CHAPTER - VI

SUMMARY & CONCLUDING REMARKS

6.1 GENERAL

Uninterrupted exploitation of natural resources and the exploding population have resulted in degradation of quality of life in general. To meet the necessities of expanding millions, it became a necessity to produce more. As a consequence, rapid industrialization has become imperative. Industrial activity is necessary for the socio-economic progress of the country. Setting up of industries without proper waste treatment and disposal plants, especially in developing countries, are causing irreparable damage to the environment. In the recent years environmental pollution control boards have imposed restriction on disposal of wastes in rivers to prevent pollution because river water is most commonly used for human consumption. To escape from these restrictions, which require costly treatment of waste water there is a tendency to dispose of waste water on ground.

Soil is a major reservoir for contaminants as it possesses an ability to bind various chemicals. These chemicals can exist in various forms in soil and different forces keep them bound to soil particles. It is essential to study these interactions because the toxicity of chemicals may strongly depend on the form in which they exist in the environment. Another thing is that soil variability and some environmental properties (e.g. climate factors) may change equilibrium found in soil and cause leaching of trace toxic elements like heavy metals tightly bound to soil particles. A number of models are being developed now which can quantitatively predict movements and sorption of heavy metals in soil with good accuracy. However, investigations for determining chemical properties of soil, heavy metal interactions, should continue because a lot of questions about this strongly heterogenic matrix are still not answered. The cardinal aim of the present study is to understand the complex phenomenon of contaminant migration through soils and also the environmental and geotechnical aspects of interaction behaviour of chemicals normally found in the industrial wastes in surrounding factories of Tirupati town in Chittoor district.
The present investigation deals with an experimental programme on the interaction behaviour of regional soils with various liquid limits in conjunction with the chemical constituents normally found in the effluent of plating industry. From the present study, the following concluding remarks may be made.

6.2 GEOTECHNICAL ASPECTS OF INTERACTION BEHAVIOR OF CHEMICALS

- The studies carried out on soil-fluid interaction behaviour in compacted state are very few.
- Leaching of chemical constituents has been noticed in contrary to the attenuation.
- Calcium is attenuated to a greater degree by all soils.
- Iron and sodium are leached out of all soils.
- When mixed spiked solution is permeated, sodium, iron and zinc have been leached out whereas chromium and calcium showed indications of being attenuated by soils.
- Attenuation of chemical constituents with trivalent and divalent has been noticed to be more significant than mono-valent when mono solution has been permeated.
- Attenuation of chemical constituents of chromium and calcium has taken preference to sodium, iron and zinc when mixed spiked solution has been permeated.
- Attenuation has been noticed to be proportional to liquid limit.
- Leaching is inversely proportional to liquid limit.
- When leaching occurred, compression was steep and co-efficient of volume change increased and when attenuation has occurred, there is no significant change in these values.
The comprehensive study undertaken to understand the basic properties of soils when interacting with water and with chemical contaminants permit the following specific remarks to be brought out. The soils considered are classified as SC to CH as per IS 1498. The plasticity index ranging from 10-41. The fine fraction ranges from 20-90 and the degree of expansion is of the order of 30%, which falls under low degree of swelling as per IS 1498-1970. The gradation curves are also seen to be distantly placed bringing out inherent variation in texture of the soils.

6.2.1 Consistency Limits

The Atterberg consistency limits of soils are used for the purpose of classification of cohesive soil materials for engineering purposes. The Atterberg limits are widely related to the shear strength, bearing capacity, compressibility, swelling potential and specific surface of soils. The plastic limits assume a lot of importance to obtain information on soil mechanical behavior. Despite experimental evidence of the relationship between soil consistency and soil compressibility, the plastic limits are not used in soil compaction research to the same extent as they are used in foundation engineering. Accordingly, an attempt has been made to correlate the consistency limits to the compaction behavior.

- The soil samples mixed with different concentrations of chemical pollutants are located above A-line.
- This indicates that the soil samples remain clayey despite interaction with the chemical constituents tested.
- The plasticity Index is found to be proportional to the respective liquid limit and linear with a correlation coefficient of 0.98.
- It is of interest to note that the samples are located above A-line and parallel to A-line when data are plotted on Modified Liquid Limit and Modified Plasticity Index axes.
- This turns out that the Modified Liquid Limit is proportional to Modified Plasticity Index.
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• The liquid limit ratios, as reported before, show that the value is sensitive in general to the interaction behaviour of chemicals but more sensitive to certain chemicals in particular.

6.2.2 Strength Characteristics

Undrained shear strength is one of the useful parameters in order to take engineering decisions. Most often the bearing capacity is estimated based on undrained shear strength to make conservative estimates. Some laboratory tests needed to obtain these values are expensive and time consuming, while soil properties like moisture content and Atterberg limits can be performed faster and cheaper. Many empirical formulae are available to estimate the undrained shear strength for fine grained soils like clay or silt. Determining of undrained shear strength and compressibility parameters in laboratory are really tedious and time consuming. Therefore, a correlation between undrained shear strength and Atterberg limits is useful for restraint of testing number and costs. However, a limited effort is made to understand weather such a relationship is possible in case of local soils.

The un-drained strength has a relationship with the plasticity index in that the strength decreases as plasticity index increases. This turns out the consistency limits have influence on strength characteristics
6.2.3 Compaction Characteristics

The compaction characteristics, if related to basic properties, the resultant relationships are useful in providing independent means of checking the test results and for use by practicing engineers in making preliminary estimates. It may be observed that the compaction characteristics are dependent on pore fluid. The variation in OMC is dependent on modified plasticity index. The rate of increase of density with molding pore fluid is flatter before dry side of optimum and the decrease in density is relatively rapid on the wet side of optimum. The rate of increase of density with molding pore fluid is flatter before dry side of optimum and the decrease in density is relatively rapid on the wet side of optimum. Because of variation of Specific Gravity, grain size distribution, the density seems to vary considerably. The compaction curves are distantly placed indicating that the Maximum Dry Density changes as Modified Plasticity Index.

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6.2.4 Surface Morphology

The test results of Electron Dispersive Spectroscopy (EDS) and Scanning Electron Microscope reinforce the observation made with respect to basic characteristics.

- Iron is seen to leach and calcium to attenuate in most of soil samples tested. With introduction of Chromium, Sodium and Zinc, it is found that sodium is leached and Chromium is attenuated where as Zinc attenuated or leached as the case may be depending on the type of soil.
Therefore, the liquid limit value plays an important role in characterising the behaviour of soils in terms of permeability, strength and. This property clearly indicates the probable effect of pollutant migration through soils.

6.3 SOLUTE TRANSPORT

6.3.1 Permeability

The permeability is directly proportional to void ratio.

The void ratio is a function of modified plasticity index which changes with the pore fluid. Normalized relation of void ratio with permeability is obtained as:

\[ \frac{e}{e_l} = 0.116 \ln(k) + 2.14 \]

6.3.2 Other Interrelationships

The compaction test results are re-plotted on modified plasticity Index and optimum moisture content and maximum dry density and modified plasticity index as shown in figures 5.8& 5.9. It may be observed that the optimum moisture content increases with the plasticity index and maximum dry density decreases with the modified plastic index. The following relationships are obtained.

\[ OMC = 0.233 \times MPI + 8.00 \]  
with a regression coefficient of 0.9790

\[ \gamma_{d(\text{Max})} = -0.033 \times MPI + 18.36 \]  
with a regression coefficient of 0.9726

The following observations may be made based on the computed results.

- The time taken by each solute is different based on the interaction behaviour exhibited by each chemical with the soil.

- The chemical composition of soil and the types of solutes play key role in the pollutant transfer.
6.3.3 Step wise Procedure to Estimate the Solute Transport

The basic properties are determined in any routine soil investigation to obtain liquid limit, particle size distribution.

The modified plasticity index can be determined as

\[ MPI = PI \times \text{percent passing 425 micron sieve size} \]

The optimum moisture content can be estimated from the following expression

\[ OMC = 0.233MPI + 8.00 \]

The maximum dry density can be obtained from the relationship as given below:

\[ \gamma_{d(\text{Max})} = -0.033MPI + 18.36 \]

The void ratio \( e \), and void ratio at liquid limit \( e_l \) can be obtained in routine calculations as

\[ e = \frac{G\gamma_w}{\gamma_d} \quad \& \quad e_l = w_l G \]

For one meter distance under unithydraulic gradient, time taken for the solute to migrate is given by

\[ \frac{e}{e_l} = 0.116 \ln(k) + 2.14 \]