JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Experimental Study Of Road Construction Soil Materials

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Abstract

There is a huge variety of materials used in the implementation of construction and restoration work. They are also used in the construction of roads. This article describes Fundamental Tests Of Road Construction Soil Materials like Grading, Atterbergs limits, Proctor (maximum dry density at optimum moisture content),Free swell index (FSI) and california bearing ratio (CBR). In this study two materials were collected one from tunnel muck and other from excavated soil to carry out these tests. The introduction contains the significance of materials in construction work. Comparison between the two materials selected for the study are described in the conclusion. From the resuts it were observed that material with greater silt and clay content has has greater liquid limit ,high plasticity,less maximum dry density,high free swell index and less California bearing ratio than soil with low silt and cay content.

1. Introduction

Soil is unconsolidated top layer of land (ground), which consists of weathered rock fragments, organic matter, minerals, water and air in different proportions. It is very important to know behaviour of soil as it is used largely for the construction of embankments and pavement layers, such as road bed, fill, improved sub-grade, sub-base, base (and wearing course for gravel roads) Consistency of soil varies considerably with location and profile(depth) due to weathering process and transportation modes. Moreover, some functional properties such as grading, plasticity, permeability, compressibility and bearing capacity also vary with soil types. Soil is very sensitive to moisture content than any other road construction material. Therefore, most of the road failures are more often subjective to its behaviour, which for the most part is affected by the *Atterberg limits* (liquid limit, plastic limit and plasticity index),*grading* (particle size distribution), *Density* (compactness) and *strength* (bearing capacity).

Humidity is a destroyer of roads. It destroys the foundation of the road structure and, when frozen in micro cracks, breaks the coating. Therefore, when designing, the level of groundwater is always considered. It is possible to build a solid highway in marshy areas. However, special advanced technologies and appropriate building materials are needed here. Under normal climatic conditions, there are the following restrictions : at high humidity it is not recommended to use materials such as dusty sand, fine sandy loam, and dusty loam in the construction of roads. Such types of soil are used exclusively in dry places, since when wet, they quite reduce the bearing property of the roadway and lead to its deformation.

The desirable properties of soil as a highway material are:

• Short and long term stability of the subgrade and slopes of embankment.

• Compressibility within permissible limits.

• Adequate permeability

• Compaction should be ease and economical

• Minimum volume change at all conditions.

2. Fundamental Tests Of Road Construction Soil Materials

Fig 1. Shows Excavated soil material selected for the study.

Fig 2. Shows Tunnel muck material selected for the study.

2.1 Grading

Grading test (also known as *Sieve analysis* or *Particle size distribution*) determines the proportion of particle sizes in a granular material(e.g. aggregate, soil, etc.) . Most of the soils are cohesive (the particles bind among themselves), wet sieving is more accurate method for determining the grading of soil than dry sieving

Fig 3. Shows Grading analysis.

2.1.1 Grading of Excavated soil

Weight of sample(grams)	6500			
Sieve Size(mm)	Mass retained	% Retained	% Retained cumulative	% Passing
75	0	0	0	100
19	1072	16.49	16.49	83.51
4.75	793	12.20	28.69	71.31
2	786	12.09	40.78	59.22
0.425	754	11.60	52.38	47.62
0.75	721	11.09	63.47	36.53

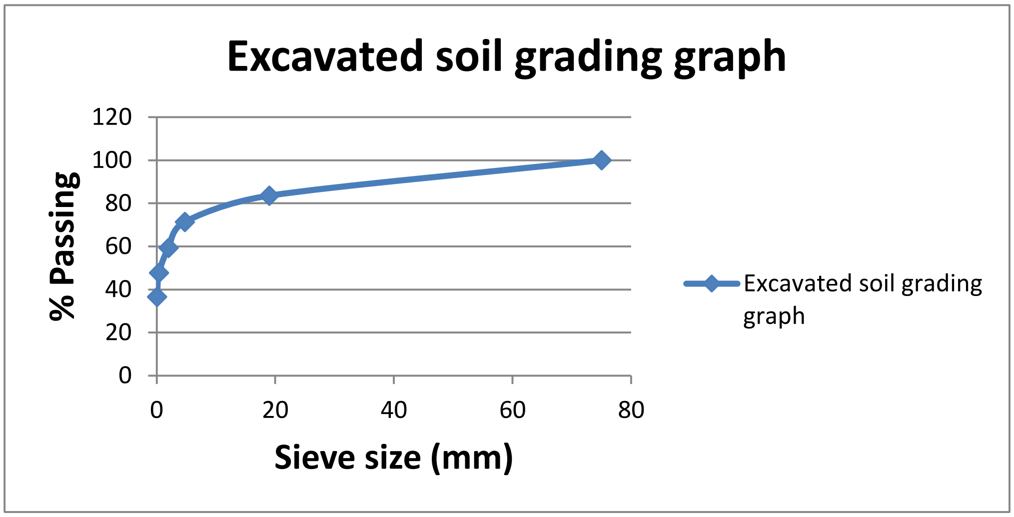

Fig 4. Shows Excavated Grading graph.

2.1.2 Grading of Tunnel muck material

Weight of sample(grams)	65000			
Sieve Size(mm)	Mass retained	% Retained	% Retained cumulative	% Passing
150	0	0	0	100
100	0		0	100
75	12590	19.37	19.37	80.63
19	20495	31.53	50.90	49.10
4.75	8435	12.98	63.88	36.12
2	13665	21.02	84.90	15.10
0.425	3900	6.00	90.90	9.10
0.75	3925	6.04	96.94	3.06

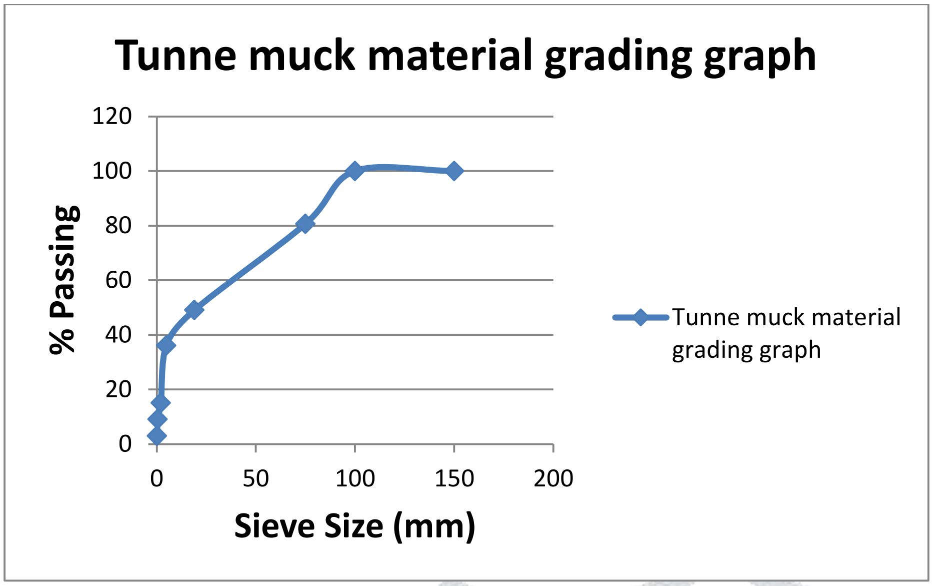

Fig 5. Shows Tunnel muck material grading graph.

2.2 Atterberg limits

Atterberg limits are simply referred to as plasticity property, since; the outward sign of the limits is *plasticity index* , which reflects the sticking property of soil (linked with clay content). However, the *Atterberg limits* determine general consistency of soil (i.e. the range of water contents, at which the soil changes from *solid* to *plastic* and from *plastic* to *liquid* states). The limits were established by a Swedish chemist know as Albert Atterberg, hence, taking the name *Atterberg*.

2.2.1 Casagrande method:

Excavated soil tested by casagrande method as given below

Fig 6. Shows liquid limit.

Description	Container No	No of Blows	Mass of wet sample + container (g)	Mass of dry sample + container(g)	Mass of container (g)	Mass of moisture(g)	Mass of dry sample(g)	% Moisture
Liquid imit	5	16	47.66	41.19	19.75	6.47	21.44	30.18
	6	21	46.19	40.3	19.95	5.89	20.35	28.94
	7	27	47.47	41.54	19.89	5.93	21.65	27.39
	8	32	42.86	38.11	19.84	4.75	18.27	26.00
Pastic imit	9	_	31.41	29.2	19.82	2.21	9.38	23.56
	10	_	32.77	30.36	19.81	2.41	10.55	22.84
				liquid limit %	27.90			
				plastic limit %	23.20			
				Plasticity index %	4.70			

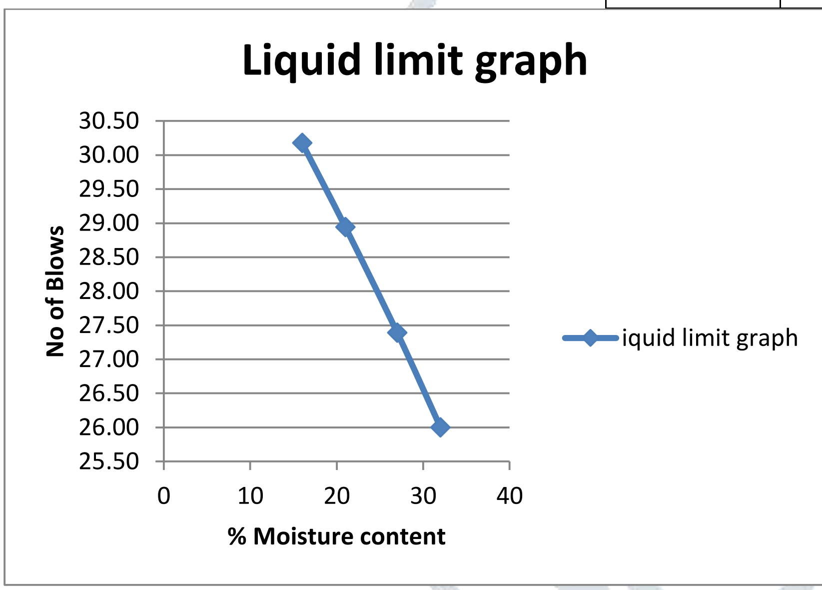

Fig 7. Shows liquid limit graph.

2.2.2 Penetrometer method:

Tunnel muck material tested by Penetrometer method as given below

Fig 8. Shows liquid limit by Penetrometer.

Container No	Penetration (mm)	Mass of wet sample + container (g)	Mass of dry sample + container(g)	Mass of container (g)	Mass of moisture(g)	Mass of dry sample(g)	% Moisture
1	15	43.57	39.19	19.73	4.38	19.46	22.51
2	18	44.74	40	19.75	4.74	20.25	23.41
3	22	47.14	41.72	19.95	5.42	21.77	24.90
4	26	48.28	42.44	19.89	5.84	22.55	25.90
			liquid limit	24.00			
			plastic limit	Non Plastic			
			Plasticity Index %	0			

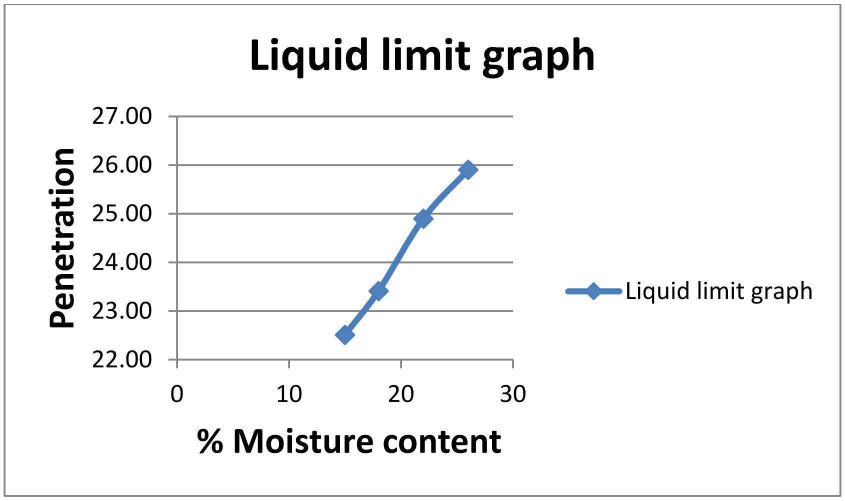

Fig 9. Shows Liquid limit graph.

2.3 Proctor

Proctor is a compaction method, used in the laboratory to show the relationship of *moisture content* and *density* of a material compacted mass of material in a unit volume through a range of moisture contents). It was named after R. Proctor who developed the relationship. The applicable terms in the test include;

Density: -Concentration of particles per unit volume.

Moisture Content: -Amount of water, expressed as percentage of the dry mass of material.

Maximum Dry Density (MDD): - The greatest dry mass of soil (or graded aggregates) achieved by compacting the soil (or graded aggregate) material in a unit volume through a range of moisture contents.

Optimum Moisture Content (OMC): - accurate amount of water that facilitates compaction to the maximum dry density.

Fig 10. Shows Maximumdry density test.

2.3.1 MDD and OMC for Excavated soil

Mould vol(cc)	2250	2250	2250	2250	2250	2250
Mass of mould and wet material(gm)	10306	10514	10780	10972	10905	10740
Mass of moulld(gm)	6022	6022	6022	6022	6022	6022
Mass of wet material(gm)	4284	4492	4758	4950	4883	4718
Wet density(gm/cc)	1.904	1.996	2.115	2.200	2.170	2.097
Container no	11	12	13	14	15	16
Mass of container and wet material(gm)	174.93	174.63	148.20	110.09	155.25	179.55
Mass of container and dry material(gm)	169.06	166.85	139.82	103.19	142.48	161.12
Mass of container(gm)	38.61	38.06	35.41	34.49	37.76	36.35
Mass of water(gm)	5.87	7.78	8.38	6.90	12.77	18.43
Mass of dry material(gm)	130.45	128.79	104.41	68.70	104.72	124.77
Moisture content(%)	4.50	6.04	8.03	10.04	12.19	14.77
Dry density(gm/cc)	1.822	1.883	1.958	1.999	1.934	1.827

Maximum Dry Density	1.999 gm/cc
Optimum Moisture Content	10.04%

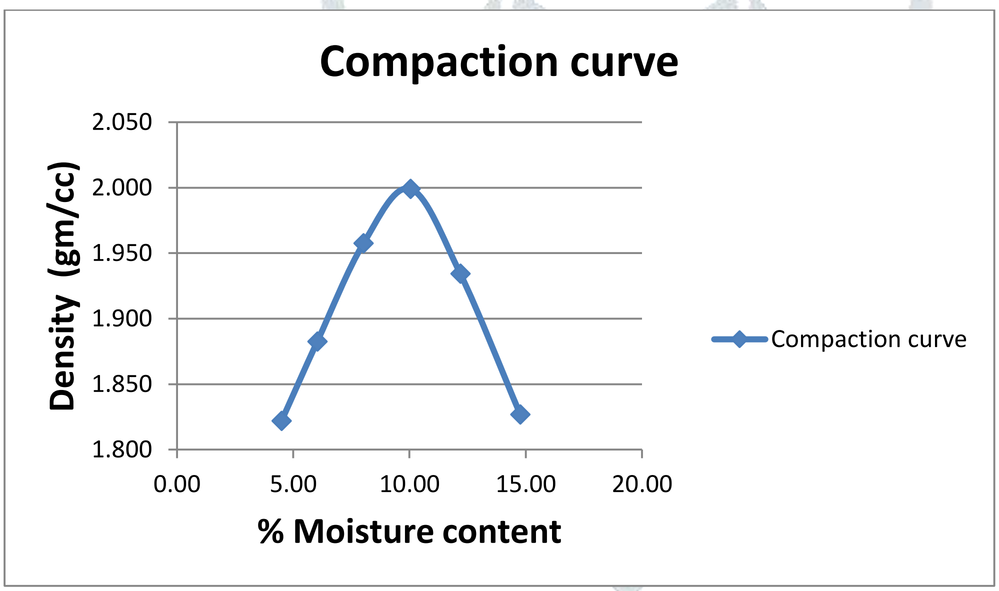

Fig 11. Shows Compaction curve.

2.3.2 MDD and OMC for Tunnel muck material

Mould vol(cc)	2250	2250	2250	2250	2250	2250
Mass of mould and wet material(gm)	10895	11095	11470	11656	11535	11256
Mass of moulld(gm)	6022	6022	6022	6022	6022	6022
Mass of wet material(gm)	4873	5073	5448	5634	5513	5234
Wet density(gm/cc)	2.166	2.255	2.421	2.504	2.450	2.326
Container no	11	12	13	14	15	16
Mass of container and wet material(gm)	165.55	169.60	166.30	160.65	175.65	150.46
Mass of container and dry material(gm)	161.00	164.28	159.75	153.4	166.48	141.73
Mass of container(gm)	38.61	38.06	35.41	34.49	37.76	36.35
Mass of water(gm)	4.55	5.32	6.55	7.25	9.17	8.73
Mass of dry material(gm)	122.39	126.22	124.34	118.91	128.72	105.38
Moisture content(%)	3.72	4.21	5.27	6.10	7.12	8.28
Dry density(gm/cc)	2.088	2.163	2.300	2.360	2.287	2.148

Maximum Dry Density	2.360 gm/cc
Optimum Moisture Content	6.10%

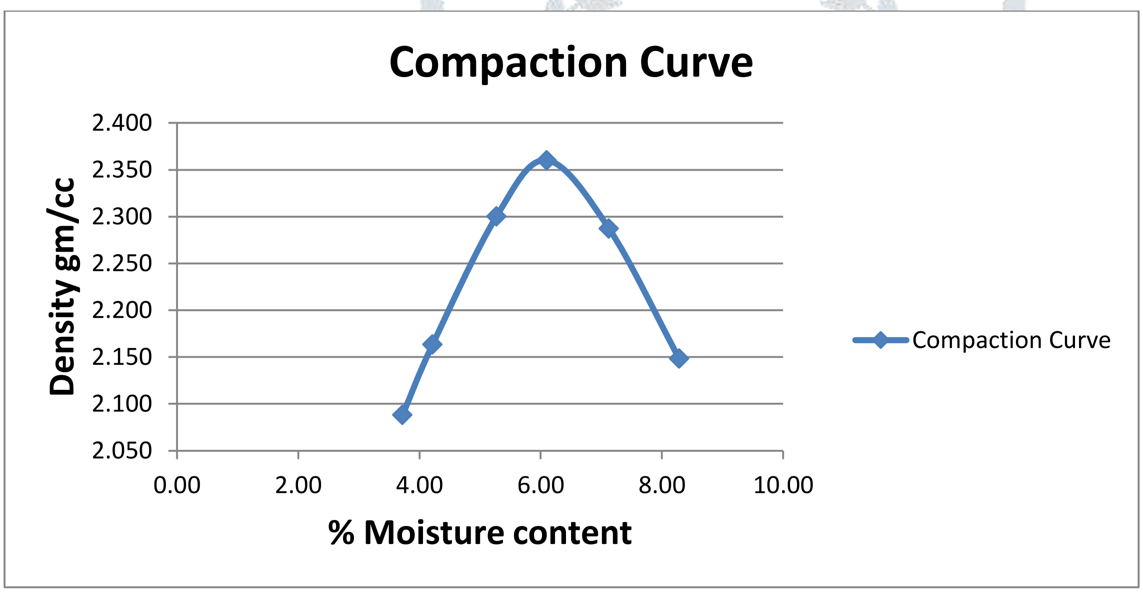

Fig 12. Shows compaction curve.

2.4 Free Swell Index (FSI)

It is a standard model which is specified by the Bureau of Indian standards (IS: 2720, 1977). 10gm of oven dried passing through 425µm sieve is placed in 100ml of graduated measuring jar comprising distilled water to that in kerosene. After an equilibrium period of 24hrs the swell potential of the soil is calculated utilizing FSI. FSI (%) = $(H2-H1)/ H1 * 100$ Where, H2 is the height of soil sample in water , H1 is the height of soil sample in kerosene.

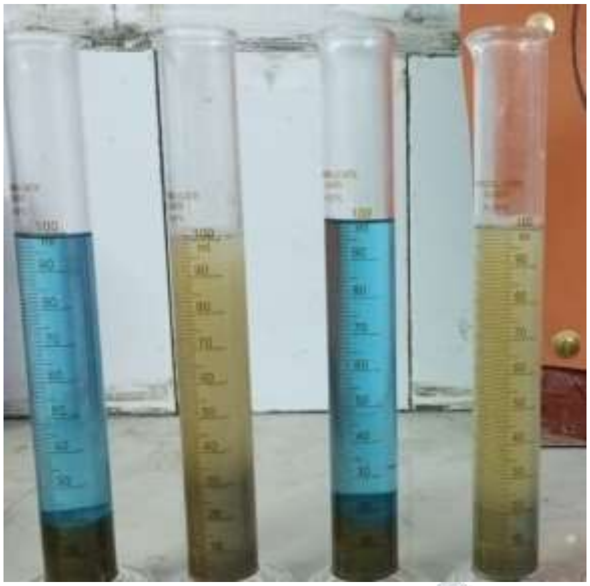

Fig 13. Shows Free swell index.

2.4.1 Free swell index of Excavated soil material

Description	Depth(mm)	Height of soil specimen in kerosene (mm)	Height of soil specimen in water (mm)	Free swell index (%)	Average
Test 1	10.00	10.00	11.50	15.00	17.48
Test 2	10.00	11.00	12.50	13.64	
Test 3	10.00	10.50	13.00	23.81	

2.4.2 Free swell index of Tunnel muck material

Description	Depth(mm)	Height of soil specimen in kerosene (mm)	Height of soil specimen in water (mm)	Free swell index (%)	Average
Test 1	10.00	11.00	12.00	9.09	9.54
Test 2	10.00	10.50	11.50	9.52	
Test 3	10.00	10.00	11.00	10.00	

2.5 CBR

CBR letters abbreviate the name *California Bearing Ratio* (the basic test used to measure strength of subgrade soil and pavement layers). The test is conducted by penetrating a moulded soil specimen with a cylindrical plunger at a constant rate of 1.25mm per minute; and the forces corresponding with penetration of *2.5mm* and *5.0mm* are computed and compared with the strength of California rocks (tested in California, USA).However the CBR test development was based on the empirical observations, which does not simulate fundamental properties that have great influence on the soil performance (e.g. elastic stiffness and resilient modulus), it is still the popular method of evaluating strength of subgrade soil and pavement materials in many countries. The common terms found in the test are:

1. *Plunger:* fixed to the proving ring of CBR machine that penetrates the soil specimen.
2. *Dial gauge:* - the instrument, which indicates the load reading or penetration of plunger as the testing continues.
3. *Surcharge:* - metal disc placed over soil specimen during soaking and testing to simulate weight of pavement layers.
4. *Swell:* - bulging or expansion of soil caused by water absorption

Fig 14. Shows CBR test.

2.5.1 CBR test of Excavated soil

Description	Mould No.1		Mould No.2		Mould No.3	
No .Of layers	5		5		5	
No. blows per layer	56		56		56	
Condition of sample while SOAKING	Before	After	Before	After	Before	After
Wt. of mould(gm)	7275		7100		7378	
Wt. of wet sample +mould(gm)	12203	12299	12023	11839	12310	12415
Wt. wet sample(gm)	4928	5024	4923	4739	4932	5037
Volume of mould/sample (cc)	2250	2250	2250	2250	2250	2250
Wet density (gm/cc)	2.190	2.233	2.188	2.106	2.192	2.239
Moisture determination						
Container no.	1	2	3	4	5	6
Wt. of container(gm)	85.70	90.30	91.31	91.04	90.59	92.30
Wt .of wet sample +cont.(gm)	329.25	329.47	309.87	352.68	356.18	320.52
Wt .of dry sample cont.(gm)	307.09	303.77	290.09	325.55	331.95	295.18
Wt. of water(gm)	22.16	25.70	19.78	27.13	24.23	25.34
Wt. of dry sample(gm)	221.39	213.47	198.78	234.51	241.36	202.88
Water content (%)	10.01	12.04	9.95	11.57	10.04	12.49

Dry density(gm/cc)		1.991	1.993	1.990	1.888	1.992	1.990
LOAD PENETRATION TEST DATA							
General information	**Penetration (mm)**	**Proving ring reading**	**Load (kgf)**	**Proving ring reading**	**Load (kgf)**	**Proving ring reading**	**Load (kgf)**
Type of compaction used: Dynamic	0.0	0	0.00	0	0.00	0	0.00
	0.5	10	62.67	11	68.94	9	56.40
Period of soaking: 4 days	1.0	19	119.07	21	131.61	22	137.87
	1.5	28	175.48	27	169.21	27	169.21
Wt. of surcharge used (kg): 5 Kg	2.0	43	269.48	45	282.02	47	294.55
	2.5	57	357.22	60	376.02	59	369.75
Proving ring Number 01 & capacity 50 KN	3.0	67	419.89	72	451.22	70	438.69
	4.0	75	470.03	81	507.63	83	520.16
Proving Ring Load Factor : 5.30	5.0	83	520.16	88	551.50	87	545.23
	7.5	97	607.90	105	658.04	102	639.23
	10.0	107	670.57	110	689.37	106	664.30
	12.5	115	720.71	117	733.24	113	708.17
CBR at 2.5mm (%)		22.05		23.21		22.82	
CBR at 5.0mm(%)		21.41		22.70		22.44	
CBR reported (%)		22.70					

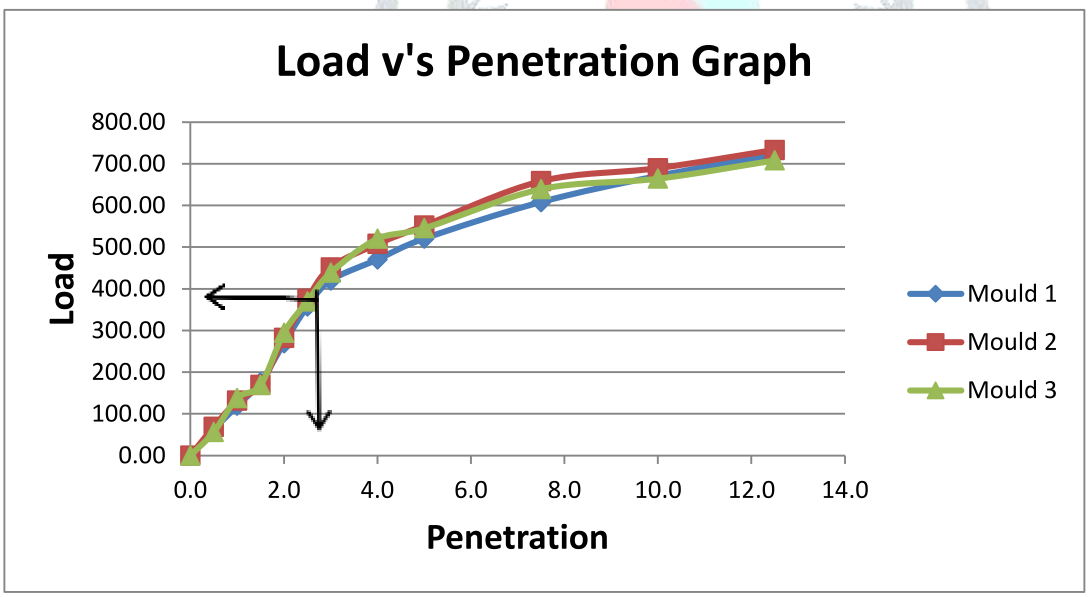

Fig 15 . shows Load v's Penetration graph.

2.5.2 CBR test of Tunnel muck material

Description		Mould No.1		Mould No.2		Mould No.3	
No. Of layers		5		5		5	
No. Of blows per layer		56		56		56	
Condition of sample while SOAKING		Before	After	Before	After	Before	After
Wt. of mould(gm)		7275		7100		7378	
Wt. of wet sample +mould(gm)		12893	12943	12706	12802	12999	13054
Wt. of wet sample(gm)		5618	5668	5606	5702	5621	5676
Volume of mould/sample (cc)		2250	2250	2250	2250	2250	2250
Wet density (gm/cc)		2.497	2.519	2.491	2.534	2.498	2.523
Moisture determination							
Container no.		7	8	9	10	11	12
Wt. of container(gm)		59.17	57.16	57.37	60.11	58.72	58.82
Wt. of wet sample +cont.(gm)		281.96	250.34	269.60	292.49	288.53	283.21
Wt. of dry sample +cont.(gm)		269.29	237.67	257.55	275.78	275.62	268.1
Wt of water(gm)		12.67	12.67	12.05	16.71	12.91	15.11
Wt. of dry sample(gm)		210.12	180.51	200.18	215.67	216.9	209.28
Water content(%)		6.03	7.02	6.02	7.75	5.95	7.22
Dry density(gm/cc)		2.355	2.354	2.350	2.352	2.358	2.353
LOAD PENETRATION TEST DATA							
General information	**Penetration (mm)**	**Proving ring reading**	**Load (kgf)**	**Proving ring reading**	**Load (kgf)**	**Proving ring reading**	**Load (kgf)**
Type of compaction used: Dynamic	0.0	0	0.00	0	0.00	0	0.00
	0.5	32	200.54	30	188.01	27	169.21
Period of soaking: 4 days	1.0	68	426.16	64	401.09	69	432.42
	1.5	95	595.37	87	545.23	92	576.56
Wt. of surcharge used (kg): 5 Kg	2.0	132	827.24	129	808.44	133	833.51
	2.5	178	1115.53	170	1065.39	179	1121.79
Proving ring Number 01 & capacity 50 KN	3.0	220	1378.74	206	1291.00	212	1328.60
	4.0	244	1529.15	232	1453.94	234	1466.48
Proving Ring Load Factor : 5.30	5.0	260	1629.42	249	1560.48	250	1566.75
	7.5	298	1867.57	276	1729.69	291	1823.70
	10.0	329	2061.84	321	2011.71	325	2036.78
	12.5	358	2243.59	351	2199.72	364	2281.19
CBR at 2.5mm (%)		68.86		65.77		69.25	
CBR at 5.0mm(%)		67.06		64.22		64.48	
CBR reported (%)		67.96					

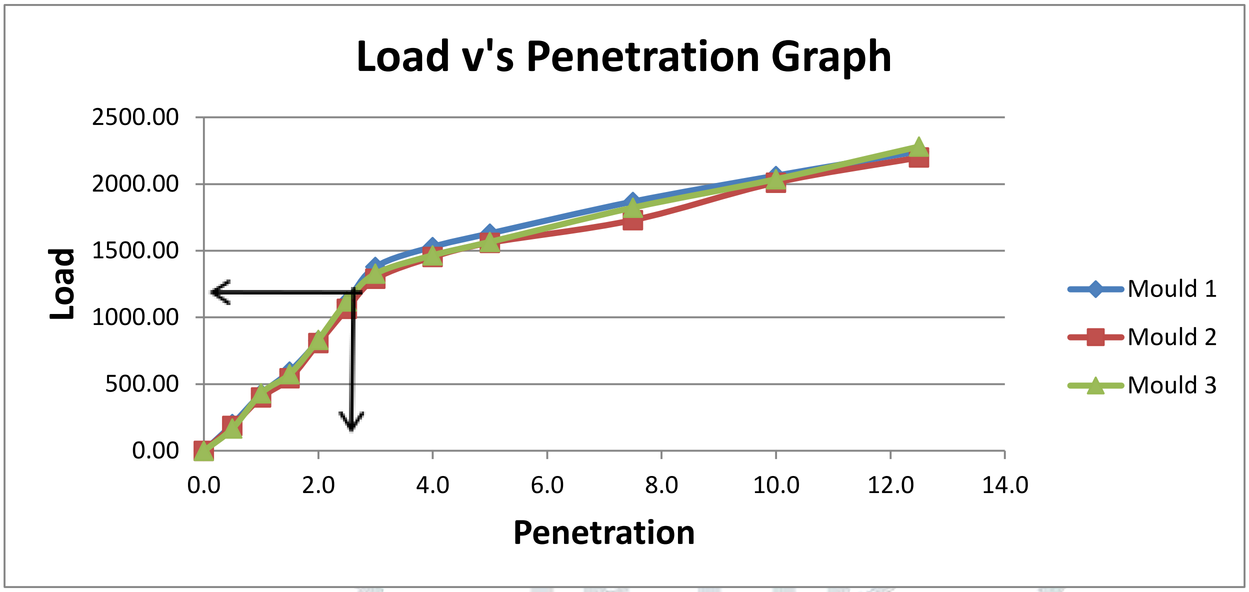

Fig 16. Shows Load v's Penetration graph,

3. Conclusion

1. *From the grading analysis of two samples selected in this study it was found that the excavated soil sample , gravel=16.49%, sand =46.98% ,and silt and clay content =36.53%, while as for tunnel muck material results were gravel=63.88%, sand=33.06, and silt and clay content =3.06*
2. *From the atterbergs limits it was found that excavated soil with more silt and cay has higher liquid limit (27.90) and possess plasticity (23.20%) Pasticity index =4.70% than tunnel muck material with lesser silt and cay content has less liquid limit (24.00) and is non plastic, plasticity index =zero.*
3. *Maximum dry density =1.999 at OMC of 10.04% for excavated soil and for Tunne muck material MDD =2.360 at OMC of 6.10% (much higher for the sample with lesse silt and clay content).*
4. *Free swell index of excavated soil sample was found to be 17.48% while as for tunnel muck material it was found to be 9.54%*
5. *CBR of the excavated soil was found to be 22.70% while as for tunnel muck material was found to be 67.96%*

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