Soil in action

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Earthwork forms the largest activity of a Civil Engineer. All structures, buildings, highways, bridge abutments, piers, industrial structures, and the like, have to have their foundations resting on soil. Besides this, a large amount of earth work is involved in the construction of earth retaining and earthen structures like earth dams, earth and rock fill dams, embankments and retaining walls. Highways, hill roads, tunnelling for various purposes including metros and buried oil pipelines deal with the handling of a large quantity of soils of various types. Thus soil has been used as foundation/supporting medium and as a construction material since the earliest days of recorded history. By the time scientific and rational methods became generally recognized as a fruitful approach to the solution of engineering problems; monumental buildings, bridges, dams, canals and roads had not only been built, but the same had served their useful purpose for many centuries. Therefore, it was inevitable that Soil Mechanics and Foundation Engineering, now called Geotechnical Engineering developed primarily as an art steeped in tradition and empirical practices based on earlier successful accomplishment until Karl Terzaghi (1883–1963) an engineering teacher in Constantinople, later in Harvard University, began some laboratory experiments on sand to discover the nature and the laws of its internal friction and volume changes under load. His searching studies on sand and clay reached a stage where the results began to group themselves into a full and highly enlightening explanation of how both plastic and granular soils behave.

From 1930 to 1970, four decades saw the development of Soil Mechanics and Foundation Engineering as a full fledged branch of Civil Engineering based on a rational basis and understanding of the behaviour of soil under stress. Terzaghi's 'Effective Stress Concept' formed the basis of 'stress definition' to be used to analyse any problem dealing with soil under stress. Laboratory methods have been fully standardized to characterize the soil depending upon the nature of the problem in the field.

The basic understanding of the behaviour of soil under stress as dictated by field drainage conditions brought a significant development in earth dam construction, the scenario changing from concrete/masonry as construction materials for a dam, to soil as a construction material. This is primarily due to significant developments in material testing procedures in the laboratories dictated by sound theoretical considerations. In the present scenario, most of the large dams of height more than 1000 feet (300 m) are being constructed with earth and rock as material in view of the large reduction in cost. Economical dam construction with soil and rock as materials to tackle the seasonal floods is of tremendous practical significance and has significant scope for further work. With the development of new synthetic materials that are available at competitive rates, the scope for use of the same as core material opens up challenging new research areas. Any breakthrough in this development will not only reduce the overall cost but also increase the safety factor. Similar scope exists for the use of drainage materials synthetically developed as toe drain materials. These developments will not only economize the project costs but will also improve the quality of the design with a reduced section. There is a significant development in the production of construction equipment opening up the possibility of achieving good compaction of soils and rock, which will further reduce the overall cost. Thus the scope of further research for more and more use of soil and rock in dam construction will be tremendous.

With the advent of 'earth reinforcement' technique using steel and other synthetic materials as reinforcement, the limitation that soil under tension is weak has been overcome. Typical reinforced earth or soil structures are retaining walls, embankments, nailed slopes, sub-grades beneath pavements, etc. There has been tremendous development in building reinforced earth structures with optimum size leading to substantial economy and space saving. This technique is being used extensively in big cities as a part of abutments for flyovers. Embankments could be constructed with this technique with side slopes almost vertical. Embankments resting on soft soils are now feasible by reinforcing

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the soft material with proper use of geosynthetic materials. With the cost of land escalating phenomenally in big cities, tall buildings with more than one basement are being planned and executed. This requires deep vertical excavations to even ten to twenty meters of depth, under difficult groundwater conditions. 'Nailing technique', i.e. inserting steel rods into the vertically excavated surface to a large length is being adopted very successfully in not only carrying out deep excavations but also taking care of the safety of adjoining buildings. Earth reinforcing technique is of recent origin and the scope for further research is plentiful, especially with modern computing facilities to rationalize many design procedures.

The composition of soils in terms of their mineralogy and pore fluid characteristics and the interaction of these phases with each other and the surrounding environment has led to the development of 'Environmental Geotechnology'. Urbanization, industrialization and the developments in modern lifestyle have contributed to the generation of large quantities of wastes, some inert, some biodegradable, some toxic and hazardous. The need for sensible disposal of these wastes through the ground has created new demands on geotechnical engineers. Waste containment in landfills and contaminated sites has become the responsibility of geotechnical engineers. Active scope for research exists in the areas of liner materials, viz. compacted clay liners, geo-membranes, geo-synthetic clay liners, soil/geo-textile filters, bentonite backfills, etc. The rational understanding of 'clay behaviour' has led to the potential use of the same as 'clay liners' for 'land fills' thereby safeguarding the groundwater against pollution. Design of landfills in which compacted soil is being used as liner material is enlarging the scope for active research in flow of contaminants through advection, dispersion and diffusion including research in contaminant transport modelling. Active research is in progress in several places for the use of the 'compacted clay barriers' to tackle nuclear waste disposal problems.

Low lands defined as lands affected by fluctuating water levels exist all over the world. Many coastal belts, notably in India, Bangladesh, Japan, Korea, Sri Lanka, The Netherlands, etc. are just at, or below mean sea level and get submerged during most or some part of the year. The submergence of coastal low lands would be further aggravated by the rise in sea level due to global warming. Further, coastal areas are vulnerable to killer waves (tsunamis) requiring many preventive measures to be taken. Humans settle in large numbers in the coastal areas creating further problems. In all of the above, the geotechnical/soil engineers have a notable role to play in developing suitable methods/techniques to improve the ground for effective use. The use of soil reinforcement technique in reclamation of soft ground in low-lying areas has significant scope for further research work.

With the recent occurrence of earthquakes in India and other parts of the world, zoning of different parts of the country has been redefined to a larger risk factor, with the result that Earthquake Geotechnical Engineering has assumed greater importance.

Geotechnical engineers have to tackle a wide range of problems, viz. establishing design ground motions, the seismic design of foundations, analysis of soil–structure interaction, evaluation of liquefaction potential, seismic response analysis of earth structures, post-liquefaction behaviour of earth structures, evaluating the design of remediation measures and seismic risk analysis of critical facilities like foundations of nuclear power stations, earth dams, etc. The state-of-the-art technology on many of these issues is much below satisfactory level, and the geotechnical engineers have to rise up to the desired level with rationalized procedures.

Geotechnical engineering has become a sound interdisciplinary applied science dealing with several problems of practical significance and national importance. Geotechnical engineering practice has expanded far beyond the traditional areas of soil mechanics and foundation engineering to include effective protection of environment against man-made pollution caused by all kinds of waste fills and waste heaps, abandoned industrial sites with contaminated ground and underground water. More and more reclaimed areas come under use. Industrial and infrastructure growth has taken place without the consideration of whether the land is suitable or not. Suitable ground improvement techniques need to be developed to tackle different and difficult natural ground situations. The future growth of this subject depends primarily on field-oriented research supported by laboratory experiments and rational design procedures and computer modelling techniques.

But for the rational developments in Geotechnical Engineering we could not have saved the LEANING TOWER OF PISA (The leaning tower of Pisa was heading towards collapse in 1992, five meters out of perpendicular (5.5 degrees of tilt). Recently (2001) the structure has been brought back to its status as of 300 years ago, after 10 years of hard remedial work).

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