

Experimental Investigation of Soil Properties for Construction in Shimla Region

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Abstract

In the current investigation, the soil sample was taken from Totu Shimla, Himachal Pradesh, India (erstwhile summer capital of British India). Initially, the index properties of the soil were examined using water content, Specific gravity, Bulk Density/ Dry Density and grain size distribution. Practise Size Distribution of Soil by Sieve analysis was also conducted as per the Indian Standard Code. Field water content or moisture content is found out by oven drying technique as described in code IS: 2720-part-2:1973. Dry density is the important index property of soil. The proctor's test (compaction test) was performed as per the guidelines of IS code: 2720 part 9-1971. The Maximum dry density & Optimum water content is found to be 2.015 g/cm³ & = 9%. A specific gravity test was performed using a pycnometer. Specific gravity of soil sample is obtained 2.3. The test was performed on soil sample as per guidelines of IS: 2720-part-3-sect-2:1981. In the last, the strength of sub grade strength soil under this moisture conditions was also explored using the CBR test. As per IS: 2720 part 4 -1975 and results it was observed that the soil is **well graded sandy soil**. It has been observed that CBR value increases with respect to observed moisture content, well graded sandy soil which leads soil as high bearing capacity, low compressibility/ Settlement, good drainage around foundation and easy compaction in backfill.

Keywords: Soil Index, Specific gravity, Bulk Density/ Dry, OMC, CBR, Well graded sandy soil, Soil Properties

Introduction:

Soil plays important roles in every construction application like Foundation, highways, building structures, dams, etc. Specially now days in shimla landslide due to poor construction you can say without any investigation of soil properties for the use construction. The structure built on weak soil may collapse. Proper analysis should be conducted to guarantee that the structure stay safe and free from any kind of tragities (Settling & collapsing). Shimla is on the south-western ranges of the Himalayas at 31.61°N 77.10°E. It has an average altitude of 2,206 metres (7,238 ft) above mean sea level and extends along a ridge with seven spurs. The city stretches nearly 9.2 kilometres (5+³/₄ mi) from east to west [1]. The city is a Zone IV (High Damage Risk Zone) per the Earthquake hazard zoning of India. Weak construction techniques and an increasing population pose a serious threat to the already earthquake prone region.[2] [3]. As a place of peace and tranquility the Shimla district attract large

number of tourists. This has created an ever increasing population pressure over the different parts of the Shimla district. A number of high-rise multistoried buildings have been constructed to accommodate the tourists and for residential purposes. This is destabilizing the existing stability of slopes. Vulnerable geological structures, heavy rainfall and deforestation have aggravated soil erosion and landslide. [4].

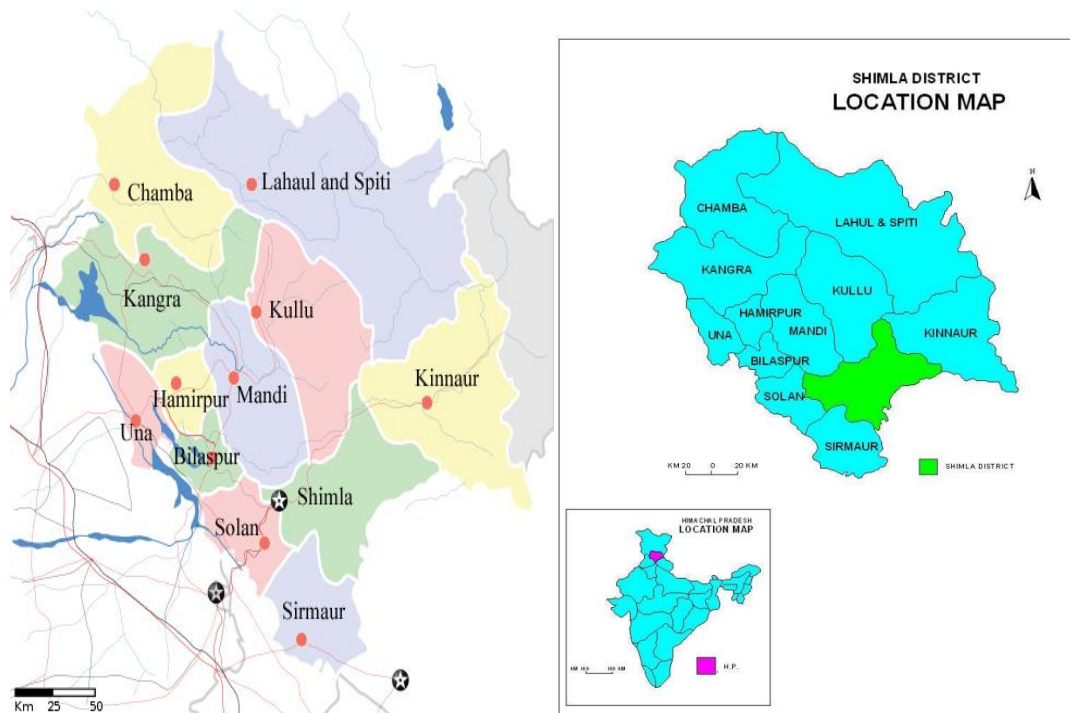


Figure 1. Himachal Pradesh

Soil varies from different place to place. Soil is often composed of a variety of particles with the variation of compositions, size and shapes. For the detailed design, the soil properties at each site, conditions need to be examined carefully. Experienced expert in soil can expected characteristics of soil by looking the soil sample but for the design of any structure labouratroy test could be performed. For the highway design soil is tested by CBR appreatus. The site amplication of soil during strong motion excitation depends upon the source, fundamental frequency, lithology, shear wave velocity, and thickness of the soil above bedrock. Shimla and Kangra district of Himachal Pradesh most of building constructed in these cities are not resonance with the soil resonance frequency. [5].The bearing strength of foundation soil is a major design criteria for civil engineering structures. This study aims to estimate the bearing strength, namely California Bearing Ratio (CBR) and ultimate bearing capacity, from simple and easy measured soil index properties. Laboratory investigation was conducted on two different soils compacted at various placement conditions (i.e. moisture content and dry density) and tested using CBR and triaxial tests. Based on test results, linear relationships of unsoaked CBR and ultimate bearing capacity with the consistency factor which is formed by combining placement conditions and soil intrinsic parameters had been developed. This result confirms that the proposed equations are reliable and useful to predict bearing strength parameters for different soils. [6]. Sometimes for saving the times the geotechnical engineer is interested to have some rough assessment of the engineering properties without conducting elaborate test. The index properties are given some information about engineering properties such as permeability, compressibility and shear strength. It is tacitly assumed that soils with

like index properties have identical engineering properties [7]. The intelligent compaction (IC) technology has been demonstrated as a powerful tool for soil compaction. However, the correlation between IC measurement values (ICMV) and in-situ tests has not been always consistent due to the influence of moisture content. Based on the test results in this study, an improved IC soil compaction system including laboratory test validations was suggested to identify the soil compactability and the target value at varying moisture contents. [8]. Experimental evidence is produced to show that it is reasonable to assign a unique strength to all soils when at their respective liquid limits, and to redefine the plastic limit as the water content at which the strength is 100 times that at the liquid limit. Having redefined the plastic limit it would be logical to use the cone penetrometer to determine this too, by using cones with different weights. Experimental data are shown to illustrate and support this proposal. [9]. Water content of soil sample is determined by the several methods. Few methods are filed and quick and some are performed in laboratory. The water content is important parameter that controls the soil sample behaviour. Oven drying method is accurate and standard method to find out the soil content. According to IS the mass of soil sample should be taken to an accuracy of 0.04 per cent. The soil sample in the container is then dried in an oven at a temperature of $110 \pm 5^\circ$ for 24 hours. The drying period of 24 hours has been recommended for normal soils, as it has been found that this period is sufficient to cause complete evaporation of water. [10]. Specific gravity is also soil fundamental property which provides the information about soil sample. Specific gravity is to determined by pycnometer method of glass jar one litters capacity of brass conical cap like as screw type cap [11]. The liquid limit is determined by Casagrande apparatus. A portion of soil paste is placed in the cup of Casagrande apparatus, and the surface is smoothened and levelled with a spatula to a maximum depth of 1 cm. A groove is cut through the sample along the symmetrical axis of the cup, in one strok, using a standard grooving tool. When the groove closes by flow, it indicates the failure of slopes formed on the two sides of the groove.

Plastic limit is the water content below which the soil does not behaving as plastic material. A Sample of plastic soil mass is taken to make the small ball. The ball is rolled with fingers on a plate to form a thread of soil sample. If the diameter of thread become smaller then 3mm, with any cracking it shows the water content is more than the plastic limit. [12][13]. Standard proctor test is used to the degree of compaction of chosen soil sample is measure in terms of its dry density and optimum moisture content. The index properties are mainly categories into two category Properties of individual particles, and properties of soil mass, also known as aggregate properties. Index properties give some information about the engineering properties. Particle size analysis is also known as mechanical analysis. It is shown graphically on a particle size distribution curve. A soil mass of about 2kg was taken as a sample with the sieve set as 100mm sieve on top 75 μ sieve at bottom above pan as per described in **IS : 2720 part 4 - 1975**. [14]. California Bearing Ratio Test represents the soil sample ability to withstand the specific stress during standard penetration. In the current investigation, the soil sample was taken from Totu Shimla, Himachal Pradesh, India Initially, the index properties of the soil were examined using water content, Specific gravity, Bulk Density/ Dry Density and grain size distribution. Practise Size Distribution of Soil by Sieve analysis was also conducted as per the Indian Standard Code. Maximum dry density & Optimum water content is found out. A specific gravity test was performed using a pycnometer. In the last, the strength of sub grade strength soil under this moisture conditions was also explored using the CBR test. It has been observed that CBR value increases with respect to observed

moisture content, well graded sandy soil which leads soil as high bearing capacity, low compressibility/ Settlement, good drainage around foundation and easy compaction in backfill.[15-19].

2. Materials and methodology

In the current study, a sample was chosen from Totu Shimla, Himachal Pradesh, India (Shimla erstwhile summer capital of British India), and various types of test were performed on soil sample.

2.1 Materials

Soil is very important in this study, and soil is fundamental component for this study. Soil is important weather in natural state, in site or transported and modified as for the different construction like foundation, highways. The soil sample was taken from Totu Shimla, Himachal Pradesh, India (erstwhile summer capital of British India), and various experiments were performed on it. The experiments were performed to check the change in load carrying limit of soil or improvement in the soil capacity. Field soil was taken for the purpose and different tests were performed on the soil sample to find its index and physical properties as explained with the observations and calculations, in which initial identification and classification of the soil were tested.



Figure 2.1 Soil Sample

2.2 Testing of Soil:

To improve the bearing capacity of earthen slope (embankment), different experiments were carried out on soil, including water content, Specific gravity, Bulk Density/ Dry Density and grain size distribution. CBR test was performed to examine the soil strength behaviour.

The work was done on genuine study or real life project however as soil is heterogeneous in nature the variable can likewise change. In the present part the enhancement of variable was attempted. For the same the experiments were performed, and testing was done to upgrade the variable and demonstrating the change of load carrying capacity of soil by any kind of sub and super structure

2.2.1 Identification of Soil.

A soil mass of about 2 kg was taken as a sample with the sieve set as 100 mm sieve on top 75 μ sieve at bottom above pan as per described in **IS : 2720 part 4 -1975**.

From particle size distribution graph figure, the values of D_{10} , D_{30} , D_{60} as 0.2, 0.5 and 1.0 respectively.

Uniformity Coefficient (C_u) = D_{60}/D_{10}

Curvature Coefficient (C_c) = $(D_{30})^2 / (D_{60} \times D_{10})$

As per **IS: 2720 part 4 -1975** and results it was observed that the soil is well graded sandy soil.

2.2.2 Water Content of Soil/Moisture Content:

It is expressed as a percentage, but used as a decimal in computation. $w = (M_w)/(M_s) \times 100$

The water content of soil specimen is determined by the oven drying method. The soil sample in the container is then dried in an oven at a temperature of $110 \pm 5^\circ$ for 24 hours. The drying period of 24 hours has been recommended for normal soils, as it has been found that this period is sufficient to cause complete evaporation of water.



Figure 2.2.2 Electronic Oven

2.2.3 Specific Gravity:

Specific gravity is key and fundamental soil property that gives insights into composition of soil particles and density.



Figure 2.2.3 Pycnometer

Table: 2.1 Typical Value of G

S.No.	Soil Type	Specific Gravity
1	Gravel	2.65-2.68
2	Sand	2.65-2.68
3	Silty Sand	2.66-2.70
4	Silt	2.66-2.70
5	Inorganic Clays	2.68-2.80
6	Organic Soil	Variable may fall below 2.00

The pycnometer method for the determination of water content can be used.

2.2.4 Liquid Limit & Plastic Limit:

The liquid limit is determined by Casagrande apparatus. A portion of soil paste is placed in the cup of Casagrande apparatus, and the surface is smoothened and levelled with a spatula to a maximum depth of 1 cm. A groove is cut through the sample along the symmetrical axis of the cup, in one stroke, using a standard grooving tool. When the groove closes by flow, it indicates the failure of slopes formed on the two sides of the groove.

Plastic limit is the water content below which the soil does not behave as plastic material. A sample of plastic soil mass is taken to make the small ball. The ball is rolled with fingers on a plate to form a thread of soil sample. If the diameter of thread becomes smaller than 3mm, with any cracking it shows the water content is more than the plastic limit.

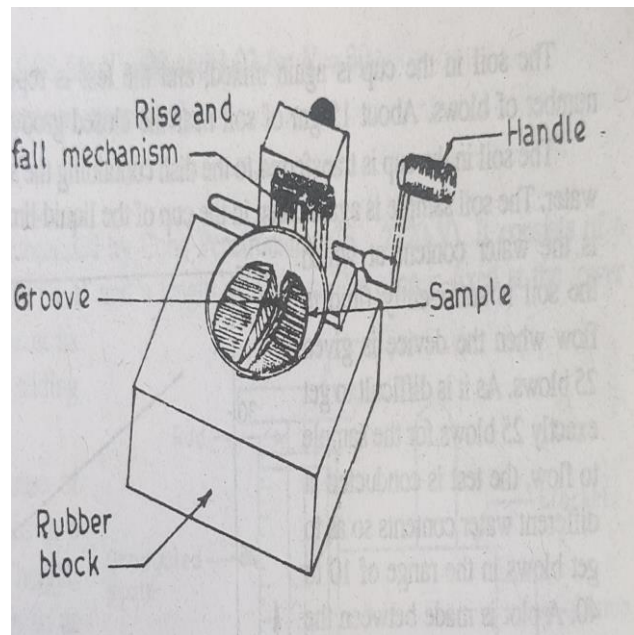


Figure 2.2.4 (a,b) Casagrande apparatus

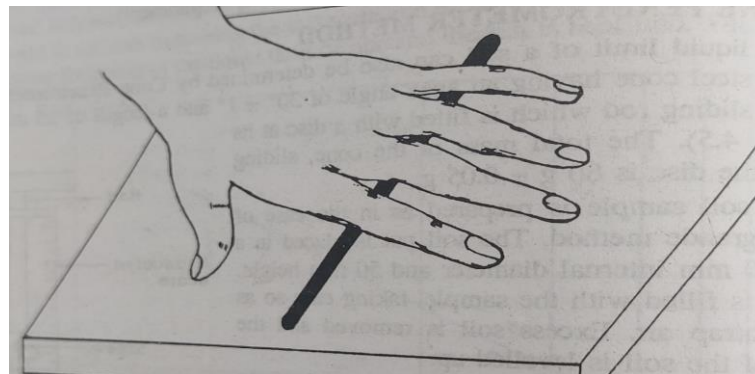


Figure 2.2.4 (c) Liquid Limit

2.2.5 Bulk Density/ Dry Density:

Compaction is the process of densification of soil by reducing air void. The degree of compaction of chosen soil sample is measure in terms of its dry density. Dry density is the important index property of soil. The proctor's test (compaction test) was performed as per the guidelines of **IS code**. A curve is drawn between the dry density and water content to obtain the maximum dry density and optimum water content.

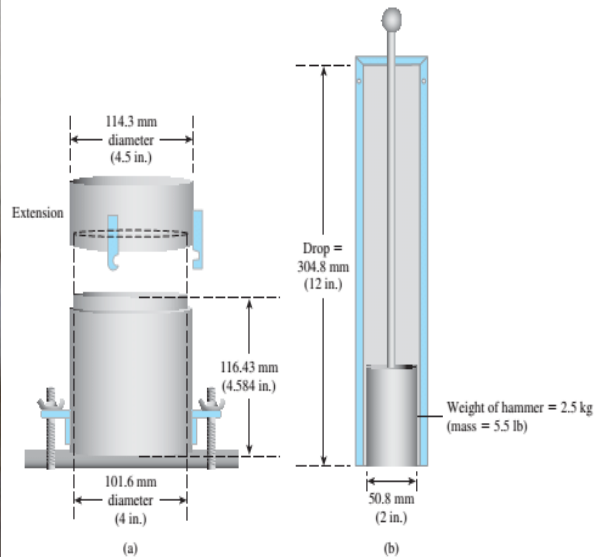


Figure 2.2.5 Compaction Mould

2.2.6 California Bearing Ratio (CBR): The California bearing ratio test is performed for evaluating the suitability of the sub grade and the material used in sub grade also is this soil sample is suitable for fixable pavement. CBR test represent the soil sample ability to withstand a specific stress level during a 1.25 mm/minute. The load required for a penetration of 2.5 and 5.0 mm are determined.

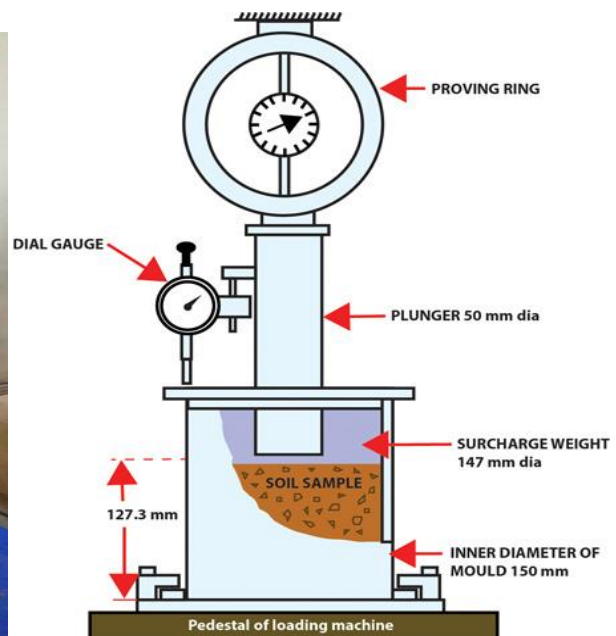


Figure 2.2.6 California Bearing Ratio machine

3. Result and discussion:

3.1 Field Water Content of Soil: Field water content or moisture content is found out by oven drying technique as described in code IS: 2720-part-2:1973

Result. From the test performed in laboratory water content of the sample is found by oven drying method. The result is 26.29% obtained for further experimental study. Water content of soil sample can calculated by, $w = (M_w)/(M_s) \times 100$.

Table: 3.1 Data sheet for water content by oven-drying method

S.No.	Observations And Calculations	Determination
1	Container no.	1
2	Mass of empty container (M1)	488g
3	Mass of container + wet soil (M2)	4743g
4	Mass of container + dry soil (M3)	3857g
5	Mass of water, ($M_w = M_2 - M_3$)	0.886g
6	Mass of solids, ($M_s = M_3 - M_1$)	3369g
7	Water content, $w = (M_w)/(M_s) \times 100$	26.298%

3.2 Specific Gravity: Specific gravity is determined by pycnometer method. The test was performed on soil sample as per guidelines of **IS: 2720-part-3-sect-2:1981**

Table: 3.2 Data sheet for specific gravity by pycnometer method

S.No.	Observations And Calculations	Determination
1	Pycnometer no.	1
2	Mass of empty pycnometer (M1)	617g
3	Mass of pycnometer + dry soil (M2)	817g
4	Mass of pycnometer + soil + water (M3)	1501g
5	Mass of pycnometer + water (M4)	1388g
6	$M_2 - M_1$	200g
7	$M_3 - M_4$	113g
8	$G = (M_2 - M_1)/(M_2 - M_1) - (M_3 - M_4)$	2.3

Result. Specific gravity of soil sample = 2.3

3.3 Bulk Density/ Dry Density: Dry density is the important index property of soil. The proctor's test (compaction test) was performed as per the guidelines of **IS code: 2720 part 9-1971.**

Table: 3.3 Data sheet for compaction test

S.No.	Observation And Calculations	1	2	3	4
1	Vol. of mould, V (cm ³)	1000	1000	1000	1000
2	Wt. of empty mould + base plate, W1(g)	3667	3667	3667	3367
3	Wt. of mould + compacted soil, W2(g)	5687	5864	5849	57744
4	Wt. of compacted soil, $W = W_2 - W_1$ (g)	2020	2197	2182	2077
5	Bulk density (g/cm ³)	2.02	2.197	2.182	2.077
6	Water content in %	6	9	12	15

7	Dry density (g/cm ³)	1.905	2.015	1.948	1.806
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Result. Maximum dry density = 2.015 g/cm³

Optimum water content = 9%

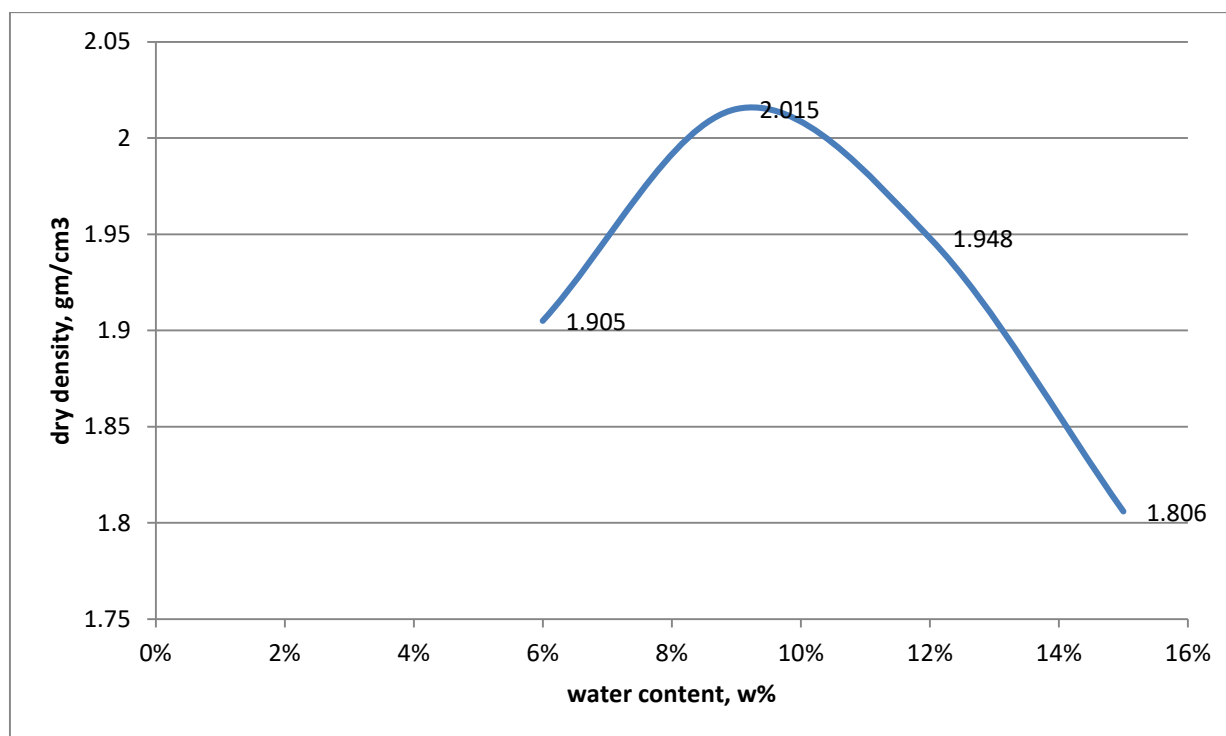


Figure 3.3 Optimum Water Content of Soil

3.4 Liquid Limit

From IS: 2720 – part 5 – 197

Table: 3.4 Data sheet for liquid limit test

S.No.	Observation And Calculation	1	2	3	4
1	No. of blows	45	22	20	19
2	Wt. of empty container, M1(g)	47	47	51	48
3	Wt. of container + wet soil, M2(g)	59	57	60	56
4	Wt. of container + dry soil, M3(g)	57	55	58	54
5	Wt. of water, M2-M3(g)	2	2	2	2
6	Wt. of dry soil, M3-M1(g)	10	8	7	6
7	Water content = $(M2-M3)/(M3-M1) \times 100$	20	25	28.57	33.33

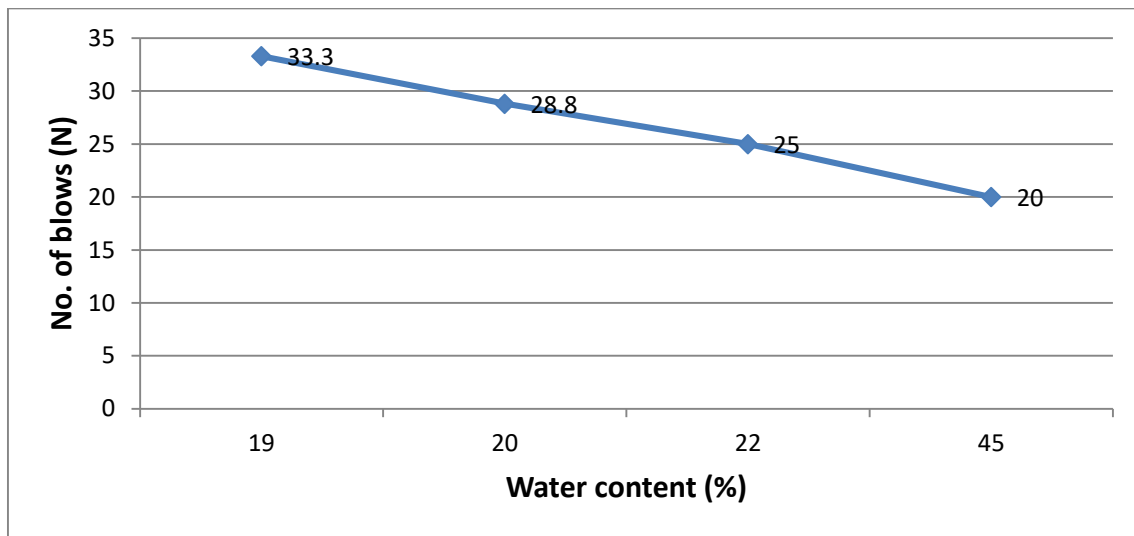


Figure 3.4 Liquid limit

3.5 Practise Size Distribution of Soil by Sieve Analysis

A soil mass of about 2kg was taken as a sample with the sieve set as 100mm sieve on top 75 μ sieve at bottom above pan as per described in **IS : 2720 part 4 -1975**. Both coarse sieve and fine sieve analysis is given in table 3.5.

Table: 3.5 Data sheet for sieve analysis

S. No.	IS Sieve	Partial Size	Weight Retained (g)	Percentage Retained	Cumulative Percentage Retained	Percentage Finer
1	100 mm	100 mm	-	-	-	100
2	63 mm	63 mm	-	-	-	100
3	20 mm	20 mm	-	-	-	100
4	10 mm	10 mm	-	-	-	100
5	4.75 mm	4.75 mm	0.490	22.8	22.8	77.2
6	2.36 mm	2.36 mm	0.271	12	35.4	64.6
7	1.18 mm	1.18 mm	0.011	0.5	35.9	64.1
8	600 micron	0.6 mm	0.534	25.2	61.1	38.9
9	300 micron	0.300 mm	0.400	18.6	79.7	20.3
10	150 micron	0.150 mm	0.326	15.1	94.8	5.2
11	90 micron	0.090 mm	0.003	0.13	94.93	5.07
12	75 microns	0.075 mm	0.017	0.8	95.73	4.27
13	PAN	PAN	0.09	4.2	99.93	-
Total			2151	100	100	-

From particle size distribution graph figure, the values of D_{10} , D_{30} , D_{60} as 0.2, 0.5 and 1.0 respectively.

Uniformity Coefficient (C_u) = D_{60}/D_{10} = $1/0.2$ = 5

Curvature Coefficient (C_c) = $(D_{30})^2 / (D_{60} \times D_{10})$
= $(0.5)^2 / (0.2 \times 1) = 1.25$

As per **IS: 2720 part 4 -1975** and results it was observed that the soil is well graded sandy soil.

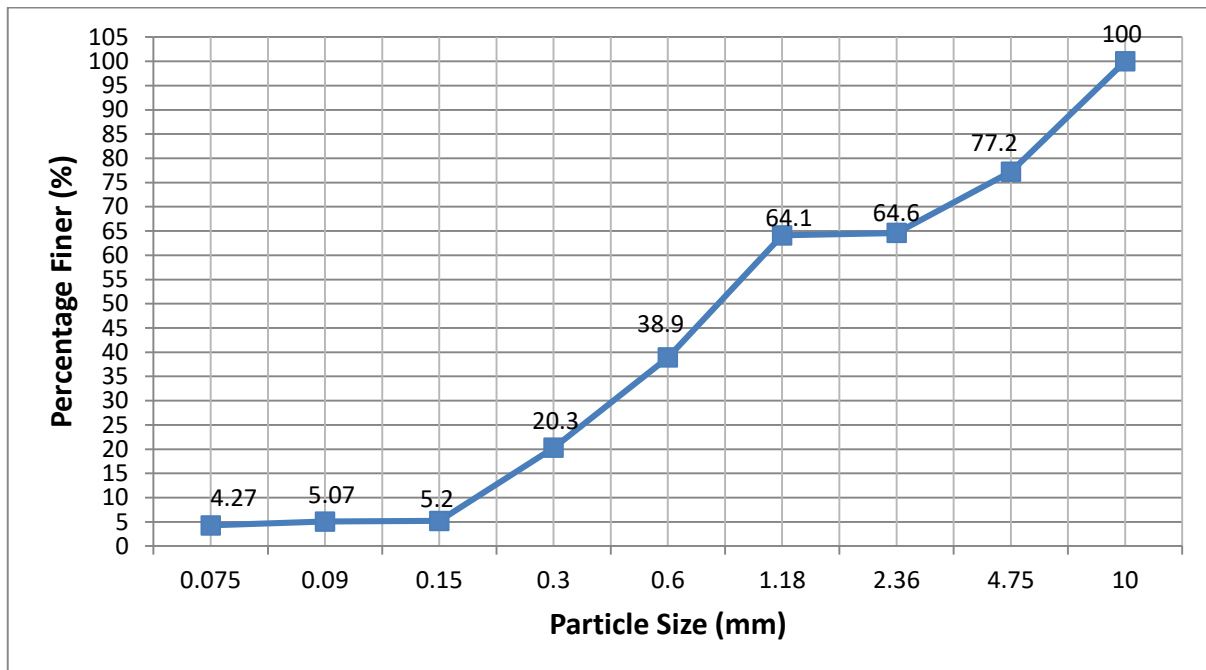


Figure 3.5 practical Size distributions

3.6 California Bearing Ratio (CBR) of a Soil Sample

Load dial reading at 2.5 mm penetration = 17

$17 \times 2.5 \div 97.1 = 0.4369 \text{ KN} = 44.5 \text{ kg}$

CBR value at 2.5 mm penetration = $44.5 \times 100 \div 1370 = 3.2\%$

Load dial reading at 5 mm penetration = 21

$21 \times 2.5 \div 97.1 = 0.539 \text{ KN} = 55.03 \text{ kg}$

CBR value at 5 mm penetration = $55.03 \times 100 \div 2055 = 2.6\%$

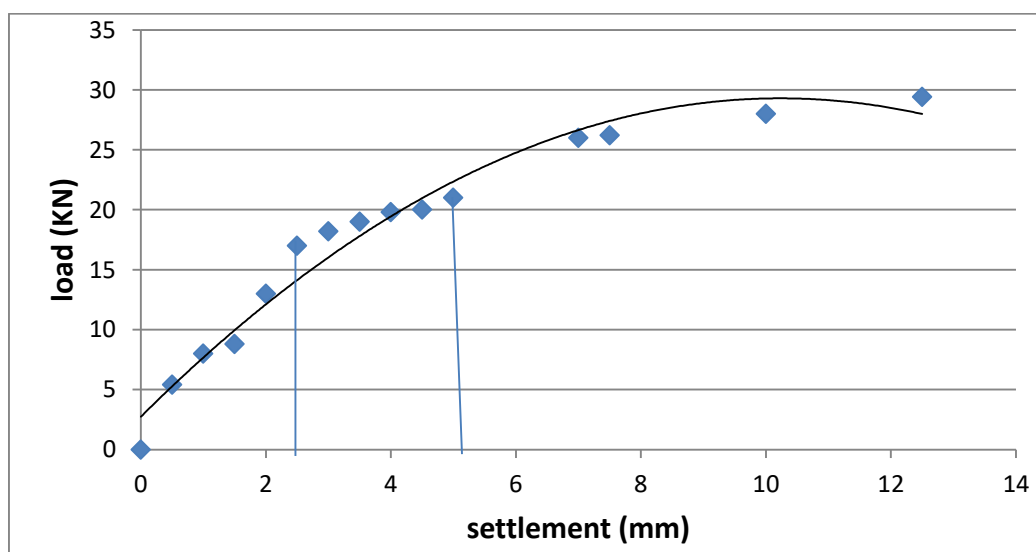


Figure 3.6 Load settlement curve for CBR

Result:

The present investigation focused on evaluating the geotechnical properties of soil collected from **Totu, Shimla (Himachal Pradesh)**. A series of laboratory tests were carried out to determine index and strength parameters with the objective of identifying suitability of the soil for construction activities and pavement subgrade applications. The results obtained from these experiments provide insight into the soil's behaviour under varying moisture and stress conditions, which are critical for design, stability, and performance of civil engineering structures.

The **natural water content** of the soil sample, evaluated by the oven-drying method as per IS: 2720-Part-2, was found to be **26.29%**, indicating a moderately high presence of moisture in the natural state. This suggests that the soil has the tendency to retain water and may require proper moisture control before use in load-bearing applications.

Excess water content reduces compaction efficiency and shear strength; therefore, moisture conditioning during construction becomes important.

The **specific gravity** of the soil determined using the pycnometer method was **2.3**, which falls in the lower range of typical values for sandy soils. This indicates the presence of light mineral constituents and confirms the predominance of sand in the soil fraction. Specific gravity plays an important role in understanding soil mineralogy and is directly used in the determination of void ratio, porosity and degree of saturation.

Compaction characteristics were studied using the **Standard Proctor Test**. The compaction curve shows that **maximum dry density (MDD) = 2.015 g/cm³** and **optimum moisture content (OMC) = 9%**. These values indicate that the soil achieves maximum compactness at comparatively low moisture content, which is favourable for construction. A high dry density illustrates that the soil can withstand heavy loads when compacted to OMC, reinforcing its suitability as a structural fill and subgrade material.

The **sieve analysis** established the gradation characteristics of the soil. The calculated values — **D₁₀ = 0.2, D₃₀ = 0.5 and D₆₀ = 1.0** — resulted in **C_u = 5** and **C_c = 1.25**, clearly classifying the sample as **well-graded sandy soil**. Well-graded sand generally exhibits good drainage, low compressibility, and high resistance to settlement under applied loads, which is highly desirable from the standpoint of foundation and pavement engineering.

Finally, the **California Bearing Ratio (CBR) test** was conducted to assess the soil's bearing strength. The values obtained were **3.2% at 2.5 mm penetration** and **2.6% at 5.0 mm penetration**. Although the results reflect moderate subgrade strength, the trend indicates that the strength improves with controlled moisture content and optimum compaction conditions. This reinforces that the soil is fit for pavement subgrade layers, provided adequate compaction is maintained during field execution.

Overall, the results demonstrate that the soil from Totu-Shimla is **well-graded sandy soil** with good compaction characteristics, high bearing potential under optimum moisture conditions and favourable

engineering properties for foundation and highway applications. Proper moisture regulation during construction would optimize performance and minimize settlement issues.

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