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Prediction of Behaviour of Natural Soils Versus Artificial Filled Up Soils

Based On Compaction Parameters and Effect of Permeability in Summer Storage Tanks

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Abstract*— This journal paper deals with the behavior of soil properties. The test done on sample gives important and main parameter that is optimum moisture content is obtained by COMPACTION test. This optimum moisture content is the guiding parameter for assessment of maximum dry density and for obtaining many other tests results. For prediction of behavior of soil, the permeability tests, constant head method and falling head method are important. Factors affecting this property are classified based on the standard formula. This permeability plays a major role in the failure of SUMMER STORAGE TANKS. For control of permeability, types of failures and causes are important. New methods are suggested by implementation of new materials like GEO-SYNTHETICS will reduce the permeability of the soil.

***Keywords*— (Optimum moisture content, Compaction test, Maximum dry density, Permeability, Summer storage tanks.)**

I. Introduction

Soil is a heterogeneous, multiphase, disperse and porous system. Soil is formed in place or deposited by various forces of nature such as glaciers, wind, lakes and rivers residually or organically. Description of soil is a statement describing the physical nature and state of the soil. It can be a description of a sample, or a soil in situ. It is arrived at using visual examination, observation of site conditions, geological history etc. Soil classification is the separation of soil into classes or groups each having similar characteristics and potentially similar behavior. Soil particles are mainly weathered rock particles. These particles are classified according to their diameters. According to Indian standard classification, Clay < 0.002 mm, Silt 0.002 - 0.075 mm, Fine Sand 0.075 - 0.425 mm, Medium sand 0.425 - 2mm, Coarse Sand 2 - 4.75 mm, Gravel 4.75 - 80mm, Fine gravel 4.75 - 20mm, Coarse gravel 20 -80mm, Cobble 80 - 300mm, Boulder > 300mm.

II. MATERIAL COLLECTION

For this research, soil samples are collected from three different villages in Guntur district. All these villages are constructed with summer storage tanks, which is the main source of water in summer. The sample sites are in Nijampatnam, Inkollu and Jillelamudi. Samples have been extracted after from the proposed soil which is used to construct the walls of the summer storage tank. All the samples are clay. The maps are shown below which specifes the site location. To reduce the permeability of the sample soils, Geo-membranes which is an impermeable membrane is used. Membrane and its specification are bought from Ayyapa suppliers from Visakhapatnam.

FIG.1 Sites sample location

III. THEORY

The paper completely deals with the comparison of behavior of natural soils and artificially filled up soils. Natural soils are the soils available in any area, which formed naturally but not by the means of human or machines process. Artificially filled up soils are the soils filled in an area by means of human or machines, the filled soils are natural soils of other sites. Due to transportation, all properties of soils slightly change.

The change in the properties of soils results in few failures after using them in any earthen structures like summer storage tanks, retaining walls, earthen dams, etc. Mainly cohesive soils are used in these soils. The most common failures encountered in natural soils are of two types. They are structural failures and seepage failures. Main structural failures can be due to change in density of the soil transported. Seepage failures are due to change in coefficient of permeability of used soils in the site. The seepage failures are common in summer storage tanks. This became a challenging task to civil engineers.

A. *Summer storage tanks:*

The catchment area surrounded by high soil bunds constructed to store the water for summer season in that area

B. *Types of failures of the summer storage tanks*

- Toe failure, in which the failure occurs along the surface that passes through toe. Toe failures are most common.
- The slope failure is the failure occurs along a surface that intersects the slope above the toe.
- The failure surface passes below the toe. Base failure occurs when a weak stratum lies beneath the toe.

C. *Causes of failures:*

- Bearing capacity of the soil decreases due to decay of organic matter in the soil.
- Bund height is more due to the terrain condition. Due to this the maximum stresses were induced in the soils which were unable to counter by the existing organic soil and hence excessive settlement yielded and ultimately caused a slope failure.
- There were an old drain passing in the failure zone of the bund, during the due course of time the is drain is filled with the soil(weak or any type of soil) and due to passage of the drain that induces some organic matter content in the soil which leads to failure.
- The failure does not take immediately after construction because the soil containing organic matter requires time to decay or decompose.
- Since the soil is decayed over a period of time completely, the bund has failed second time also as the decayed soil was not identified and removed.

So as to reduce the above stated failures, GEO-MEMBRANES which are one among the GEO-SYNTHETICS are selected. GEO-MEMBRANES are stiff and impermeable. Most of them are available in different thickness; they are 0.5, 0.75, 1.0, 1.5, 2.0, 2.5, and 3.0. The different properties of GEO-MEMBRANES are given in the below table (Test methods are based on ASTM).

Property	Test method	Unit	Test value						
Thickness	D 5199	mm	0.50	0.75	1.00	1.50	2.00	2.50	3.00
Density (min)	D 1505	g/cm³	0.94	0.94	0.94	0.94	0.94	0.94	0.94
Yield strength	D 638 IV	kN/m	9	13	17	26	34	43	50
Break strength	D 638 IV	kN/m	14	21	28	43	57	71	85
Yield elongation	D 638 IV	%	14	14	14	14	14	14	14
Break elongation	D 638 IV	%	750	750	750	750	750	750	750
Tear resistance	D 1004	N	70	110	155	213	290	376	465
Stress crack resistance	D 5397	Hr	300	300	300	300	300	300	300

Table.1 Properties of GEO-MEMBRANES

D. *Engineering properties of GEO-SYNTHETICS and experimental Methods:*

- **Tensile strength BS EN ISO 10319** (replacing BS6906 Part 1): A sample is clamped between two jaws and strained at a constant rate until failure. Maximum load and extension are recorded.
- **Characteristic opening size: BS EN ISO 12956** (replacing BS6906 Part 2): A sample is placed in a sieve shaker (as used for soil particle size analysis). 0-90 graded sand is flushed through the geo-synthetics using water.
- **Water flow or permeability: BS EN ISO 11058** (replacing BS6906 Part 3). The rate at which water flows through the geo-synthetics at a 100mm hydraulic head is measured and quoted in liters per square meter per second.
- **CBR puncture resistance: BS EN ISO 12236** (Replacing BS6906 Part 4). A sample is clamped in a ring and a 50mm diameter plunger is pushed against the Centre of the sample extending it until failure. Maximum load and plunger displacement are recorded.
- **Tensile creep: BS EN ISO 13431** (Replacing BS6906 Part 5). Very rarely used and only where soil reinforcement is involved

- **Cone Drop Perforation: BS EN 13433** (Replacing BS6906 Part 6). A sample is clamped in a ring and a 45" cone allowed to free fall half a meter on to it. The diameter of any resulting perforation is measured.
- **In-plane flow capacity: BS EN ISO 12958** (Replacing BS6906 Part 7). This is not often used. It measures the water flow within the plane of the sample under various reassures and hydraulic gradients.
- **Shear resistance: BS EN ISO 12957-1** (Replacing BS6906 Part 8). Again very rarely used. Shear characteristics are measured in a 300mm box with the sample fixed to one half.

E. GEO-MEMBRANE features:

- Excellent physical and mechanical performance.
- High tearing resistance.
- Good deformation adaptability.
- High puncture resistance.
- High aging resistance.
- High UV resistance.
- Anti-acid& alkali.
- Excellent low & high temperature resistance.
- Innocuous, long life span.
- Perfect water proof performance.

F. GEO-MEMBRANE Applications:

- As liners for secondary containment of underground storage tanks.
- As liners for solar ponds.
- As liners for water conveyance canals.
- As floating reservoirs for seepage control.
- To prevent infiltration of water in sensitive areas.

G. Placement of GEO-MEMBRANE in summer storage tank:

This placement is done in five basic steps. They briefly explained as follows:

- **First step:** Soil is has to be excavated, after excavation compaction has to be done over the soil to obtain the level ground.
- **Second step:** GEO-MEMBRANE has to be placed evenly over the soil surface without any folds. The membrane may be slightly compacted or pressed for bonding purpose.
- **Third step:** The layer of GEO-MEMBRANE is covered with hard soil or medium dense soil. To prevent erosion of soil we can advise bed pitching or lining on bunds.
- **Fourth step:** Finally, compaction is done evenly over the top surface for good bonding between the membrane and the soil particles.

H. Experimentation with the implementation of GEO-MEMBRANE:

- By the influence of above properties of GEO-MEMBRANE, permeability tests are conducted with it.
- According to availability and required characteristics 2mm thick GEO-MEMBRANE is used in experiments.
- GEO-MEMBRANE of 10cm diameter is placed in the permeability mold along with soil sample.
- GEO-MEMBRANE is compacted along with the soil and permeability experiment has been done.

IV. EXPERIMENTAL PROGRAMS

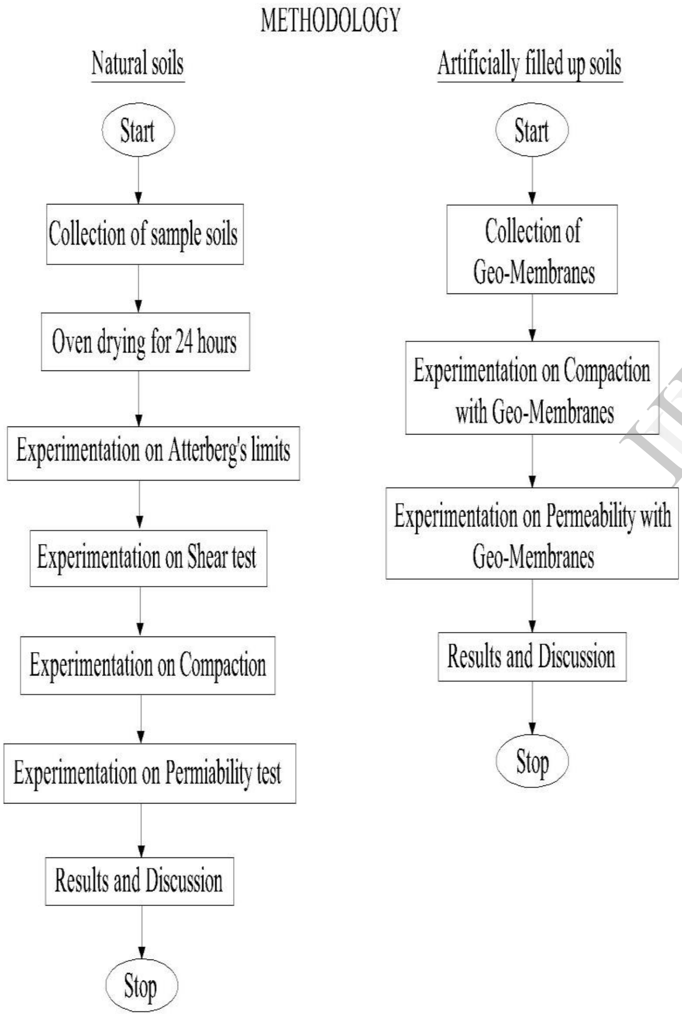
All the three soil samples are brought to laboratory and tested with basic and required tests in the following order,

1. Atterberg's limits
   a. Liquid limit
   b. Plastic limit
   c. Shrinkage limit
2. Specific gravity tests
3. Direct shear test
4. Compaction test
5. Permeability tests
   a. Constant head method
   b. Falling head method.

Fig.2 Permeability apparatus.

Fig.3 Compaction apparatus

Fig.3 Liquid limit apparatus



V. EXPERIMENTAL VALUES RESULTS FOR NATURAL SOILS:

A. NIZAMPATNAM SOIL SAMPLE:

1. Liquid limit:

Table 2: Liquid limit table

CASAGRANDE'S METHOD					
1	Number of blows	45	32	28	23
2	Water content (%)	55	57	59	61

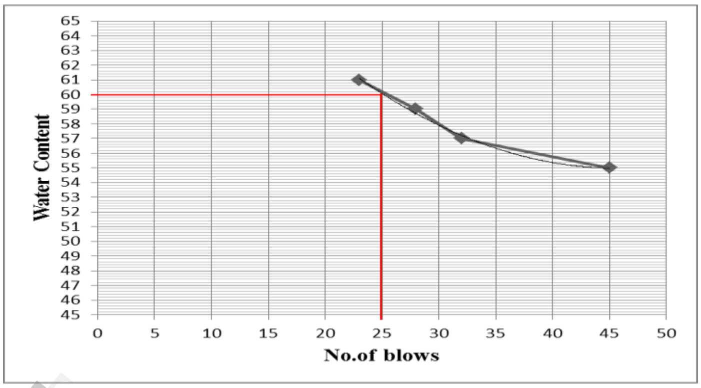


Chart.1: Graph representing L.L of soil sample

- Liquid limit for the soil sample is 60%

2. Plastic limit of soil sample is 22.22%.
3. Shrinkage limit of soil sample is 13.63%.
4. Shear strength:

Table.3: Shear strength tabulation

Normal stress	Shear stress
0.102	0.207
0.208	0.339
0.316	0.544
0.428	0.648

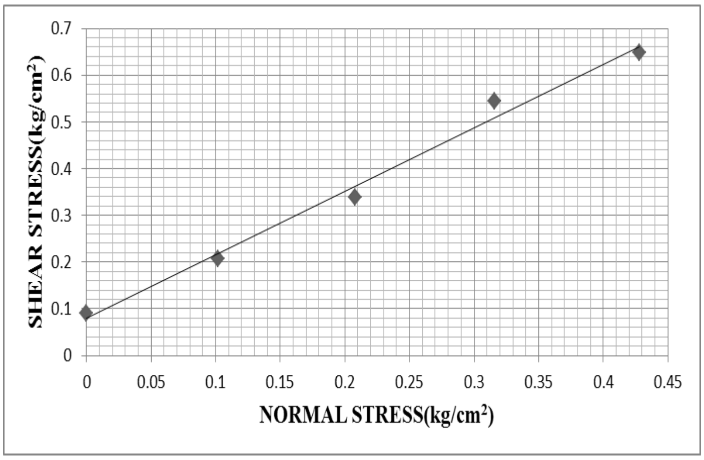


Chart.2: Graph representing Shear strength of soil sample

- Shear strength for soil sample is 0.165 kg/cm^2.

5. Compaction parameters:

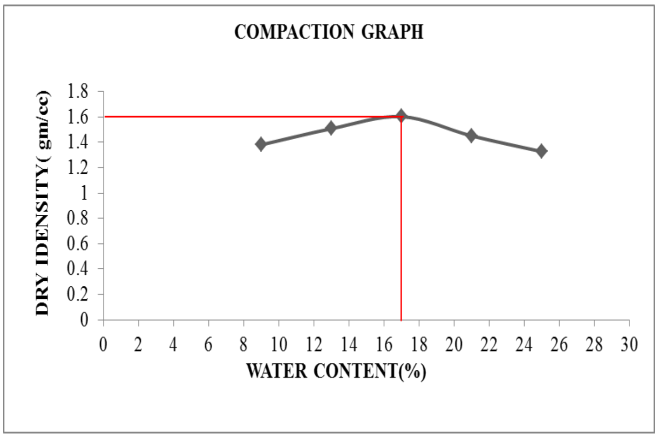


Chart.3: Graph representing OMC and MDD of soil sample

- Maximum dry density of soil is 1.6 gm/cc.
- Optimum moisture content of soil is 17 %.

6. Permeability parameter:
   - Coefficient of permeability based on Constant head method of soil sample is $6.74*10^{-4}$cm/sec.
   - Coefficient of permeability based on falling head method of soil sample is $7.098*10^{-6}$cm/sec.

B. INKOLLU SOIL SAMPLE

1. Liquid limit:
   Table.4: Liquid limit table

CASAGRANDE'S METHOD					
1	Number of blows	42	37	22	17
2	Water content (%)	44	48	52	56

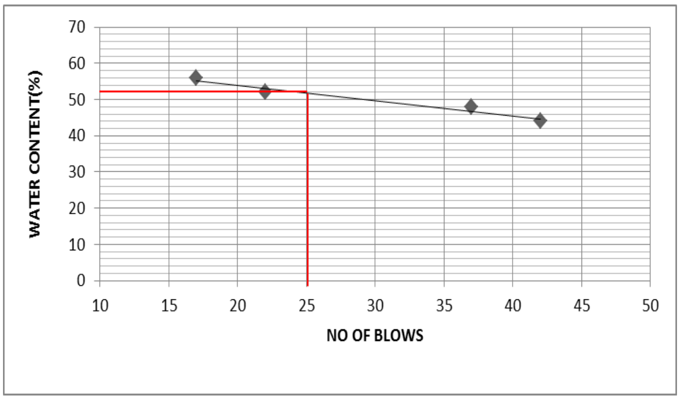


Chart.4: Graph representing LL of soil sample

- Liquid limit soil sample is 51%.

2. The plastic limit of soil sample is 20%.
3. The shrinkage limit of soil sample is 16.67 %.

4. Shear strength:
   Table.5: Shear strength table

NORMAL STRESS	SHEAR STRESS
0.110	0.447
0.224	0.566
0.339	0.737
0.456	0.794

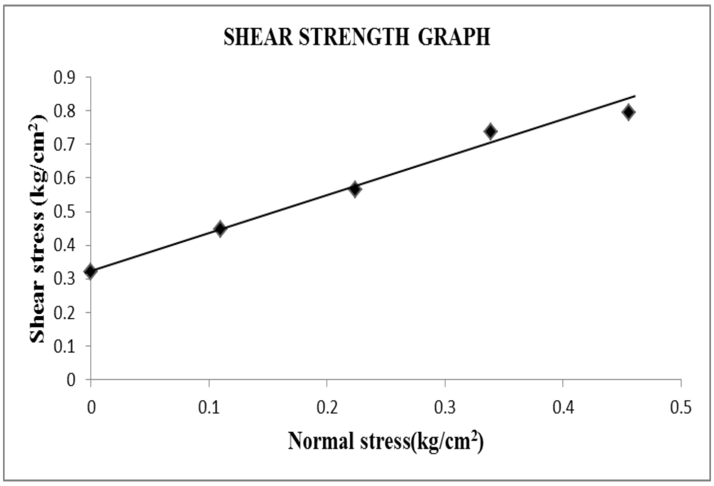


Chart.5: Graph representing Shear strength of soil sample

- Shear strength of soil sample is 0.422 kg/cm^2.

5. Compaction parameters:

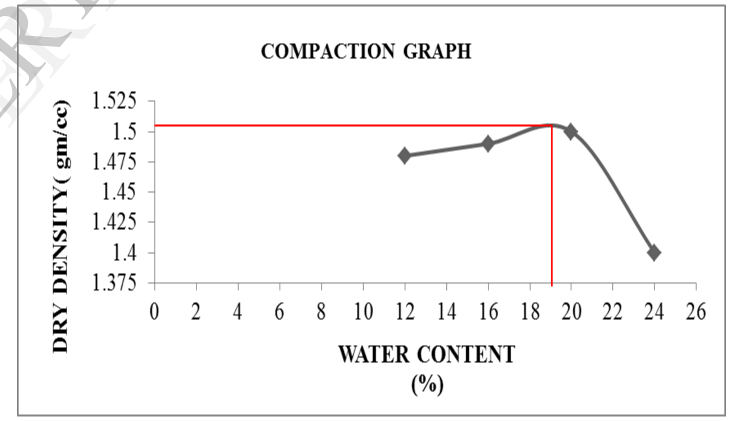


Chart.6: Graph representing OMC and MDD of soil sample

- Maximum dry density of soil is 1.5gm/cc.
- Optimum moisture content of soil is 19%.

6. Permeability Parameter:
   - Coefficient of permeability based on Constant head method of soil sample is $3.702 *10^{-4}$cm/sec.
   - Coefficient of permeability based on falling head method of soil sample is $5.645*10^{-6}$cm/sec.

C. JILLELLAMUDI SOIL SAMPLE

1. Liquid limit:
   Table.6: Liquid limit table

CASAGRANDE'S METHOD					
1	Number of blows	40	30	18	10
2	Water content (%)	50	53	56	59

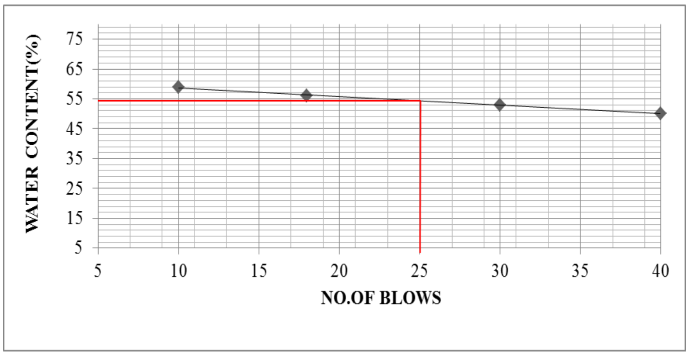


Chart.7: Graph representing LL of soil sample.

- Liquid limit of soil sample is 53%.

2. The plastic limit of soil sample is 25%.

3. The Shrinkage limit of soil sample 11.1%.

4. Shear strength:
   Table.7: Shear Strength table

NORMAL STRESS	SHEAR STRESS
0.108	0.656
0.217	0.807
0.330	0.939
0.108	0.656

- Shear strength of soil sample is 0.694 kg/cm ^{2}.

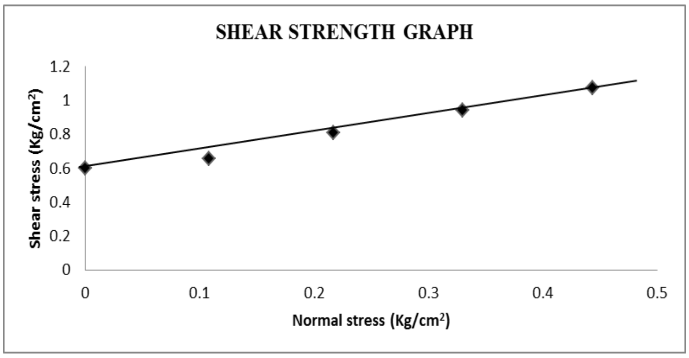


Chart.8: Graph representing Shear Strength of soil sample

5. Permeability Parameter:
   - Coefficient of permeability based on Constant head method of soil sample is 3.702 $*10^{-4}$cm/sec.
   - Coefficient of permeability based on falling head method of soil sample is 5.645$*10^{-6}$cm/sec.

6. Compaction Parameter
   - Maximum dry density of soil is 1.53gm/cc.

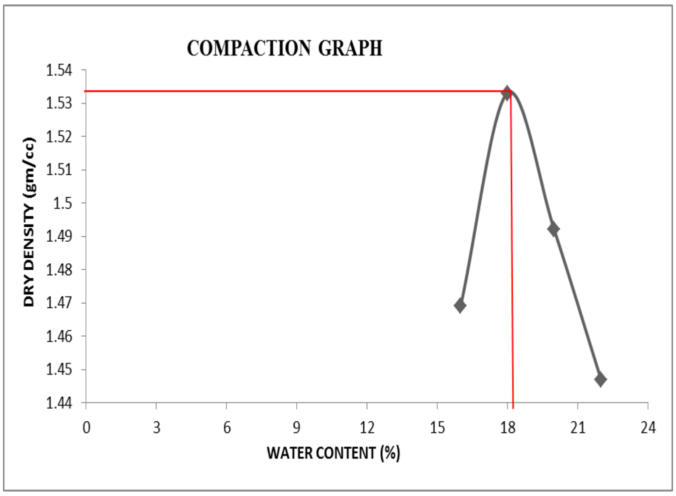


Chart.8: Graph representing OMC and MDD of soil sample

- Optimum moisture content of soil is 18.5%.

VI. EXPERIMENTAL VALUES RESULTS FOR ARTIFICIALLY FILLED UP SOILS (ONLY PERMEABILITY)

A. NIZAMPATNAM SOIL SAMPLE

1. Permeability Parameter:
   - Coefficient of permeability based on Constant head method of soil sample is 7.66$*10^{-7}$cm/sec.
   - Coefficient of permeability based on falling head method of soil sample is 4.34$*10^{-7}$cm/sec.

B. INKOLLU SOIL SAMPLE

1. Permeability Parameter:
   - Coefficient of permeability based on Constant head method of soil sample is 7.66$*10^{-7}$cm/sec.
   - Coefficient of permeability based on falling head method of soil sample is 4.34$*10^{-7}$cm/sec.

C. JILLELLAMUDI SOIL SAMPLE

1. Permeability Parameter:
   - Coefficient of permeability based on Constant head method of soil sample is 5.516 $*10^{-7}$cm/sec.
   - Coefficient of permeability based on falling head method of soil sample is 5.79$*10^{-7}$cm/sec.

VII. DISCUSSIONS

By considering the data from the above chart and comparing to our results, we get

- Coefficient of permeability for natural soil is in the range of 10^{-6}, which is slightly pervious.
- Coefficient of permeability for soil with GEO-MEMBRANE is in the range of 10^{-7}, which is impervious**.** By observing above results of artificially filled up soils, by using GEO-MEMBRANES, coefficient of permeability is reduced. Soil became

impermeable. Stability is assured, as GEO-MEMBRANE acts as reinforcement also.

VIII. Recommendations

In some cases GEO-MEMBRANE may not be available, on other hand cost plays important role and miscellaneous reasons also govern the selection of material. At such situations the following techniques may be implemented to reduce the permeability of the natural soil.

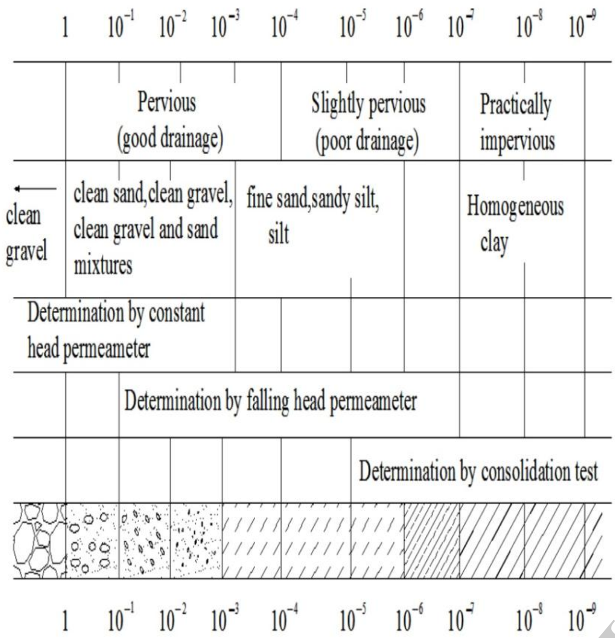


Fig.5 Particle size distribution chart

- Provide an impermeable clayey soil layer at a depth of 0.5m or 1m, over the top surface of the summer storage tank, so as to reduce the seepage of stored water. The clay which is going to be used should have permeability ranging 10^{-6} to 10^{-7}.
- Grouting can be done by injecting concrete slurry with a great force into bore hole where voids are high.
- Bentonite clay liners are to be used in the side walls or in the base so as to reduce the failures of the soil due to sliding and erosion.

CONCLUSION

The modified proctor test plays a major role in predicting the changed properties and behavior of cohesive, granular soils which are classified according to IS specifications. The effect of permeability in summer storage tanks can be controlled by using GEO-MEMBRANES in the soil by detail study of placing and implementation. We can provide GEO-MEMBRANE at a minimum depth of one foot from top. When GEO-MEMBRANE is not available, the above recommendations are to be implemented which reduces the permeability nearly up to desire level and will reduce the cost.

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