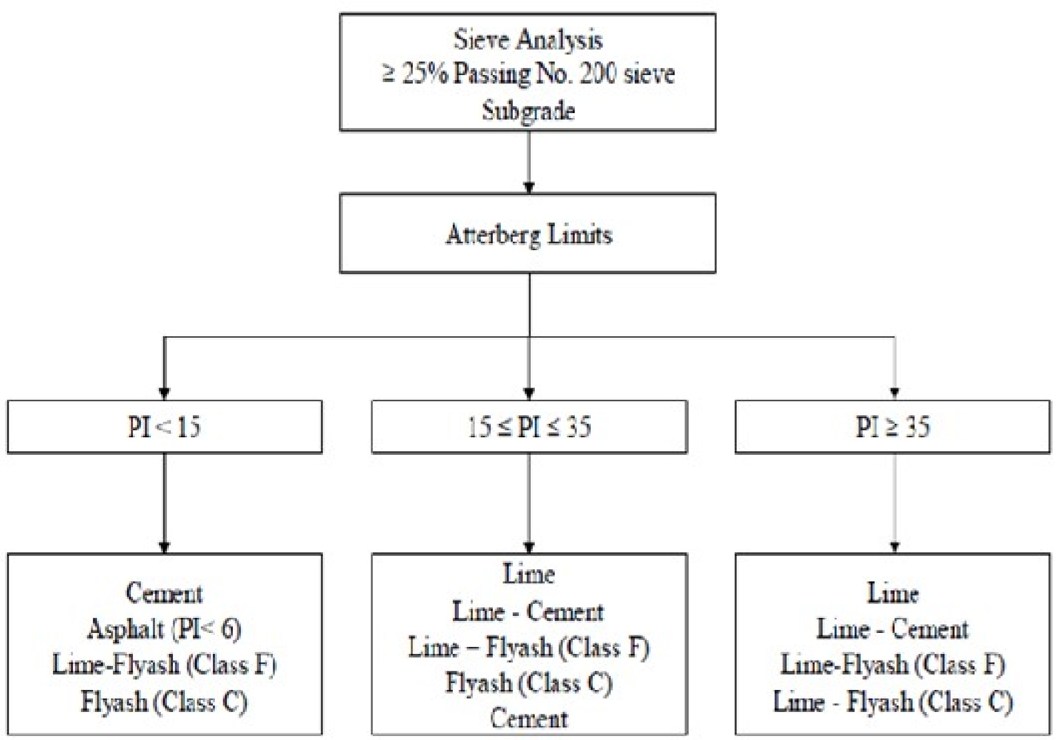

Fig (2.1) Decision tree for selecting stabilizers for use in subgrade soils [80]

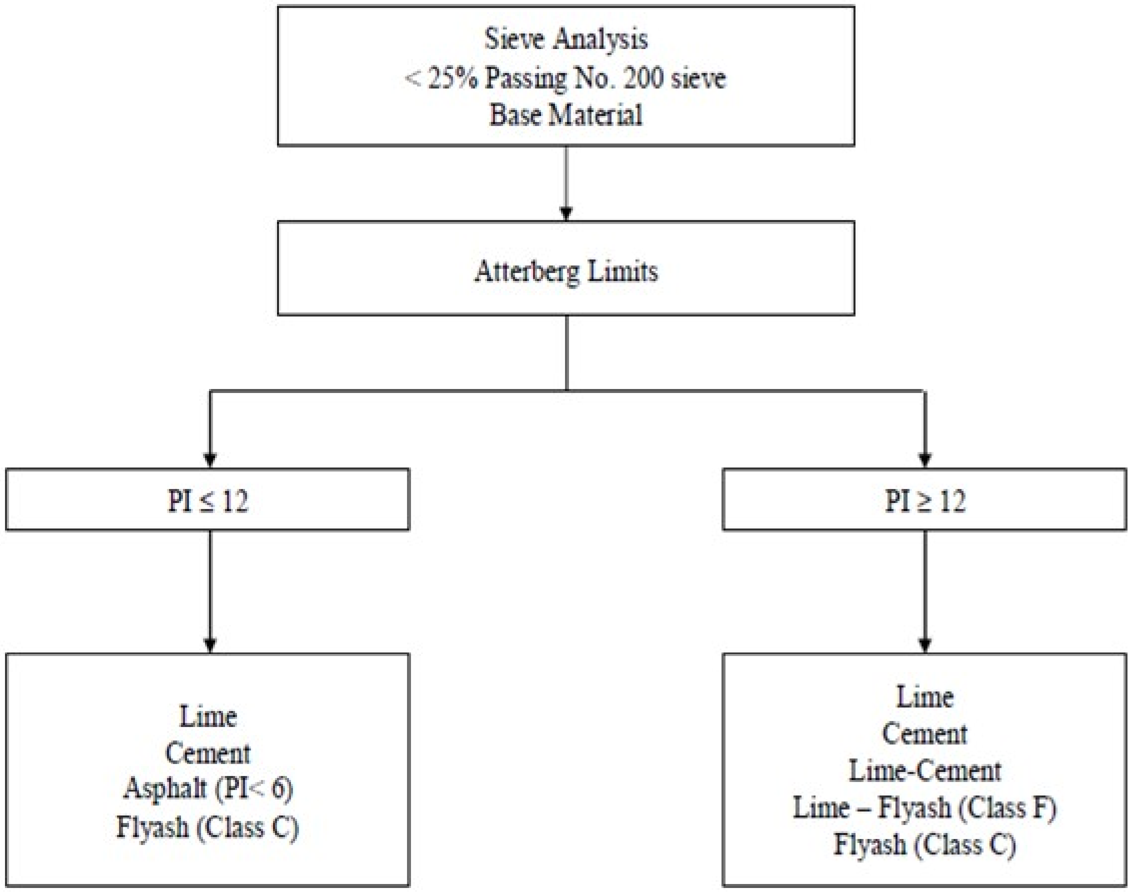

Fig (2.2) Decision tree for selecting stabilizers for use in Base materials [80]

2.1.6 Types of Waste Considered as Stabilizers:

Disposal of different waste materials produced from various industries is a serious problem. The wastes pose environmental pollution problems for the surrounding disposal area because some of the wastes are not biodegradable. The utilization of industrial wastes in road construction has been of great interest in industrialized and developing countries during recent years. Such utilizations are commonly based on technical, economical, and ecological considerations. Lack of conventional materials and improvement of the environment renders it imperative to search for substitutions, including that of industrial wastes. [49]

It is important to realize that the generation of wastes is an inherent part of productive systems. The quantities and characteristics of the waste generated depend on the technologies used by companies. Sometimes companies need to restructure their productive systems in order to treat the waste they generate and many times its elimination is not easy, especially in sectors where production technologies are much matured. In this context, one of the possibilities for the recovery of these materials is their reuse and recycling in the construction sector. The construction sector annually consumes large volumes of materials, which clearly gives this sector potential to absorb and give value to the large quantities of wastes produced in the industry. On the one hand, this situation can achieve the environmental protection demanded by Society, and on the other hand allows to the companies to operate more sustainable productive systems. The reuse of waste may enable the attainment of a “sustainable construction” procedure, which can be defined as a set of constructive actions which take into account technical, economical, environmental and social aspects.[42]

Table 2.1, compiled by Mandeep and Mittal (2014)[42] presents a partial list of industrial waste materials that may be used in civil construction (high ways construction).

Table 2.1: Possible usage of industrial waste products [42]

Waste product	Source	Possible usage
Fly ash	Thermal power station	Bulk fill, filler in bituminous mix, artificial aggregate
Blast furnace slag	Steel industry	Base/ Sub-base material, Binder in soil stabilization(ground slag)
Construction and demolition waste	Construction industry	Base/ Sub-base material, bulk-fill, recycling
Colliery spoil	Coal mining	Bulk-fill
Spent oil shale	Petrochemical industry	Bulk-fill
Foundry sand	Foundry industry	Bulk-fill, filler for concrete, crack-relief layer
Mill tailings	Mineral processing industry	Granular base/sub-base, aggregates in bituminous mix, bulk-fill
Cement kiln dust	Cement industry	Stabilization of base, binder in bituminous mix
Used engine oil	Automobile industry	Air entraining of concrte
Marble dust	Marble industry	Filler in bituminous mix
Waste tires	Automobile industry	Rubber modified bitumen, aggregate
Glass waste	Glass industry	Glass- fiber reinforcement, bulk fill
Nonferrous slag	Mineral processing industry	Bulk- fill, aggregate in bituminous mix
China clay	Bricks and tile industry	Bulk- fill, aggregate in bituminous mix

2.1.7 Material Acceptability Criteria:

Structures constructed from layers of compacted materials, and generally its strength decreases downwards. For conventional materials, a number of tests are conducted and their acceptability is decided based on the test results and the specifications. This ensures the desirable level of performance of the chosen material, in terms of its permeability, volume stability, strength, hardness, toughness, fatigue, durability, shape, viscosity, specific gravity, purity, safety, and temperature susceptibility, whichever are applicable.

The tests and specifications, which are applicable for conventional materials, may be inappropriate for evaluation of non-conventional materials, such as industrial wastes. This is because the material properties, for example, particle sizes, grading and chemical structure, may differ substantially from those of the conventional materials. Thus for an appropriate assessment of these materials, new tests are to be devised and new acceptability criteria are to be formed. However, with the advent of performance based tests, it is expected that the performances of the conventional as well as new materials can be tested on a same set-up and be compared. Figure 2.3 presents a flow chart to evaluate the suitability of industrial waste for potential usage in highway construction. Health and safety considerations should be given due importance handing industrial waste materials [48], [61].

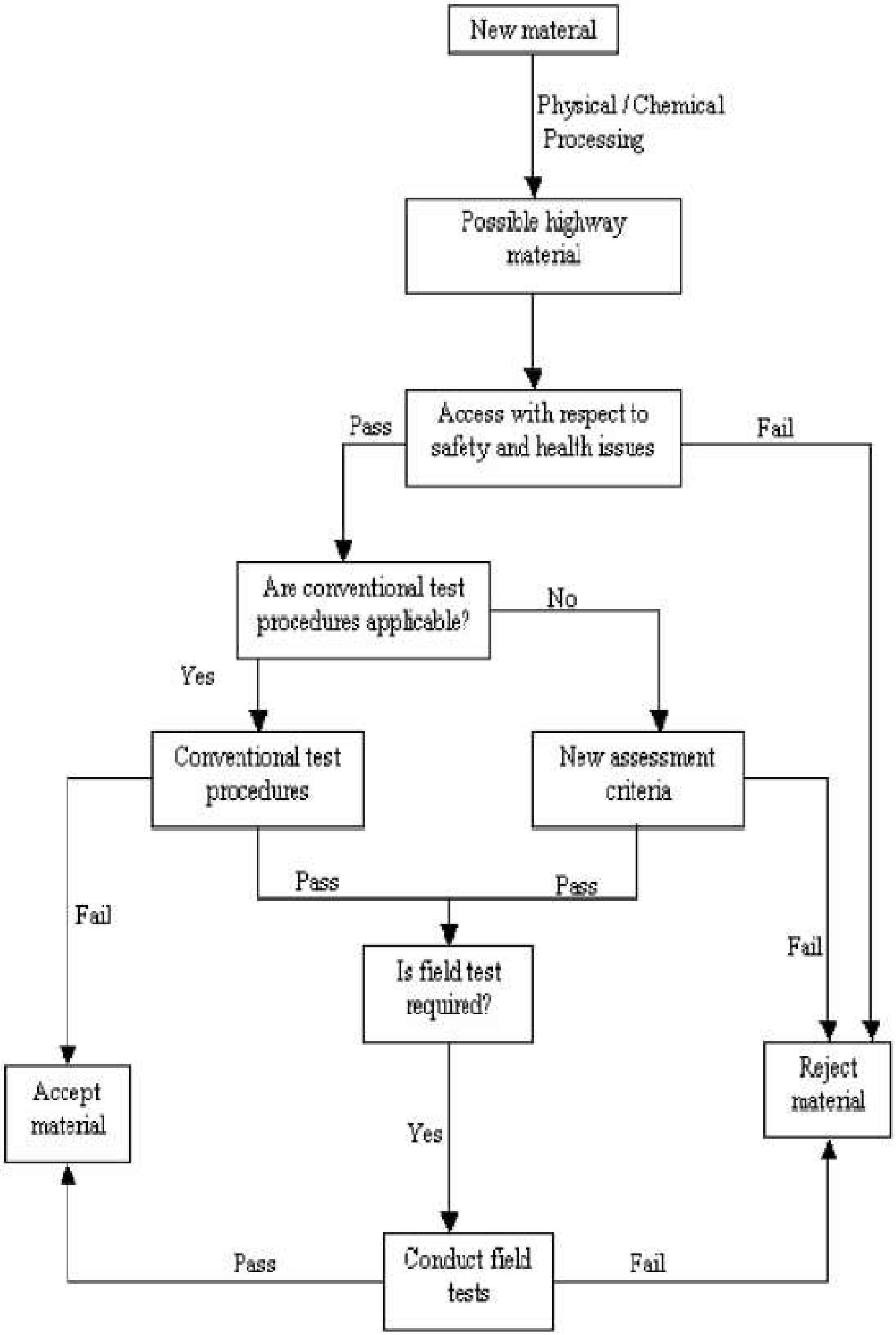

Fig.2.3: material acceptability tree [48]

2.1.8 Soil Reinforcement

According to Hejazi et al. (2012) [30] Soil reinforcement is a procedure where natural or synthesized additives are used to improve the properties of soils. Several reinforcement methods are available for stabilizing problematic soils. Therefore, the techniques of soil reinforcement can be classified into a number of categories with different points of view. Some of the methods appeared in Fig 2.4 may have the disadvantages of being ineffective and/or expensive.

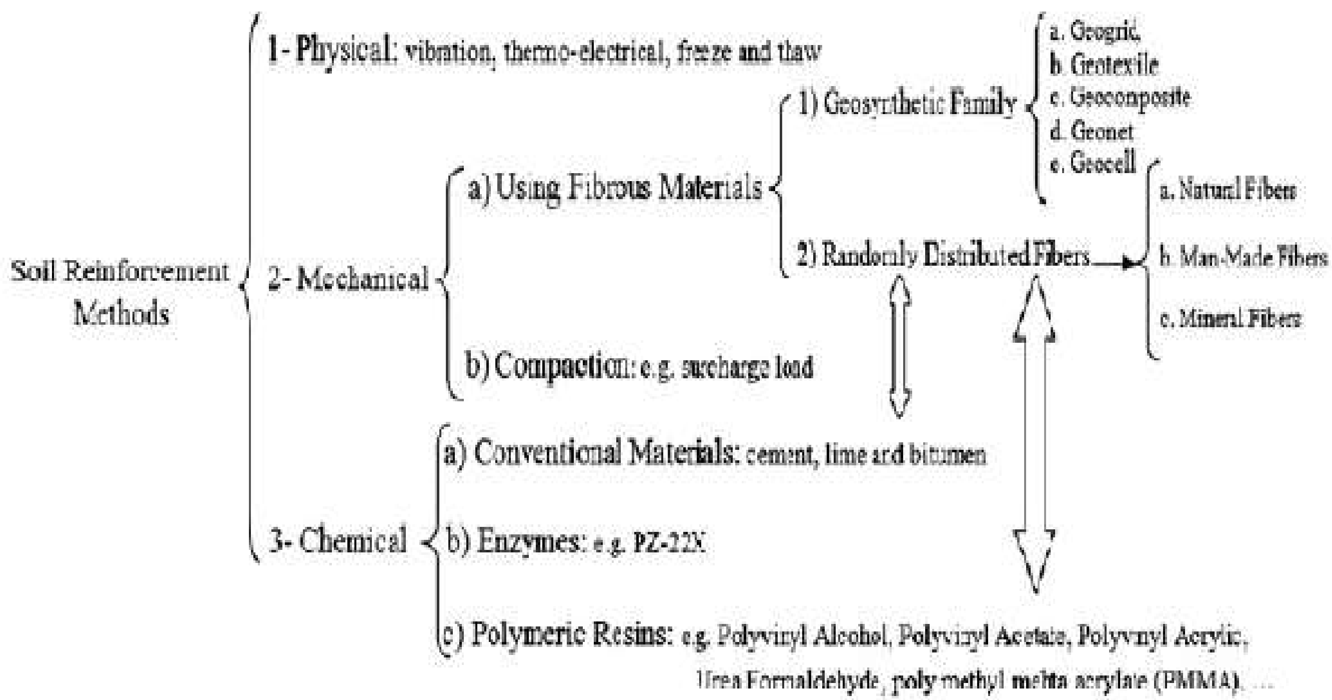

Fig 2.4: Different procedures of soil reinforcement (Hejazi et al., 2012).[30]

Fig (2.5) obtained by Mishra Brajesh (2016) [46] showed that extensive, deep and wide cracks were formed in the unreinforced sample. This clearly shows the effectiveness of random recycled PET fibers addition in resisting and reducing aridness cracking which is of supreme importance in surface cracking of clay covers used in landfills. Therefore, it can be concluded that random fiber addition seems to be an effective method of increasing tensile strength of the clayey soils to resist volumetric changes.

Fig. 2.5 Aridness cracking (X) unreinforced sample (Y) reinforced sample [46]

PART TWO: A REVIEW ON THE SOIL STABLIZATION WITH CEMENT KILN DUST, FIBER WASTE AND PLASTIC WASTE (BET)

According to Mandeep and Mittal (2014) [42] Solid waste term includes all those solid and semi-solid materials that are discarded by the community. Improper management of solid wastes causes adverse effects on the ecology which may lead to cause possible outbreak of diseases and epidemics. Solid wastes are broadly classified in to three group's namely Industrial waste, Agricultural waste, and Municipal waste apart from other categories of wastes.

2.2.1 Cement kiln Dust:

Tarun and Yoon-moon (2003) [79] and Adaska Wayne (2008)[3] stated that cement kiln dust is created in the kiln during the production of cement clinker. The dust is a particulate mixture of partially calcined and unreacted raw feed, clinker dust and ash, enriched with alkali sulfates, halides and other volatiles. These particulates are captured by the exhaust gases and collected in particulate matter control devices such as cyclones, baghouses and electrostatic precipitators (Figure 2.6).

Figure 2.6 Dust control device (Courtesy of Capitol Cement) [3]

Several factors influence the chemical and physical properties of CKD. Because plant operations differ considerably with respect to raw feed, type of operation, dust collection facility, and type of fuel used, the use of the terms typical or average CKD when comparing different plants can be misleading. The dust from each plant can vary markedly in chemical, mineralogical and physical composition. However, to provide a general reference point, a typical dust composition as reported by the Bureau of Mines (1982) [31] is given in Table 2.2.

Table 2.2 Typical Composition of Cement Kiln Dust (Haynes and Kramer, 1982) [31]

Constituent	% by weight	Constituent	% by weight
$CaCO_3$	55.5	Fe_2O_3	2.1
SiO_2	13.6	KCI	1.4
CaO	8.1	MgO	1.3
K_2SO_4	5.9	Na_2SO_4	1.3
$CaSO_4$	5.2	KF	0.4
Al_2SO_4	4.5	Other	0.7

The purpose of using CKD, and the other additives, is to improve the texture, increase the strength and reduce the swell characteristics of the various soils. When the additives containing free calcium hydroxide are mixed with the soil, the calcium causes the clay particles to flocculate into a more sand-like structure reducing the plasticity of the soil [39], [40]

2.2.1.1 Cement Kilns and Air Pollution

Tarun and Yoon-moon (2003)[79] stated that "CKD as collected is a fine-grained, solid, highly alkaline material that is generated at a temperature near 1,482°C (2,700°*F*). These characteristics tend to limit the types of dust collection devices that can be used to control air pollutant emissions from cement kilns. For example, because its fine-grained nature (diameter ranging from near zero micrometers or microns [μm] to greater than 50 μm) allows CKD to be easily entrained in exhaust gases, settling chambers that rely on gravity to separate particulate matter from a gas stream can only be used as a primary dust collection device to remove coarse dust particles and, in general, must be combined with more complex devices such as fabric filters (i.g, baghouses) or electrostatic precipitators. Wet scrubbers, commonly used in many mineral processing industries, cannot be used in the cement industry because adding water to the captured CKD causes it to harden ("set up") due to its cementitious properties" .

2.2.1.2 CKD Gross Characteristics

According to Tarun and Yoon-moon (2003)[79] and Keerthi et al (2013)[36] CKD is comprised of thermally unchanged raw materials, dehydrated clay, decarbonated (calcined) limestone, ash from fuel, and newly formed minerals corresponding to all stages of processing up through the formation of the clinker. An unusual feature of CKD is that, unlike typical process wastes that are substantially different than the product, CKD is essentially cement clinker that does not quite meet commercial specifications"

2.2.1.3 Physical Characteristics

Although the relative constituent concentrations in CKD can vary significantly, CKD has certain physical characteristics that are relatively consistent. When stored fresh, CKD is a fine, dry, alkaline dust that readily absorbs water. When managed on site in a waste pile, CKD can retain these characteristics within the pile while developing an externally weathered crust, due to absorption of moisture and subsequent cementation of dust particles on the surface of the pile" [79]

2.2.1.4 List of Beneficial Uses of CKD

As outlined by Tarun and Yoon-moon (2003) [79] the following list is the beneficial uses of CKD:

- Stabilization of sludge, wastes, and contaminated soils
- Soil stabilization
- Land reclamation
- Agricultural applications (fertilizer, liming agent)
- Livestock feed ingredient
- Lime-alum coagulation in water treatment
- Construction applications (blending with portland cement, use as a road base material)
- Sanitary landfill daily cover
- Mineral filler
- Lightweight aggregate
- Glass making

2.2.1.5 Influence of Soil Type on Stabilization with CKD:

During the manufacture of portland cement, a large amount of dust is collected from kiln exhaust gases. While some of this cement kiln dust (CKD) is recycled, a large amount is disposed in landfills. The CKD has cementitious properties that make it an effective stabilizer for certain soil types. Miller et al (2000) [45], investigated the effectiveness of CKD for stabilizing low and high plasticity soils. A tentative method based on pH measurements of soil-CKD mixtures is presented for rapidly assessing potential strength increases due to the addition of CKD

2.2.1.6 Previous Work Related to CKD:

A number of researchers have proposed alternative approaches to solve environmental problems due to the progressive rate of waste generation. Some acceptable waste disposal projects are outweighed by the disadvantages of the rising price of land, high operation costs and more stringent regulations. As stated by Cyr et al, (2007) [15] and Nontananandh *et al*. (2011) [59] had focused on the utilization of wastes as raw materials for construction and cement manufacturing according to 4th 3R (Reduce, Recycle,Reuse) waste management.

Heeralal and Praveen, (2011) [29], had shown that the inclusion of fiber reinforcement within soil and CKD soil mix caused an increase in the unconfined compressive strength UCS, shear strength and axial strain at failure. They stated that increasing fiber content could increase the peak axial stress, decrease the stiffness and the loss of post-peak strength and weaken the brittle behavior of cemented soil. The increase in strength of combined fiber and CKD inclusions was much more than the sum of the increase caused by them individually. It could be concluded from their study that the combination of discrete fiber and CKD has the virtues of both fiber-reinforced soil and cements stabilized soil, and therefore the addition of fiber– CKD to soil can be considered as an efficient method for ground improvement.

Nontananandh and Yoobanpot (2012),[60] focused in their research on the potential utilization of waste-based cement (WBC) as a stabilizer to improve the compressive strength of soft clay and also aimed to verify the hardening effects of WBC compared to ordinary portland cement (OPC). The potential utilization of various types of industrial wastes as raw materials to produce WBC was studied based on newly developed concepts and techniques. As a stabilizer for soft clayey soil, the WBC had hydraulic properties to improve the strength of soft clay comparable to ordinary Portland cement. The newly developed cement provided hydration and subsequent reaction products such as calcium silicate hydrate and calcium aluminate hydrate, which contributed to the strength development of the stabilized soil.

Rahman et al (2011) [70] concluded that CKD is potentially useful in stabilizing a variety of soils (i.g. sandy and clayey). However, the stabilizing effect is primarily a function of the chemical composition, fineness, and addition level of the CKD as well as the type of parent soil. They stated that the following general conclusions can be made from the literature research and the experimental investigation carried out in their study: The CKD with high free lime and low alkalis resulted in compact soils of improved compressive strengths. Free lime is potentially reactive and quickly hydrates to promote the stabilization reactions, the CKDs with low free lime and high alkali adversely affect the unconfined compressive strength. Higher alkalis in CKD could counter the stabilization reactions because of the ionic interference, particularly with clayey soils. And the CKDs with low loss on ignition (LOI) and moderate alkalis reduced the plasticity index (PI) and improved the unconfined compressive strength of clay soils. In some cases, the shrinkage limits increased to higher values than their respective optimum moisture contents.

Tarun et al (2003) [79] stated that addition of CKD to soil can substantially improve the unconfined compressive strength, relative to untreated soil, CKD provides some protection from the adverse effects of saturation on strength, Addition of CKD rapidly increases unconfined compressive strength for 7-14 days after compaction, and thereafter more slowly, Then CKD-treated soil exhibits brittle behavior during unconfined compression. Significant increases in modulus and decreases in the strain at failure occur with the addition of CKD and The optimum moisture content and maximum dry unit weight, increase and decrease, respectively, with increasing amounts of CKD

Keerthi et al (2013) [36] concluded that CKD has been used as a soil additive to improve the texture, increase strength and reduce swell characteristics, Treatment with CKD was found to be an effective option for improvement of soil properties, Strength and stiffness were improved and plasticity and swell potential were substantially reduced, The percentage of cement added for clay soils was determined by the amount of cement needed to lower the PI below 10. And for light applications, it was expected that 12-30 % CKD should be sufficient to upgrade dune sand; however, for heavily loaded applications, it was expected to raise the CKD content to about 50%.Specimens of CKD revealed high compressive strength but failed the freeze-thaw durability requirement

Yooban et al. (2010) [83] and Nontananandh et al. (2011) [59] reported on attempts to produce clinker and cementing material using the combination of certain types of industrial wastes. The WBS contained the essential Bougue's compounds such as C3S, C2S, C3A and C4AF and had a hardening effect similar to that of OPC. The results of analysis also revealed that the cement produced from wastes was an environmentally friendly product having a heavy metals content that conformed to the US Environmental Protection Authority's standard (USEPA, 1993; Nontananandh, (2011)[59]. However, the quality of the so-called WBC, such as its hydraulic properties and enhancement on hydration, still need to be improved. Its potential utilization as a construction material in place of OPC also needs to be established.

2.2.2 Fiber Waste:

Youjiang (2006) [84] stated that fiber waste found from various sources have been studied as reinforcement in soil and concrete, including tire cords, carpet fibers, feather fibers, steel shavings, wood fibers from paper waste, and high density polyethylene

The main types of fiber studied as reinforcement are:

1. Polypropylene Fibers

According to Mondal (2012) [47] Overall, polypropylene seems to be one of the most common materials used for fiber reinforcement of soils, and it is manufactured in two forms: monofilament and fibrillated.

Fletcher and Humphries (1991) [23] conducted compaction as well as CBR tests on silty, clay reinforced soil. The results of compaction tests for silty, clay soil specimen reinforced with fibres indicate that increasing the volume of fibres in the soil generally causes a modest increase in the maximum dry unit weight, and a slight decrease in the optimum moisture content. Also reinforcement of micaceous, silty soil specimens significantly enhanced the California Bearing Ratio (CBR) values, with an increase in CBR values from 65% to 133% over that of the unreinforced soil specimens. The micaceous, silt soil specimens containing fibrillated fibres yielding 16% higher CBR values than soil specimen containing monofilament fibres.

Puppala and Musenda (2000) [69] indicated that PP fiber reinforcement enhanced the unconfined compressive strength (UCS) of the soil and reduced both volumetric shrinkage strains and swell pressures of the expansive clays. From the experiments on field test sections in which a sandy soil was stabilized with PP fibers, Santoni and Webster (2001) [73] concluded that the technique showed great potential for military airfield and road applications and that a 203-*mm* thick sand fiber layer was sufficient to support substantial amounts of military truck traffic. Field experiments also indicated that it was necessary to fix the surface using emulsion binder to prevent fiber pullout under traffic.

Setty and Rao (1987) [75] and Setty and Murthy(1987) [76], carried out tri-axial tests, CBR tests and tensile strength tests on silty sand and black cotton soil, reinforced with PP fibers. The test results illustrated that both of the soils showed a significant increase in the cohesion intercept and a slight decrease in the angle of internal friction with an increase in fiber content up to 3% by weight

Muntohar et al (2013) [49] studied the engineering properties of fiber (polypropylene showed in fig (2.7))/lime/ rice husk ash RHA soil. The shear strength of the soil increased by addition of the lime/ RHA mixture. The inclusion of fibers resulted in a decrease in the friction angle. The cohesion of fiber-reinforced lime/RHA/soil mixtures increased initially and then decreased with increasing fiber content, and the maximum value was observed at a fiber content of 0.4%. Plastic fibers in the soil/ lime/RHA mixtures had a significant influence in development of the cohesion rather than friction angle of the soil. Inclusion of the plastic-waste fiber reduced the brittleness behavior of the stabilized soil. Addition of 0.1% fiber was enough to decrease the brittleness of the stabilized soil. In general, inclusion of the plastic-waste fiber increased the secant modulus of the stabilized soil specimen

Pal et al (2015) [63] studied on soil stabilisation using polypropylene as waste fiber material and they concluded that The direct shear strength parameters of the soil reinforced with waste fibers of polypropylene used for the improvement of the engineering properties of the soil with 20 *mm* length and 0.35% weight of polypropylene by weight of dry soil sample, is found as 25.18% increase in the angle of internal friction (Φ) and 46.88% increase in cohesion (c). The unconfined compressive strength (UCS) of the soil reinforced with waste fibres of polypropylene used for the improvement of the engineering properties of the soil with 20 *mm* length and 0.25% weight of polypropylene by weight of dry soil sample, is found as 52.80% increase in UCS.

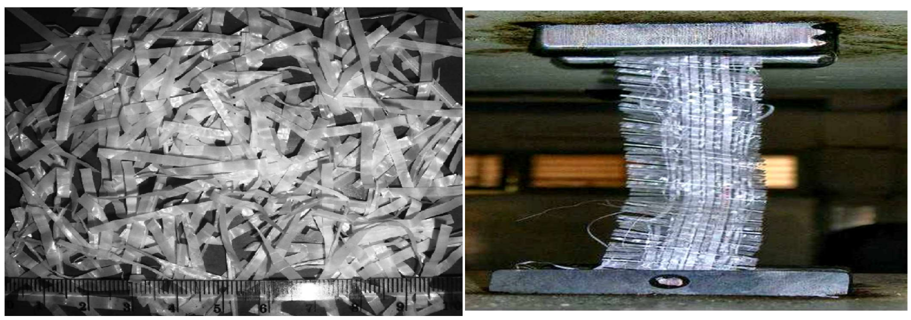

Fig 2.7:Polypropylene fiber

2. Nylon Fibers

Nylon fibers are used as reinforcement in concrete to increase its ductility, durability, and toughness. According to Zellers and Cruso (2002) [85], when the nylon fibers are used in concrete, they can absorb water, allowing the fibers to cure the concrete from the inside out. In addition to curing the concrete, this absorbed water also contributes to adhesion between the fibers and concrete. Although very little research has been done on the use of nylon fibers with soil, these fibers may have the ability to mechanically and chemically stabilize soil, especially when combined with cement. [47]

Kumar and Tabor (2003) [37] studied the strength behavior of nylon fiber reinforced silty clay with different degree of compaction. The study indicates that peak and residual strength of the samples for 93% compaction are significantly more than the samples compacted at the higher densities.

Gosavi et al (2006) [26], reported that by mixing nylon fibers and jute fibers, the CBR value of soil is enhanced by about 50% of that of unreinforced soil, whereas coconut fiber increases the value by as high as 96%. The optimum quantity of fiber to be mixed with soil is found to be 0.75% and any addition of fiber beyond this quantity does not have any significant increase in the CBR value

Murray and Wang (2000) [52], conducted a laboratory test program to evaluate the properties of nylon carpet waste fiber reinforced sandy silt soil .Increasing the triaxial compressive strength by 204% with 3% carpet fibers.

3. Poly (vinyl) Alcohol Fibers

Like the nylon fibers, poly (vinyl) alcohol (PVA) fibers are typically not used for soil stabilization, but they are used as concrete reinforcement in Engineered Cementitious Composites (ECC) to increase ductility, durability, and toughness. Kanda and Li (1998) [35] state that when PVA fibers are used in cement, hydrogen bonds form between the hydroxyl groups of the PVA fibers and the cement particles. However, De Bussetti and Ferreiro (2004) [20] report that clay has been stabilized with PVA solution instead of PVA fibers, where hydrogen bonds form between the hydroxyl groups of the PVA molecules and the silicate sheets of the clay. [47]

Park et al [65], [66] found that the addition of 1% polyvinyl alcohol (PVA) fiber to 4% cemented sand resulted in a two times increase in both the UCS and the axial strain at peak strength when compared to non-fiber-reinforced specimen

4. Glass Fibers

Consoli et al (2002) [19] indicated that inclusion of glass fibers in silty sand effectively improves peak strength

In another work, Consoli et al (2004) [18] examined the effect of PP, PET and glass fibers on the mechanical behavior of fiber-reinforced cemented soils. Their results showed that the inclusion of PP fibersignificantly improved the brittle behavior of cemented soils, whereas the deviatoric stresses at failure slightly decreased. Unlike the case of PP fiber, the inclusion of PET and glass fibers slightly increased the deviatoric stresses at failure and slightly reduced the brittleness.

Maher and Ho (1994) [41] studied the behavior of kaolinite–fiber (PP and glass fibers) composites, and found that the increase in the UCS was more pronounced in the glass fiber-reinforced specimens.

5. Steel Fibers:

Steel fiber reinforcements found in concrete structures are also used for the reinforcement of soil–cement composites [14, 53]. In addition, steel fibers can improve the soil strength but this improvement is not compared with the case of using other types of fibers [27]. However, Ghazavi and Roustaie (2010)[25] recommended that in cold climates, where soil is affected by freeze–thaw cycles, polypropylene fibers are preferable to steel fibers. Since, polypropylene fibers possess smaller unit weight than steel fibers. In other words, the former fibers decrease the sample volume increase more than steel fibers [25].

2.2.2.1 Engineering Properties of Fiber Reinforced Soil

As outlined by Olufowobi et al (2014) [62], the addition of fiber reinforcement in the sand and clay specimens was reported to cause a substantial increase in the peak friction angle and cohesion values. The shear strength envelope for the clay specimens is described by a combination of curvilinear and linear sections. The friction angle at low confining pressures was found to be slightly larger than that at higher confining pressure. The phenomenon was explained as an effect of dilatancy which increases the interface shear strength between fiber and soil. This effect is more pronounced at low confining stresses than at high confining stresses.

Roohul et al (2016) [72] stated that the CBR value of RDFS is more than that of unreinforced clay. CBR value considerably increased with increase in fiber content from 0.1% to 0.3%. A variation of increase in C.B.R. with fibre content shows maximum value of percentage increases in C.B.R. of RDFS as that of unreinforced clay. The C.B.R. value of randomly distributed reinforced fibre soil also increases with length of fibre. C.B.R. value increases with increase in fibre length from 6mm to 18mm length of fibre. Variation of CBR value with fibre length shows similar linear trend as that of with fibre content. At 18*mm* fibre RDFS shows maximum percentage increase in CBR value as that of unreinforced clay. From both trend, it leads to conclude that at 0.3% FC with 18*mm* fibre shows maximum value of RDFS.

Chegenizadeh and Hamid (2011) [17] investigated on the compaction Parameters of Reinforced Clayey Sand by natural fiber in fig (2.9). This investigation proved that:

- Maximum dry density showed slight decrease due to induction of fibre
- Optimum Moisture Content (OMC) increased with increasing in fibre content

- Increasing in compaction effort causes increasing maximum dry density, this fact was observed for composite soil as well.

Fig.2.8 Natural fiber [Google image]

2.2.2.2Previous Work Related to Fiber Reinforcement:

Ayyappan et al **(**2010**)** [13] investigated the engineering behavior of soil, polypropylene fiber and fly ash mixtures for road construction and it concluded the fiber increase the peak compressive strength and ductility of soil fly ash specimens and the relative benefit in CBR values due to fibers increase only up to 1.0 % by dry weight and length up to 12 *mm* for all soil fly ash specimens.

Munmorah (2009) [50] studied the effect of the fiber length and content on the compressive and split tensile strength was investigated. His laboratory investigation result showed that inclusion of the plastic waste fiber increased significantly both the unconfined compressive strength and tensile-split strength of the stabilized clay soil. The fiber length played a significant contribution in increasing the soil strength. To contribute for any significant improvement on compression as well as tensile strength, the fiber length should be in the range of 20*mm* to 40*mm*. Fiber reinforcements also reduced soil brittleness by providing smaller loss of post-peak strength.

Venkata et al (2012) [82] made an attempt to use the fly ash and fiber to modify the properties of the soil which was available at the construction site. They stated that by addition of the fly ash and fiber to the expansive soils the CBR value was increased.

George et al (2013) [24], concluded that addition of 1 % fiber waste was not enough for the reinforcement and an addition of 4% fiber waste gave a non workable mix. Significant amount of fiber reinforcement was achieved by addition of 2% fiber. When quarry dust was mixed along with 2 % fiber waste, marginal improvement in dry density and CBR values of kaolinite clay were observed. Hence addition of 2% fiber was selected as the optimum percentage. With the increase in percentage of quarry dust, the CBR value went on increasing. But considering economy a combination of soil with 40% quarry dust and 2% fiber waste was considered as most suitable.

Naeini and Sadjadi (2008) [55] investigated the effect of waste Polymer materials on shear strength of unsaturated clays. Their study concluded: When the soil is reinforced with the waste polymer fiber, the dry density of the soil is reduced due to a low specific gravity and unit weight of polymer fiber. The increase in the fiber content also reduces the optimum moisture content (OMC) of the soil. The variation is linear for both cases; the value of cohesion is increased due to the inclusion of fiber. The variation of cohesion with percentage of fiber content is non-liner. The cohesion of fiber specimens increases while increasing fiber content up to 2% and then decreases slightly with additional amounts of fibers. The shear strength of fiber reinforced soil is improved due to the addition of the waste polymer fibers. The shear strength is increased non-linearly with increase in fiber content. They stated that in general, the shear strength values increased with increasing tire fiber contents up to 2% and then decreased.

Al-Akhras et al.(2008) [4] had shown that both nylon and palmary fibers linearly reduced the swelling pressure and the swelling potential of the clayey soils, the higher the percentage of fiber content in the soil the more impact it had on these swelling properties. Additionally, They noted that palmary fibers had more impact on reducing the swelling pressure of soils than the nylon fibers.

Gray (2003) [27] carried out series of laboratory unconfined compression, splittingtension, three-point-bending and hydraulic conductivity tests on kaolinite clay reinforced with fiber, and reported that randomly distributed fibers increase the peak unconfined compressive strength, ductility, splitting tensile strength and flexural toughness of kaolinite clay. The contribution of fiber-reinforcement was found to be more significant for specimens with lower water contents. Some researchers have studied the use of fibers to improve the ductility of cementstabilised soils.

Al-Khafaji and Andersland (1992) [5] performed triaxial tests on kaolinite clay reinforced with cellulose pulp fibers. The shear strength under various testing conditions (undrained, consolidated drained and consolidated undrained) increased with increasing fiber content and the mode of failure changed from brittle to plastic. The ductility of the specimen was also found to increase with increasing fiber content.

Al-Joulani (2000) [6] evaluated the use of waste fiber materials such as scrap tire rubber, polyethylene and polypropylene fiber for the modification of clayey soils under unconfined compression, shear box and resonant frequency tests .It was discovered that waste fibers improve the strength properties and dynamic behaviour of clayey soils.

Roohul et al (2016) [72] presented the CBR value of randomly distributed reinforced fibre soil RDFS is more than that of unreinforced clay. CBR value considerably increases with increase in fibre content from 0.1% to 0.3%. A variation of increase in CBR with fibre content shows maximum value of percentage increases in CBR of RDFS as that of unreinforced clay. The CBR value of also increases with length of fibre, CBR value increases with increase in fibre length from 6*mm* to 18*mm* length of fibre, Variation of CBR value with fibre length shows similar linear trend as that of with fibre content. At 18*mm* fibre RDFS shows maximum percentage increase in C.B.R. value as that of unreinforced clay. From both trend, it leads to conclude that at 0.3% FC with 18*mm* fibre shows maximum value of RDFS.

Nataraj and McManis (1997) [57] performed a series of laboratory tests on a clay and sand reinforced randomly distributed fibrillated fibres to investigate the strength and deformation characteristics of soil. They used polypropylene synthetic fibre as a reinforcing material. The laboratory tests performed include compaction, direct shear test, unconfined compression, and CBR test. In this study, the influence of test parameters such as normal stress, the amount of reinforcement, specimen size, and the moisture content is addressed. Results showed that, the compaction characteristics of the fibre reinforced soil were similar to that of the unreinforced soils. The maximum dry unit weight reached a maximum value at fibre content of 0.2% for clay specimens and 0.1% for sand specimens. The CBR values increases significantly with the addition of reinforcing fibres.

2.2.3 Plastic waste (PET):

Plastics are commonly used substances which play an important role in almost every aspect of our lives. The widespread generation of plastics waste needs proper end-of-life management. The highest amount of plastics is found in containers and packaging's (i.g. bottles, packaging, cups), but they also are found in durables (e.g. tires, building materials, furniture.) and disposable goods (e.g medical devices) [77]. Diversity of plastics applications is related with their specific properties, low density, easy processing, good mechanical properties, good chemical resistance, excellent thermal and electrical insulating properties and low cost (in comparison to other materials).

Post-production and post-consumer plastics are utilized in a wide range of applications. However, in this field two main directions should be mentioned:

1) Using of plastic waste as alternative fuel (burning) in cement kilns and power plants

2) Material recycling of waste polymers.

As stated by Sulyman et al (2016) [78] plastic (polymers) used for applications in bitumen modifications, can be subdivided into two main types depending on their behavior after exposure to heat. First type is thermosetting polymers (e.g. resins, elastomers) which are cured during heating. Three-dimensional structure of cross-linking bonds formed during curing unable softening of polymer matrix and its easy re-processing. Second types are thermoplastic polymers. This type of polymers can be shaped and designed in new shapes using heat. In contrary to thermosetting polymers this process is reversible. Examples of aforementioned materials are shown in the Table 2.3. The plastics used for bitumen modification may be also classified as thermoplastic and thermosets. [78]

Table 2.3 Examples of thermoplastics and thermoplastics and Thermosetting [78]

Thermoplastics	Thermosetting
Polyethylene Terephthalate (PET)	Bakelite
Polypropylene (PP)	Epoxy resins
Polyvinyl Acetate (PVA)	Melamine resins
Polyvinyl Chloride (PVC)	Polyesters
Polystyrene (PS)	polyurethane
Low density polyethylene (LDPE)	Urea - Formaldehyde
Low density polyethylene (LDPE)	Alkyd resins

2.2.3.1 Problems of Plastics:

Plastics may be easy and convenient for everyday use. However, their negative impacts on our health cannot be. In the long run, overuse of plastics and lack of proper recycling are going to yield many undesirable effects on our health. Plastics are harmful to manufacture and use, and pose a great challenge of recycling at the same time. Hence, when it comes to plastics, it is a full circle of problems and challenges that need to be resolved. [58]

2.2.3.2 Plastic Waste and Environmental Impacts:

One of the biggest problems today is the waste produced annually by the use of plastics and the long-lasting effects it has on the environment. According to the data presented by EPA, Municipal Solid Waste (MSW) generated in (2006) is 251 *million tons*. There are several ways to manage MSW including source reduction, recycling, composting, landfills, and combustion in order of preference (EPA, Municipal Solid Waste 2008). The trend of MSW is shown in Figure 2.10 and shows that while each person in the U.S. generates about the same amount of MSW per day, the total MSW generation increased. [58]

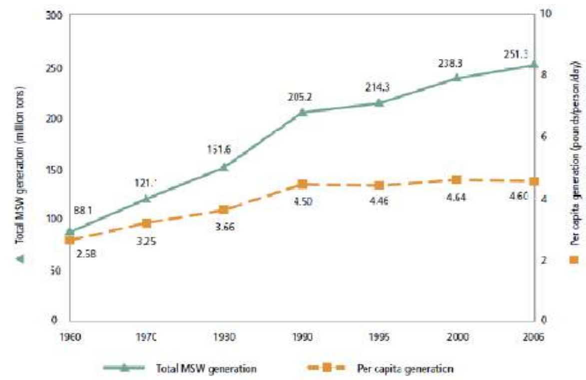

Figure 2.9 MSW Generation Rates from 1960 to 2006 (EPA 2007, Municipal Solid Waste Generation, Recycling and Disposal in the United States) [58]

The growing amount of plastic waste and the small amount of plastic being recycled have two major environmental impacts; one is the consumption of petroleum and global warming, and the other is the accumulation of plastic wastes in nature.

Poly (ethylene terephthalate) (PET) is the most commonly used thermoplastic polyester. It is often called just “polyester,” which often causes confusion, because polyester resins are thermosetting materials. PET is a transparent polymer, with good mechanical properties and good dimensional stability under variable load. Moreover, PET has good gas barrier properties and good chemical resistance.

Abovementioned properties of PET caused its wide application in the form of bottles, thermally stabilized films (e.g. capacitors, graphics, film base and recording tapes) and electrical components. PET is also used for production of fibers for a very wide range of applications in textile industry.

PET belongs to thermoplastics with excellent physical properties. It constitutes is around 18% of the total polymers produced worldwide and over 60% of its production is used for synthetic fibers and bottles, approximately 30% of global PET demand [78]

2.2.3.3 Sources of PET Waste:

According to Sulyman and formela (2013)[77] waste PET source can be categorized into three main stream:

a) Bottles - small problems with material recycling; problems related with impurities (e.g. glue on labels), different types additives used during production (e.g.stabilizers, pigments), molecular weight of PET, etc., which are affecting on repeatability of obtained products.

b) Foils - small problems with material recycling; problems related with additives used during production (e.g. stabilizers, pigments), molecular weight of PET, etc., which are affecting onrepeatability of obtained products.

c) Cord from tires – huge problem with material recycling. Currently, this fraction of waste PET is used as alternative fuel. Example of waste tire cord is presented in Fig. 1 and its composition in Table III. Waste tire cord can be significant and cheap source of valuable poly (ethylene terephthalate). The main problem during material recycling of waste tire cord are contaminations of ground tire rubber and metals.

Table (2.4) Compositions of waste tire cord [77]

Compositions	Weight percent %
Poly(ethylene therephthalate) (PET)	77.6
Polyamide (PA)	18.7
Polypropylene (PP)	3.7

Fig (2.10) Recycled textile fiber from used tires [84]

2.2.3.4 Previous Work Related to Plastic Waste Rienforcement:

Fauzi et al (2016) [22] investigated on the Soil Engineering Properties Improvement by Utilization of Cut Waste Plastic and Crushed Waste Glass as Additive , the study concluded that the engineering properties of stabilized clayey samples were improved: The PI values were decreased when content of waste HDPE and Glass were increased, The CBR values were increased when content of waste HDPE and Glass increased and C, ϕ Values were decreased and increased respectively when content of waste HDPE and Glass were increased

Dutta and Sarde (2007) [21] investigated in their study the CBR behavior of stone dust/fly ash reinforced with 3 different sizes of waste plastic strips overlying saturated clay. The effect of waste plastic strips content on CBR and secant modulus of strip reinforced stone dust/fly ash overlying saturated clay was investigated. The study yielded the following conclusions: 1.Addition of waste plastic strip inclusions in stone dust/fly ash overlying saturated clay subgrade resulted in an appreciable increase in the CBR and the secant modulus. 2.The reinforcement benefits increased with an increase in waste plastic strip content and length. 3. The addition of waste plastic strips beyond 2% did not improve the CBR or secant modulus appreciably.

Consoli et al. (2002) [19] studied engineering behavior of sand reinforced with polyethylene terephthalate fiber separately and also when it was combined with Portland cement. The study's findings show that the inclusion of polyethylene terephthalate fiber increased the peak and ultimate strength of both cemented and non-cemented soil and reduced the brittleness of the cemented sand.

Mishra (2016) [46] investigated on use of Polyethylene Terephathalate (PET) Fiber for Stabilization of Subgrade Soil of Road Pavement and concluded the following: 1.Liquid limit and plastic limit of reinforced soil with recycled PET fibers, increases with increase in content of PET fiber. With addition of PET fibers, the plasticity index was decreased by factors 0.77 for PET fiber content of 1.2%.

2. With increase in PET fiber content the shear strength of reinforced soil increases in such a way that with addition of 0.6% recycled PET fibers, at normal stress 16.67 N/cm^2, the shear strength of reinforced-soil, become 1.45 times of shear strength of unreinforced natural soil. 3. Both angle of internal friction and cohesion increase with increase in PET fiber content. By Introduction of 0.6% dose of recycled PET fibers the angle of internal friction and the cohesion got increased by a factors1.73 and 1.75 respectively. 4. Shear modulus also increases with increase in PET fiber content. With introduction of 0.6% of recycled PET fibers, at normal stress 16.67 N/cm^2, the shear modulus was increased by factors 1.23. 5. With increase in PET fiber content, the CBR value increases. On introduction of

0.6% recycled PET fibers, the CBR value fiber reinforced-soil, becomes 1.67 times of natural or unreinforced soil. The increase in CBR value is responsible for improvement in the soil strength and hence a reduced crust thickness for road pavement will serve the purpose and ultimately it will result in economy in the cost of construction.

Nagle et al (2014) [56] studied on CBR of soil, reinforced with natural waste plastic material and concluded that: The addition of reclaimed plastic waste material to local soil increases the CBR, The maximum improvement in CBR is obtained while using 1.0% plastics strips having aspect ratio 3, .The CBR value at 0.25 & 0.50% plastic minimum increase.

Acharyya et al (2013) [2] assed and examined the improvement of shear strength of a clayey soil by mixing PET bottle strips. A series of Proctor Compaction, Unconfined Compression and Triaxial Compression tests were carried out adopting standard procedures on different mixes of soil(at OMC) and PET bottle strips.and concluded: 1.Maximum dry density of fibre mixed soil increases with increase in fibre content but it occurs up to its addition of 1 % when other parameters do not alter. Optimum value occurs at aspect ratio 2, Optimum moisture content of fibre mixed soil decreases with increase in fibre content but it occurs up to its addition of 1 % when other parameters do not change, UCS of fibre mixed soil increases with increase in fibre content but it occurs up to its addition of 1% when other parameters do not alter. Optimum value comes at aspect ratio 2. And At aspect ratio of 3, Φ increases up to 1% of plastic strip but since there is an appreciable reduction in C, effectively the shear strength is reducing. Hence optimum value occurs at aspect ratio 2.