Experimental Study of Poorly Graded Sand Soil by Partial Replacement with Industrial Waste Aluminium Powder at Varying Percentage

Er. Barun Hijam[1], Er. Hema Rani[2], Er. Manjit Kaur[3]

[1]*Research Scholar, Dept. of Civil Engineering, Indo-Global Group of Colleges*
[2]*Assistant Professor, Dept. of Civil Engineering, Indo-Global Group of Colleges*
[3]*Assistant Professor, Dept. of Civil Engineering, Indo-Global Group of Colleges, Punjab, India*

---***---

Abstract:- *In this paper the properties of poorly graded sand soil and industrial waste aluminium powder are studied and the effect on geotechnical properties of the soil is investigated by replacing different amount industrial aluminium waste powder into it. The percentage replaced are 1%, 2%, 3% & 4% by weight respectively. Numerous laboratory experiments are performed on soil, aluminium powder and additive of both. For soil, Specific Gravity test by Pycnometer Method, Sieve Analysis, Standard Proctor Test, Liquid limit, Plastic limit, California bearing Ratio (CBR) test are done. For aluminium powder, Specific Gravity by density bottle method and Sieve Analysis are performed. California Bearing Ratio (CBR) Test is done for the soil mixed with aluminium powder by increasing the quantity of aluminium powder on soil at varying percentage. The maximum value of CBR was obtained at 2 % replacement of aluminium powder with the value of 14.79, which is comparatively satisfactory as per IS 1498 – 1970*

Key words :Poorly graded sand soil, Industrial waste aluminium powder, Specific Gravity – Pycnometer, Density bottle, Sieve Analysis, Standard Proctor, Liquid limit , Plastic limit, , CBR

1. INTRODUCTION

Soil is a mixture of organic matter, minerals, gases, liquids and organisms that together support life. Earth's body of soil, called pedosphere, has four important functions

- As a medium for plant growth
- As a means of water storage, supply and purification
- As a modifier of Earth's atmosphere
- As a habitat for organisms

Soil consist of a solid phase of minerals and organic matter (the soil matrix), as well as porous phase that holds gases (the soil atmosphere) and water (the soil solution). Accordingly, soils scientists can envisage soils as a three state system of solids, liquids and gases.

Soil stabilization is the process of blending and mixing materials with a soil to improve certain properties of the soil. The process may include the blending of soils to achieve a variety of additives including lime, flyash, cement kiln dust, brick kiln dust, and other industrial by products desired gradation or the mixing of commercially available additives that may alter the gradation, texture or plasticity, or act as a binder for cementation of the soil. It is the modification of one or more engineering soil properties by mechanical or chemical methods. The importance of soil stabilization is due to the fact that it enhance their physical properties. Stabilization can increase the shear strength of a soil and control the shrink-swell properties of a soil, thus improving the load bearing capacity of a sub grade to support pavements and foundations. Soil stabilization can be utilized on roadways, parking areas, site-development projects, airports, and many other situations where sub-soils are not suitable for construction. Stabilization can be used to treat a wide range of sub grade materials, varying from expansive clays to granular materials. This process is accomplished using wide.

A poorly graded sand soil is a soil that does not have a good representation of all sizes of particles from the 4.75 mm to 75 micron sieve. A poorly graded sand is symbolize by SP. This type of soil is more susceptible to soil liquefaction than well graded soils.

Aluminium is the most abundant metal in the earth's crust. It ranks second, next only to steel, in terms of volume used due to its versatility, which stems from its excellent and diverse range of physical, chemical and mechanical properties. Aluminium, which is only one – third the weight of steel is highly resistant to most forms of corrosion, is non magnetic, non combustible, is non toxic and impervious (hence used in the food and packaging industries) and is also super conductor of electricity. Other valuable properties include high reflectivity and rapid heat dissipation. The metal malleable and easily worked by the common manufacturing and shaping processes. Aluminium was first produced in 1808. There are three main steps in the process of aluminium production First is the mining of aluminium ore, most commonly bauxite, referred to as bauxite mining. Second is the refining of bauxite aluminum oxide trihydrate known as alumina, and the third is the electrolytic reduction of alumina into metallic aluminium. The process requires approximately two to three tonnes of bauxite for the production of one tonne of alumina, and in turn, approximately two tonnes of alumina is required for making one tonne of aluminium. Aluminium powder is a fine granular powder made from Aluminium. In form of powders, Aluminium is used for several applications such as manufacture of slurry, explosive and detonators, thermit process used for manufacture of ferro alloys and for specialised welding applications such as rails, polytechnic to manufacture crackers, sparkles and other pyrotechnic products; manufacture of aluminium paste, paints and several powder components used in automobiles.

2. LITERATURE REVIEW

Weeraya Chimoye (2017) have studied the behavior of strength of poorly graded sand stabilized with cement and bagasse ash by using shell waste sand. The pozzolanic contents are 5%, 7% and 9% by dry weight of sand and the replacement ratio of cement by bagasse ash are 100:0, 80:20, 60:40, 40:60, 20:80 and 0:100. The strength of specimens was tested by unconfined compression test (USC). It is found that the unconfined compressive strengths of shell waste sand mixed with cement and bagasse ash at the wet side increase with the increasing of percent of pozzolanic. On the opposite way, the unconfined compressive strengths decrease with the increasing of the replacement ratio of cement and bagasse ash. From the standard of Highway Department, it is found that if the admixed shell waste sand with cement and bagasse ash should not exceed 40 percent for pozzolanic content from 5%. But in case, if this admixed shell waste sand with cement and bagasse is used as the base, the replacement ratio of cement and bagasse ash should not exceed 40 percent for pozzolanic content from 7 percent.

Zuheir Karabash, Ali Firat Cabalar and Nurullah Akbulut (2015) studied 'The Behavior of Clayey Soil Reinforced with Waste Aluminium Pieces'. Test were conducted using clayey soil passing the 4.75mm sieve. The soil was filtered to a viscosity limit, plastic limit, plasticity index values of 49, 23 and 26 respectively. The specific density of the clayey soil was found to be 2.72g/cm^2. The soil was classified as CL according to Unified Soil Classification System. The waste materials used during the experimental work were aluminium pieces. The aluminium pieces were the results of the mechanical processing of the metal using CNC (computer numerical control machine). The aluminium pieces had a specific gravity of 2.80g/cm^2. The aluminium pieces have a spiral shape. The maximum dry unit weight and optimum water content for each test was determined using modified compaction test (ASTM 698). Unconfined Compression Strength Test is used to determine the stress-strain behavior of clay-aluminium mixture. The UCS specimens were prepared at variable water contents to study the effect of the compaction water content to the UCS values of the specimens. UCS Tests have been conducted on clay mixtures with various ratios of waste aluminium namely 0, 5, 10, 15 and 20 percent from the dry weight of the mixture. The tests were performed as described in the ASTM D2166 standard. The test results given in this study show the behavior of clay with various aluminium contents: An increase in unconfined compression strength values has been observed until 10 % of a decrease has been observed. Addition of waste aluminium inclusion. Behind that percentage weight. As the waste aluminium content increases optimum water content decreases. The material becomes more ductile as thw waste material increase in the mixture and the failure strain increases.

Ayobami Adebola Busari, Isaac Akinwumi, Paul O. Awoyera, O.M. Olofinnade, T.I Tenebe & J.C Nwanchukwu (2018) have studied 'Stabilization Effect of Aluminium Dross on Tropical Laterite Soil'. This experimental research assessed the engineering and geotechnical properties of Aluminium dross (ALDR). Glumy, this solid waste is usually open dumped with determental effect on the environment. In a bid to reduce solid waste in the environment and also improve pavement interlayer properties, this research utilized ALDR as a stabilizer for the tropical laterite soil. The laterite soil was stablized with the addition of the solid waste at 2 % interval from 2 % to 16 %. Response surface analysis was used in optimizing the strength and consistency of the stabilized soil sample. The addition of this non conventional stabilizer helped in modifying the engineering properties of the soil sample, this had indications on the atterberg limit as the liquid limit, and the plasticity index increased from 43 % to 54.61 % and 28.02 % to 40.8 % respectively, while the plasticity index reduced from 15.1 % to 13.8 % signifying soil improvement. The load bearing capacity of the sample increased from 51.22 % to 62.41 %. Additionally, the unconfined test showed that additional of ALDR residue improved the consistency of the stabilized soil sample. From the model equation, a positive relationship exists between CBR and UCS. R^2 value 0.81 showed the robustness of the model developed. The research showed that aluminium dross is a suitable material for improving the engineering properties of the tropical laterite soil towards a sustainable road construction.

S. K. Tiwari and J. P. Sharma (2013) have studied 'Influence of Fiber-Reinforcement on CBR-Value of Sand'. The effectiveness of inclusion of randomly distributed fibers in sandy soils for improving the California bearing ratio values is investigated through an experimental investigation. The California Bearing Ratio (CBR) Tests were conducted on fine sand reinforced with randomly distributed discrete polypropylene and coir fibers, under both soaked and unsoaked conditions. The paper describes the load penetration response obtained from CBR tests performed on fine sand. The CBR values of fine sand increase significantly due to inclusion of randomly distributed fibers under soaked and unsoaked conditions. The increase in CBR is as high as 100% due to addition of 1.5% fiber.

3. OBJECTIVE OF THE STUDY

1. To determine the index properties of virgin soil.
2. To determine the OMC and MDD of soil by standard proctor test.
3. To find Plasticity Index of soil by finding out Liquid limit (Casagrande Apparatus) and Plastic limit.
4. To determine the index properties of aluminium powder.
5. To determine the impact on soil by evaluating the CBR values with aluminium powder replace at varying percentage.
6. To find the overall effect of aluminium powder on soil.

4. MATERIALS

The soil sample used for this experimental study was collected locally from a construction site of power sub-station near the Botanical Garden, Chandigarh (UT), and the industrial waste aluminium powder used for addition to the soil sample was collected from Industrial Area, Phase 2, Chandigarh.

5. LABORATORY EXPERIMENTS AND RESULTS

Test conducted on soil sample -

1. Specific Gravity by Pycnometer Method.
2. Sieve Analysis.
3. Standard Proctor Test
4. Atterberg Limits (Limit Limit and Plastic Limit)
5. California Bearing Ratio (CBR) Test

Test conducted on Aluminium Powder -

1. Specific Gravity by Density Bottle Method
2. Sieve Analysis

Test conducted on Admixed sample (Aluminium Powder + Soil)

1. California Bearing Ratio

Specific Gravity of Soil by Pycnometer Method

The specific gravity of a soil refers to the ratio of the solid particle's unit weight to the unit weight of water. The test was performed as per IS:2386 (Part 3), 1963. Specific Gravity of Soil was 2.52

Sieve Analysis of Soil

The sieve analysis of soil determines the particle size distribution of a given soil sample and hence helps in easy identification of a soil's mechanical properties. The test was performed as per IS:2720 (Part 4) – 1985. 200g of soil sample is taken for the experiment.

Sl No.	IS Sieve	Mass of Soil Retained	% Retained	Cumulative % Retained	% Finer
1	2 mm	14 g	7	7	93
2	1 mm	20 g	10	17	83
3	0.600 mm	24 g	12	29	71
4	0.425 mm	82 g	41	70	30
5	0.300	6 g	3	73	27

	mm				
6	0.212 mm	26 g	13	86	14
7	0.150 mm	14 g	7	93	7
8	0.075 mm	10 g	5	98	2
9	Pan	4g	2	100	-

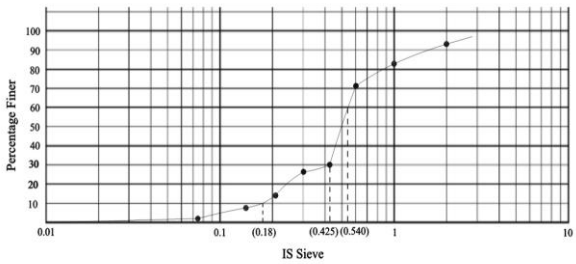

Fig. – Sieve Analysis Graph of Soil

From the graph plotted,

D_{10} = 0.18 mm

D_{30} = 0.425 mm

D_{60} = 0.540 mm

$Cu = D_{60}/D_{10} = 0.540/0.18 = 3$

$Cc = (D_{30})^2/D_{60}xD_{10} = (0.425)^2/(0.540x0.18) = 1.85$

According to Indian Standard Soil Classification System (ISC System), the soil sample was classified as Poorly Graded Sand which is symbolize by SP.

Standard Proctor Test of Soil

The standard proctor test determines the optical moisture content at which a given soil type become most dense and achieve dry density. The test was performed as per IS 2720 (Part 7) – 1980. The diameter of the mould used is 100mm, Height of the mould is 127.3 mm and Volume of the mould is 1000 cc. The amount of soil sample used is 3000 g. The amount of water added is 4% of 3000g = 120g, 8 % of 3000g = 240g, 12% of 3000g = 360g, 16 % of 3000g = 480g respectively.

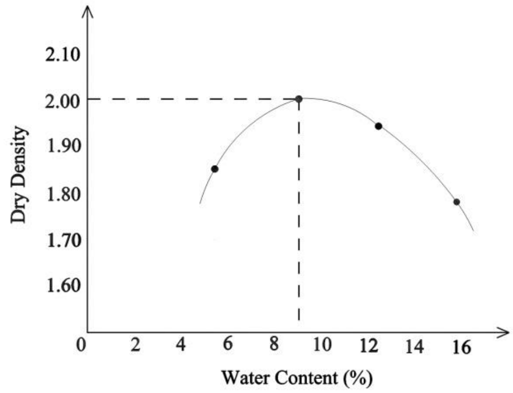

Fig. OMC and MDD Graph of Soil

From the graph plotted,

Maximum Dry Density (MDD) = 2.02 g/cc

Optimum Moisture Content (OMC) = 9.01 %

Atterberg Limit Test of Soil

Liquid Limit of Soil

The liquid limit of a soil is the water content at which the soil behaves practically like a liquid, but has a small shear strength. Liquid limit of soil is done by Casagrande Apparatus as per IS:2720 (Part 5) – 1985.

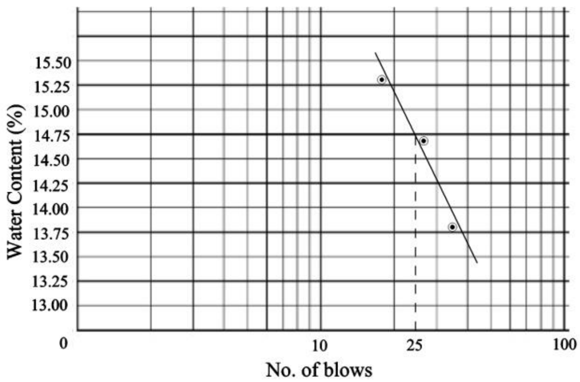

Fig. Liquid Limit Graph

From the above graph,

Liquid Limit (L_L) = 14.75

Plastic Limit of Soil

The plastic limit of a soil is the water content of the soil below which it ceases to be plastic. It begins to crumble when rolled into threads of 3mm diameter. The test was performed as per IS:2720 (Part 5) – 1985.

Plastic Limit (P_L) = (15.76+16.54+17.10)/3 = 16.46

Plasticity Index

The plasticity index (PI) is the size of the range of water contents where the soil exhibits plastic properties. Therefore, PI = Liquid Limit (L_L) - Plastic Limit (P_L) = 14.75 – 16.46 = -1.71 = 0

Specific Gravity of Aluminium Powder by Density Bottle Method

The specific gravity of solid particles is the ratio of mass density of solid to that of water. The test was performed as per IS:2720 (Part 3/Sec 1) – 1980.

The Specific Gravity of Aluminium Powder = (1.15+1.04+1.13)/3 = 1.11

Sieve Analysis of Aluminium Powder

The sieve analysis determines the particle size distribution of a given solid sample and hence helps in easy identification of a solid's mechanical properties. The test was performed as per IS:2720 (Part 4) – 1985. 200 g of aluminium powder sample is taken for the experiment.

Sl No.	IS Sieve	Mass of Soil Retained	% Retained	Cumulative % Retained	% Finer
1	2 mm	14 g	7	7	93
2	1 mm	66 g	33	40	60
3	0.600 mm	100 g	50	90	10
4	0.425 mm	18 g	9	99	1
5	0.300 mm	2 g	1	100	-
6	0.212 mm	-	-	-	-
7	0.150 mm	-	-	-	-
8	0.075 mm	-	-	-	-
9	Pan	-	-	-	-

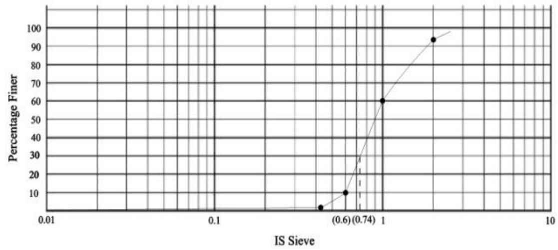

Fig. – Sieve Analysis Graph of Aluminium Powder

From the graph plotted,

D_{10} = 0.6 mm
D_{30} = 0.74 mm
D_{60} = 1 mm
Cu = D_{60}/D_{10} = 1/0.6 = 1.66
Cc = $(D_{30})^2/D_{60}xD_{10}$ = $(0.74)^2/(1x0.6)$ = 0.91

California Bearing Ratio (CBR) Test of Soil

The California Bearing Ratio test is conducted for evaluating the suitability of the sub-grade and the material used in sub-base and base of a flexible pavement. The following tests was conducted as per IS:2720 (Part 16) – 1987. All the CBR tests done in this study are performed in un-soaked condition with heavy compaction as per specification. 5000g of sample is taken for each experiment. The varying quantity of aluminium powder to be replaced on soil are done within the 5000g sample. The quantity of water used for mixing the sample is taken from the Optimum Moisture Content (OMC) value i,e 9.01 %. The CBR tests was first performed on virgin poorly graded sand soil, then replaced with 1 %, 2%, 3% and 4% of industrial waste aluminium powder by weight and all the results were monitored and observed carefully.

Sl No.	Penetration Dial Gauge		Penetration Load	Standard Load (kg)
	Penetration (mm)	Dial Gauge Reading		
1	0.0	0	0	
2	0.5	5.2	26	
3	1.0	8.8	44	
4	1.5	12	60	
5	2.0	15.2	76	
6	2.5	17.8	89	1370
7	3	20.6	103	

8	4	26.8	134	
9	5	32.4	162	2055
10	7.5	42	210	
11	10	49.4	247	
12	12.5	62.8	314	

CBR value for 2.5 mm penetration = (89/1370)x100 = 6.49 %
CBR value for 5 mm penetration = (162/2055)x100 = 7.88 %
CBR value of this test is 7.88 %

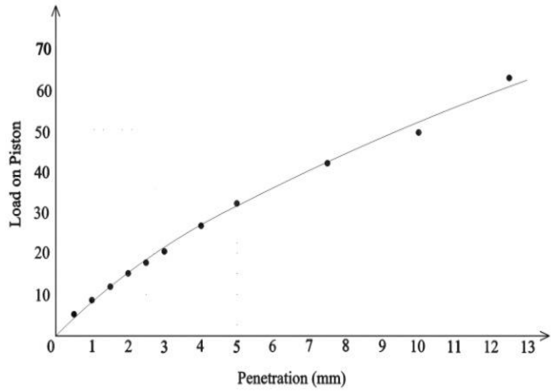

Fig. CBR Graph for Soil

California Bearing Ratio (CBR) of Soil with 1 % Replacement of Aluminium Powder

Sl No.	Penetration Dial Gauge		Penetration Load	Standard Load (kg)
	Penetration (mm)	Dial Gauge Reading		
1	0.0	0	0	
2	0.5	6.2	31	
3	1.0	10	50	
4	1.5	14	70	
5	2.0	17.8	89	
6	2.5	22	110	1370
7	3	25.8	129	
8	4	34	170	
9	5	42.4	212	2055
10	7.5	63.4	317	
11	10	86	430	
12	12.5	108.2	541	

CBR value for 2.5 mm penetration = (110/1370)x100 = 8.02 %
CBR value for 5 mm penetration = (212/2055)x100 = 10.31 %
CBR value of this test is 10.31 %

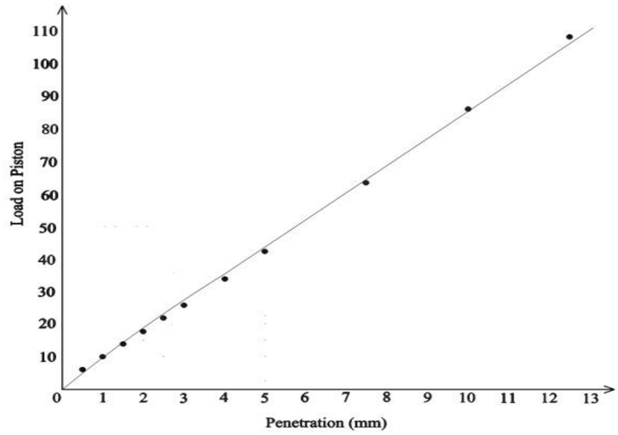

Fig. CBR Graph for Soil with 1 % Replacement of Aluminium Powder

California Bearing Ratio (CBR) of Soil with 2 % Replacement of Aluminium Powder

Sl No.	Penetration Dial Gauge		Penetration Load	Standard Load (kg)
	Penetration (mm)	Dial Gauge Reading		
1	0.0	0	0	
2	0.5	10.8	54	
3	1.0	16.8	84	
4	1.5	22.4	112	
5	2.0	27.8	139	
6	2.5	33	165	1370
7	3	38.6	193	
8	4	49.8	249	
9	5	60.8	304	2055
10	7.5	88.8	444	
11	10	115.2	576	
12	12.5	143.8	719	

CBR value for 2.5 mm penetration = (165/1370)x100 = 12.04 %
CBR value for 5 mm penetration = (304/2055)x100 = 14.79 %
CBR value of this test is 14.79 %

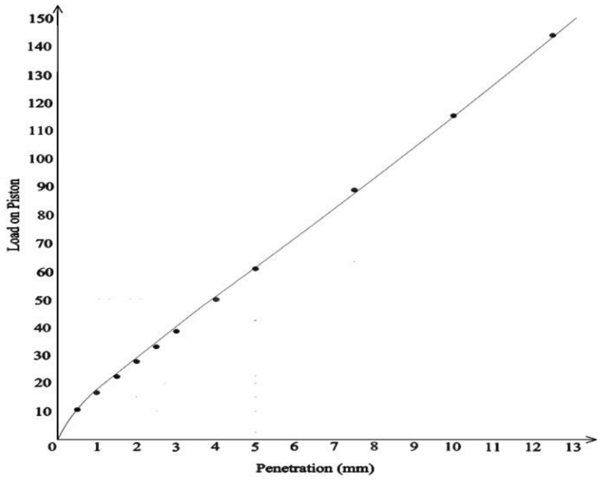

Fig. CBR Graph for Soil with 2 % Replacement of Aluminium Powder

California Bearing Ratio (CBR) of Soil with 3 % Replacement of Aluminium Powder

Sl No.	Penetration Dial Gauge		Penetration Load	Standard Load (kg)
	Penetration (mm)	Dial Gauge Reading		
1	0.0	0	0	
2	0.5	4.4	22	
3	1.0	6.2	31	
4	1.5	8.2	41	
5	2.0	10.2	51	
6	2.5	12.6	63	1370
7	3	15	75	
8	4	20.2	101	
9	5	26,4	132	2055
10	7.5	44.4	222	
11	10	62.6	313	
12	12.5	82	410	

CBR value for 2.5 mm penetration = (63/1370)x100 = 4.59 %
CBR value for 5 mm penetration = (132/2055)x100 = 6.42 %
CBR value of this test is 6.42 %

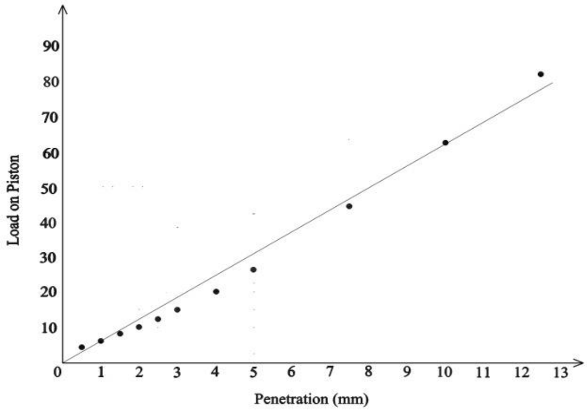

Fig. CBR Graph for Soil with 3 % Replacement of Aluminium Powder

California Bearing Ratio (CBR) of Soil with 4 % Replacement of Aluminium Powder

Sl No.	Penetration Dial Gauge		Penetration Load	Standard Load (kg)
	Penetration (mm)	Dial Gauge Reading		
1	0.0	0	0	
2	0.5	7	35	
3	1.0	11	55	
4	1.5	15	75	
5	2.0	19	95	
6	2.5	23.2	116	1370
7	3	27.6	138	
8	4	36.2	181	
9	5	45.2	226	2055
10	7.5	69	345	
11	10	93.8	469	
12	12.5	119.8	599	

CBR value for 2.5 mm penetration = (116/1370)x100 = 8.46 %
CBR value for 5 mm penetration = (226/2055)x100 = 10.99 %
CBR value of this test is 10.99 %

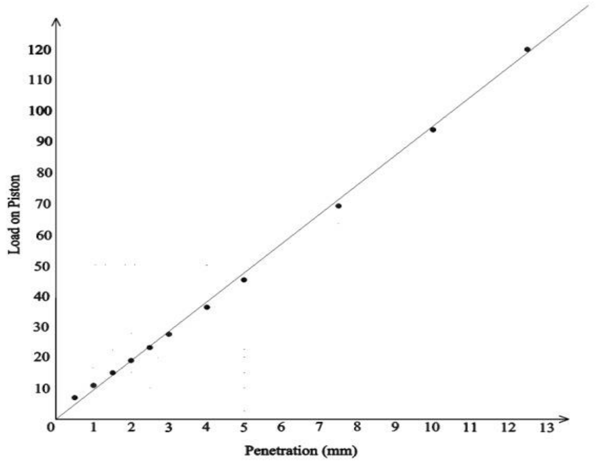

Fig. CBR Graph for Soil with 4 % Replacement of Aluminium Powder

The graph below shows comparison of CBR values of soil mixed with different percentage of aluminium powder namely 0,1,2,3 and 4 percent.

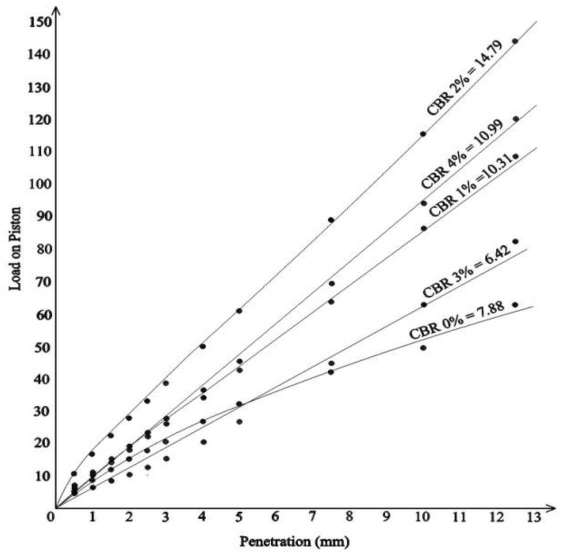

Fig. Combination CBR Graph for Soil and Soil Admixed with 1,2,3 and 4 % of Aluminium Powder

6. CONCLUSIONS

1. According to the Indian Standard Soil Classification System (ISC System) the soil is classified as poorly graded sand soil i,e SP
2. The Specific Gravity of the soil sample is found out to be 2.52 whereas for aluminum powder the specific gravity is 1.11
3. From the sieve analysis of soil, we find Cu = 3 and Cc = 1.85
4. Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) of the soil is found out be 9.01 % and 2.02 g/cc respectively.
5. The Liquid limit and the Plastic limit of the soil is obtained as 14.75 and 16.46 respectively. Plasticity Index is 0
6. After performing the California Bearing Ratio Test, the CBR value for the virgin soil is obtained as 7.88 %. And for the admixed sample with 1 %, 2%, 3% and 4 % of aluminium powder, we obtained the values of 10.31, 14.79, 6.42 and 10.99 respectively. The maximum value of CBR was obtained at 2 % replacement of aluminium powder on poorly graded sand soil.

7. FUTURE SCOPE

1. Examine the overall effect on poorly graded sand by partial replacement with different form of aluminium i,e pieces and crumbles etc at varying percentage.
2. Determine the effect of poorly graded sand mixed with aluminium powder and other various metal powders.
3. Determine the impact of poorly graded sand replace with steel powders at various percentages.
4. Determine the geotechnical properties of clayey soil by adding aluminum powder.

8. REFERENCES

[1] Weeyara Chimoye (2017) “Strength Behavior of Poorly Graded Sand Improved by Cement and Bagasse Ash” International Journal of Engineering Research and Technology, vol. 6, Issue – 06

[2] Zuheir Karabash, Ali Firat Cabalar and Nurullah Akbul=ut (2015) “The Behavior of Clayey Soil Reinforced with Waste Aluminium Pieces”, Procedia Earth and Planetary Science, vol. 15, pp 353-358

[3] Ayobami Adebola Busari, Isaac Akinwumi, Paul O. Awoyera, O.M. Olofinnade, T.I Tenebe & J.C Nwanchukwu (2018) “Stabilization Effect of Aluminium Dross on Tropical Laterite Soil”, International Journal of Engineering and Research in Africa, vol. 29, pp 86-96

[4] S. K. Tiwari and J. P. Sharma (2013) "Influence of Fibre-Reinforcement on CBR value of sand" Electronic Journal of Geotechnical Engineering. Vol. – 18

[5] IS: 2386 (Part III), 1963, Method of Test for Aggregates for Concrete. Specific Gravity, Density Voids, Absorption and Bulking, 2.4. Method III – Aggregate smaller than 10 mm, pp – 8 - 11, Bureau of Indian Standard, New Delhi.

[6] IS: 2720 (Part 4) – 1985, Method of Test for Soils - Grain Size Analysis. 4. Sieve Analysis of Soil Passing 4.75 mm and Retained on 75 Micron IS Sieve, pp – 6 – 8, Bureau of Indian Standards, New Delhi.

[7] IS: 1498 -1970, Classification and Identification of Soils for General Engineering Purposes, Bureau of Indian Standards, New Delhi.

[8] IS 2720 (Part 7) – 1980, Method of Test for Soils - Determination of Water Content Density Relation using Light Compaction, Bureau of Indian Standard, New Delhi.

[9] IS: 2720 (Part 5) – 1985, Method of Test for Soils – Determination of Liquid Limit and Plastic Limit, Bureau of Indian Standard, New Delhi.

[10] IS:2720 (Part 3/Sec 1) – 1980, Method of Test for Soils – Determination of Specific Gravity, Bureau of Indian Standard, New Delhi.

[11] IS:2720 (Part 16) – 1987, Methods of Test for Soil – Laboratory Determination of CBR, Bureau of Indian Standard, New Delhi.