1.1SOIL AND SOIL ENGINEERING:

The term 'Soil 'have various meanings, depending upon the general professional field in which it is being considered. To an agriculturist, soil is the substance existing on the earth's surface, which grows and develops plant life. To the geologist also, soil is the material in the relatively thin surface zone within which roots occur, and all the rest of the crust is grouped under the term rock irrespective of its hardness. To an engineer, soil is the unaggregated or uncemented deposits of mineral and/or organic particles or fragments covering large portion of the earth's crust. It includes widely different materials like boulders, sands, gravels, clays and silts, and the range in the particle sizes in a soil may extend from grains only a fraction of a micron (10^{-4} cm) in diameter up to large size boulders.

Soil engineering, Soil Mechanics or Geotechnique is one of the youngest disciplines of civil engineering involving the study of soil, its behavior and application as an engineering material. According to Terazaghi (1948): 'Soil Mechanics is the application of laws of mechanics and hydraulics to engineering problems dealing with sediments and other unconsolidated accumulations of solid particles produced by the mechanical and chemical disintegration of rocks regardless of whether or not they contain an admixture of organic constituent'. The term Soil Engineering is currently used to cover a much wider scope implying that it is a practical science rather than a purely fundamental or mathematical one. The term Foundation Engineering is a branch of civil engineering, which is associated with the design, construction, maintenance, and renovation of footings, foundation walls, pile foundations, caissons, and all other structural members which form the foundations of buildings and other engineering structures (Taylor, 1948).

Soil is considered by the engineer as a complex material produced by the weathering of the solid rock. The formation of soil is as a result of the geologic cycle continually taking place on the face of the earth. The cycle consists of weathering or denudation, transportation, deposition and upheaval, again followed by weathering, and so on. Weathering is caused by the physical agencies such as periodical temperature changes, impact and splitting action of flowing water, ice and wind, and splitting actions of ice, plants and animals. Cohesionless soils are formed due to physical disintegration of rocks. Chemical weathering maybe caused due to oxidation, hydration, carbonation and leaching by organic acids and water. Clay minerals are produced by chemical weathering. Soil obtained due to weathering may be residual or transported. Residual soils, which remain in place directly over the parent rock, are relatively shallow in depth. The deposits of the transported soils may be considerable in depth and their homogeneity or heterogeneity depends upon the manner of their transportation and deposition. The various agencies of transporting and redepositing soils are : water, ice, wind and gravity. Water-formed transported soils arc termed as alluvial, marine or lacustrine. All the material, picked up, mixed, disintegrated, transported and redeposited by glaciers either by ice or by water issuing from melting of glaciers, is termed glacial drill or simple drift. The glacial deposits in general consists of a heterogeneous mixture of rock fragments and soils of varying sizes and proportions and except the stratified drift deposited by glacial streams, are without any normal stratification. Dune sand and loss are the wind-blown (aeoline) deposits. Loess is the wind-blown silt or silty clay having little or no stratification. Soils transported by gravitational forces are termed colluvial soils, such as talus. The accumulation of decaying and chemically deposited vegetable matter under conditions of excessive moisture results in the formation of cumulous soils, such as peat and muck .

1.1.1 HISTORY OF DEVELOPMENT OF SOIL MECHANICS

The knowledge of the use of soil extends into prehistoric times, when man started constructing dwellings for living and roads for transportation. In the more primitive civilizations, soil was used by man as a construction material for foundations of structure and for the structures themselves. The knowledge of soils for the foundations, bunds and roads was gained by trial and error experiences. Through ancient times and even within the last few generations practically all improvement was the result of a continuously broadening by empirical knowledge. The use of both timber and stone caissons of soft-ground shaft construction was known in Egypt in 2000 BC. The cutting edge was made of a round limestone block with a vertical hole bored into its middle. The outside surface of the caisson was made smooth for reasons of reducing sinking resistance caused by friction. One of the greatest structures in ancient times was the famous 'hanging garden' built by the Babylonian King Nebuchadnezzar. The big retaining walls to support the terraces of the garden required some knowledge of earth pressures, even if the knowledge was empirical (Jumikis, 1962). The technical literature of the time during the Roman Empire supplies ample evidence that the Romans paid much attention to some properties of soils, and to the stability of foundations. The Romans built notable engineering structures, such as : harbors, moles, break-waters, aqueducts, bridges, large public buildings, sewage lines and a vast network of durable and excellent roads, requiring solutions of earth work and foundation design. The Roman engineer Vitruvius wrote his Ten books on Architecture sometimes in the first century tic discussing the stability of buildings, Vitruvius writes that " greatest care must be taken in the substructure, because, in these, immense damage is caused by the earth piled against them. For it cannot remain of the same weight as it usually has in the summer it swells in the winter by absorbing water from the rains. Consequently, by its weight and expansion it bursts and thrusts out the retaining wall" — (Jumikis, 1962). For foundations in loose or marshy land, he recommends the use of 'piles to be driven close together by machinery, and the intervals between them to be filled with charcoal.' In India also, Mansar, Mayamata, Visvakarma, Agastya, Santakumara, Mandana, Srikumara, etc. wrote books laying down rules of construction. Among these, Mansar's 'Silpa Sastre,' written sometimes in sixth or seventh century, became very popular. Mansar recommended compaction of soil by cows and oxen, and dewatering of foundations.

Many structures were built during the medieval period (about 400 to 1400 no). One of the main problems they had was about the compression of soil and the consequent settlement of buildings. During the past centuries, the compressible soil upon which heavy structures such as cathedrals etc. were built had enough time to consolidate, causing large settlements. The Leaning Tower of Pisa, constructed between 1174 to1350 AD, is one such example. In India, Taj Mahal was constructed between 1632 to1650 AD. It had unique foundation problems because of its proximity of the river Yamuna. The terrace and the mausoleum building, as well as the minarets, rest on one firm, compact bed of masonry, supported on masonry cylindrical wells sunk at close intervals. In the field of earth dams, the most notable example reported is that of Mudduk Masur dam in South India, of 33 m height, and built in 1500 no (On, 1969). In 1661, France undertook an extensive public works programme in improving the highways, and the building of canals. In the later part of the 17th century, French Military engineers contributed some empirical and analytical data pertaining to earth pressure on retaining walls for the design of revetments of fortifications. France established a Department of Roads and Bridges in 1715, and in 1747, the Famous Ecole des ponts et chausses was started. The first major contribution to the present scientific study of soil behaviour may be traced back towards the end of the eighteenth century, when Coulomb (1776), a Frenchman, published his wedge theory of earth pressure. Coulomb was the first to introduce the concept that shearing resistance of soil is composed of two components, namely, cohesion and friction. Poncelet (1788-1867), a famous geometer, extended Coulomb's theory, giving a graphical method of finding the magnitude of earth pressure on the wall, vertical as well as for inclined wall surface on the back fill side, and for arbitrary broken polygonal surfaces. K.Culmann (1866) gave the Coulomb-Poncelet theory a geometrical formulation. The earth pressure theory was elaborated by graphical analysis also by Rebhann (1871) and Weyrauch (1878). Two important laws—Darcy's law for flow of water through soils and Stoke's law for settlement of solid particles in liquid—were put forward in 1856. Even today, these laws play an important role in soil engineering. In 1857, Rankine presented his theory for calculating earth pressure and safe bearing capacity of foundation. Rankine and other workers of his time did not take cohesion of clay soil into calculations, although they knew its existence. Another important contribution in the nineteenth century was made by Boussinesq (1885) who gave his analysis for stress distribution in a semi-infinite, elastic medium under surface point loads. To test the earth pressure theories, Muller-Breslau (1906) performed some relatively extensive and elaborate experiments with a large scale model retaining wall. In 1871,0. Mohr gave a graphical representation of stress at a point, popularly known as Mohr's stress circle. In soil mechanics, Mohr's stress circles are extensively used in the analysis of the shearing strength of soils. It is only in the beginning of the twentieth century that the basic physical properties of soil in general were understood, and the work of Atterberg, a Swedish soil scientist, and that of the Geotechnical Commission of the Swedish Government under the chairmanship of Dr. Fellenius, in this direction arc remarkable. Atterberg was the first to propose in 1911 the different stages of consistency in which a clay soil may exist, depending upon its water content. To measure the shear strength of sand, shear box was probably first developed in France, by Leygue in about 1885. Later, it was improved by Krey (1918) in Germany, and Terzaghi and Casagrande in U.S.A. Resat (1910) and Bell (1915) are credited to have extended Rankine's analysis of earth pressure so as to include soil with both friction and cohesion. Bell also suggested a method of calculating the bearing capacity of cohesive soils. In 1916, Petterson and Hultin used the circular sliding theory with the so-called friction circle in stability calculations. This method was further developed by Fellenius in 1926, and is now known as the Swedish method of slope analysis. In 1913, the Swedish Geotechnical Commission was appointed, with Fellenius as its chairman. In 1920, L. Praridtl gave his theory of plastic equilibrium, which forms the basis of various bearing capacity theories developed later. Dr. Terzaghi published his theory of consolidation in 1923 and the term Soil Mechanics was coined by him in 1925 when his book under the equivalent German title Erdbaumechanik was published. Dr. Teaaghi's contributions in the field of soil engineering have been immense and he is fittingly called the 'Father of Soil Mechanics'. Another important contribution made recently (1933) is that of Proctor on the principles of soil compaction. In 1922-23 Pavlovsky in Russia solved the complex problems of seepage below the hydraulic structures, and gave the electrical analogy method for the seepage computations. However, since his work was in Russian language, it remained unknown to the English literature till 1933, Weaver (1934) and Khosla (1936) solved some of the seepage problems independently. During World War II (1939-45) and after, a great impetus to the development of soil engineering has been made by various scientists and engineers of different countries of the World, and today it is recognised as a well-established branch of engineering. Several International conferences on Soil Mechanics and Foundation Engineering have been held till now under the auspices of International

Society of Soil Mechanics and Foundation Engineering such as at Harvard (Massachusetts, U.S.A.) 1936, Rotterdam (Netherlands) 1948, Zurich (Switzerland) 1953, London (U.K.) 1957, Paris (France) 1961, Montreal (Canada) 1965, Mexico city (Mexico) 1969, Moscow (U.S.S.R.) 1973, Tokyo (Japan) 1977, Stockholm (Sweden) 1981, San Fransisco (U.SA) 1985, Riode Jeneiro (Brazil) 1989, New Delhi (India) 1994, etc.

1.1.2 FIELD OF SOIL MECHANICS

The field of soil mechanics is very vast. The civil engineer has many diverse and important encounters with soil. Apart from the testing and classification of various types of soils in order to determine its physical properties, the knowledge of soil mechanics is particularly helpful in the following problems in civil engineering.

1. Foundation design and construction. Foundation is an important element of all civil engineering structures. Every structure — building, bridge, highway, tunnel, canal or dam — is founded in or on the surface of the earth. It is, therefore, necessary to know the bearing capacity of the soil, the pattern of stress distribution in the soil beneath the loaded area, the probable settlement of the foundation, effect of groundwater and the effect of vibrations, etc. The suitability of various types of foundations — i.e.. spread foundation, pile foundation, well foundation, etc. — depend upon the type of soil strata, the magnitude of loads and groundwater conditions. A knowledge of shrinkage and swelling characteristics of soil beneath the foundation is also very essential.

2. Pavement design. A pavement can either be flexible or rigid, and its performance depends upon the subsoil on which it rests. The thickness of a pavement and its component parts, depends upon some certain characteristics of the subsoil, which should be determined before the design is made. On busy pavements, where the intensity of traffic is very high, the effect of repetition of loading and the consequent fatigue failure has to be taken into account. Apart from these, other problems of pavement design are : frost, heave and thaw with their associated problems of frost damage to pavements ; frost penetration depth ; remedial measures to prevent frost damage ; problems of 'pumping' of clay subsoils and suitability of a soil as a construction material for building highways or railways, earth fills or cuts, etc.

Knowledge of the techniques for the improvement of the soil properties such as strength and stability is very much helpful in constructing pavements on poor soils by stabilising them.

3. Design of underground structures and earth retaining structures. The design and construction of underground (subterranean) and earth retaining structures constitute an important phase of engineering. The examples of underground structures include tunnels, underground buildings, drainage structures and pipelines. The examples of earth retaining structures are: gravity retaining wall, anchored bulk heads and cofferdams. Knowledge of soil structure interaction is essential to design properly such structures subjected to soil loadings.

4. Design of embankments and excavations. When the surface of the soil structure is not horizontal, the component of gravity tends to move the soil downward, and may disturb the stability of the earth structure. A thorough knowledge of shear-strength and related properties of soil is essential to design the slope and height (or depth) of the embankment (or excavation). The possibility of the seeping groundwater reducing the soil strength while excavating must also be taken into account. It may sometimes be essential to drain the subsoil water, to increase the soil strength and to reduce the seepage forces. Deep excavations require lateral braces and sheet walls to prevent caving in.

5. **Design of earth dams**. The construction of an earth dam requires a very thorough knowledge of whole of the Soil Mechanics. Since soil is used as the only construction material in an earth dam, which may either be homogeneous or of composite section, its design involves the determination of the following physical properties of soil : index properties such as density, plasticity characteristics and specific gravity, particle size distribution and gradation of the soil; permeability, consolidation and compaction characteristics, and shear strength parameters under various drainage conditions. Since huge earth mass is involved in its construction, suitable soil survey to the nearby area may be essential for the borrow-pit area. The determination of the optimum water content at which maximum density will be obtained on compaction, is probably the most essential aspect of the design. Apart from the seepage, characteristics of the dam section must be thoroughly investigated since these have the greatest impact on the stability of the slopes as well as the foundations of the dam. The consolidation characteristics help in predicting the long range behaviour of the dam toward settlement and the consequent reduction in the pore pressure. Lastly, the possible effect of vibrations during an earthquake should also be taken into account while designing.

The performance of the soil in the designs cited above depends upon the characteristics of soil. Therefore, the testing of soil with relation to the determination of its physical properties, and the evaluation of effects of certain other factors such as seepage conditions, etc. forms the most essential part of the development of soil engineering. It is through research only that design and construction methods are modified to give maximum safety and/or economy, and new methods are evolved. The knowledge of theoretical soil mechanics, assuming the soil to be an ideal elastic isotropic and homogeneous material, helps in predicting the behaviour of the soil in the field.

1.1.3.SOIL:

The term 'Soil' has various meaning, depending meanings, depending upon the generalprofessional field him which it is being considered.

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2) To the Geologist: Soil is the material in the relatively than surface zone within which roots occur, and all the rest of the cruet is grouped under the term Rock irrespective of its hardness.

3) To an Engineer:- Soil is the unaggregated or uncommented deposits of the of mineral and organic particles or fragments convening Large portion of the earth's crust.

Different materials are

Boulders Sands Gravels	-	Coarse grained soils
Clays, Silts	-	Fine grained Soils

Range: - Particle sizes from micron (10^{-4} cm) in diameter up to layer size boulders

1.1.4. SOIL ENGINEERING:-

Soil Mechanics (or) Geotechnique

It is of the youngest discipline of civil engineering involving the study of soil, its behaviour and application as an engineering material.

According to Terazaghi (1948):-

Soil Mechanics is the application of lawn of Mechanics and hydraulics to engineering problems dealing with sediment and other unconsolidated accumulations of solid particles produced by the mechanical and chemical disintegration of rock which may or not they contain organicconstituent.

Foundation Engineering:-

It is a branch of civil Engineering which is associated with the design, construction, maintenance and renovation of toothily. Foundation walls, file foundation caimans and all other structures members which from the foundations of buildings and other engineering structures.