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SWELL BEHAVIOUR OF EXPANSIVE SOILTREATED WITH GRANULATED MILD STEEL SLUDGE

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Abstract: Engineering restrictions because of loose soils have been observed in large number of countries all around the world. They waste millions of dollars due to their ill effects on structures. Such damages are very effective especially in the arid and semi-arid zones. Expansive soils with the composition of the clay mineral montmorillonite with clay stones, sedimentary, shales and residual soils are having the tendency of absorption of water and thereby swell. The porous nature of the soil is very rare near the ground surface where the wearing layer is enhanced to seasonal and environment variations. As they absorb the water more and more, their volume increases. Similarly Expansive soils shrink due to the loss of water.

1.0 Introduction

1.1 Expansive soils: Expansive soils are also known as swelling soils or shrink-swell soils because they are having the tendency to swell and shrink with the changing environmental conditions usually moisture content. This Swell and Shrink behavior of soil causes significant distress in the soil, leading to severe damage to the both sub as well as super structure. During rainy seasons, these soils undergo absorption of water, then swell and become soft hence their capacity is reduced, alternatively while in drier seasons, the voids are reduced and the soils shrinks and become compacted due to loss of water being evaporated. Such types of soils are commonly found in arid and semi-arid regions of the world. These soils are almost harmful unless mechanically stabilized and are considered as a potential natural hazardous.

These soils if not treated well can cause robust damages to both the structures built upon them and which are to be build and also can cause loss of human life. Montomorillonite clay minerals containing soils generally exhibit these properties. The approximate annual cost of damage to the civil engineering structures built on such soils caused by the shrink and swell are estimated to be many billions of dollars worldwide.

Blast furnace slag is a waste and by-product material generated from thermal power plants due to combustion of iron, iron ore, iron scrap, and fluxes (limestone or dolomite) are changed into a slag along with coke for fuel. The combustion of coke is used to produce carbon monoxide, which changes the iron ore to molten iron. This molten iron product can be iron products, usually it is used as a feedstock in steel manufacturing and production. Blast furnace slag is a non-metallic by-product produced in the process. The main constituents of Blast furnace slag are silicates, alumina silicates, and calcium alumina silicates.

The molten slag comprises about 20 percent by mass of iron production, which absorbs much of the sulphur from the charge. Most of the by products are considered as Scrap, blast furnace slag also is considered as a waste disposal which can be only be used in the construction material like road, pavement, railway ballast, landfills etc. GMSS is obtained by quenching molten iron slag (a by-product of iron and steel-making) from a blast furnace in steam, to produce a crystal, rounded product that is then dried and grounded into a very fine powder. As it is considered as pozollanic material, it has a cementitious property which acts as binding material in the soil. In general, the presence of sufficient quantity of lime results in increasing the slag basicity and compressive strength.

This waste material is readily available and also economical. The chemical composition of a slag varies considerably depending on the composition of the raw materials used in the process of iron production. Silicate and aluminate impurities from the ore and coke are mixed in the blast furnace with a flux which reduces the viscosity of the slag. In the case of pig iron production the flux consists mostly of a mixture of limestone and forsterite or in some cases dolomite. In the blast furnace the slag floats on top of the iron and is decanted for separation. Slow cooling of slag melts results in an unreactive crystalline material consisting of an assemblage of Ca-Al-Mg silicates.

2.0 Swelling Soils:

Swelling soils are soft bedrock soils that undergo change in volume due to the change in moisture; they increase in volume as they get wet and shrink as they dry out. These soils are also commonly known as expansive, bentonite, or montmorillinitic soils. The uneven swelling and heaving of steeply dipping bedrock layers result in "roller-coaster road". Soils which are having high shrink–swell capacity mostly damage the crops during dry spells, as the soil contracts, and the roots are pulled apart. Soil with shrink-swell tendency causes engineering problems, and heavy damage to existing structures. The swelling of soils forces the structures to heave or uplift, and the shrinking can cause uneven settling of sediment underneath foundations, drastically causing the structure instability and hence to fail.

Most of the structures that sustain soil damage are foundations, walls, driveways, swimming pools, roads, pipelines, and basement floors. Very less construction in the India are built on soils that are considered unstable, because of the severe damaging effect in such soil. This damage includes large cracks in walls and foundations, buckling of driveways and roads, and jamming of doors and windows. The rapid urbanization and industrialization have resulted in generation of large quantities of wastes, most of which do not find any effective use and create use and create environmental and ecological problems apart from occupying large portions of valuable land.

Disposal of industrial waste or by-products also has become more difficult and expensive because of increasing stringent environmental regulations and shortages of suitable nearby disposal sites. It has been observed that some of these wastes have high potential and can be utilized as raw mix or blending ingredient in cement manufacturing or other industries. If these materials can be suitably utilized in construction of roads, highways and embankments then the pollution problem caused by the industrial wastes can be greatly reduced along with the problems related to the scarcity of land for the disposal.

3.0 Experimental Investigations

3.1 Materials Used

3.1.1 Expansive/loose soil: Soil used in this experiment has been collected from a village near Pattan located in Srinagar (J&K). The soil is classified as highly compressible clay, CH, as per IS:1498(1970). The grain size distribution and the other physical properties of soil have been reported in Table 4.1.

3.1.2 Mild Steel Sludge: Mild Steel Sludge has been procured from Everest Industries, Roorkee. It has been pulverized and sludge particles passing through 425micron sieve have been used in the study. The specific gravity of the Sludge is 7.86 as obtained from the manufacturer.

3.2 Methodology: Various test methods have been used for the research including field as well as lab work. The important among all were Swell Pressure Test by Consolidometer Method and the Standard Proctor Test.

3.2.1 Standard Proctor Tests: In geotechnical engineering, soil compactions the process in which a stress applied to a soil causes densification as air is displaced from the pores between the soil grains. It is an instantaneous process and always takes place in partially saturated soil (three phase system). The Proctor compaction test is a laboratory method of experimentally determining the optimal moisture content at which a given soil type will become most dense and achieve its maximum dry density.
Determination of the relationship between the moisture content and density of soils compacted in a mould of a given size with a 2.5 kg rammer dropped from a height of 30 cm. the results obtained from this test will be helpful in increasing the bearing capacity of foundations, Decreasing the undesirable settlement of structures, Control undesirable volume changes, Reduction in hydraulic conductivity, Increasing the stability of slopesand so on.

In this research the SPT have been conducted to determine the Optimum Moisture Content and Max Dry Density of the parent Soil and the Stabilized Soil with 4,8,12,16 and 20% of mild Steel Sludge passing through IS 425 micron sieve.

These tests were carried in order to prepare specimens at maximum dry density by adding desired optimum moisture content as per specifications of IS: 2720(1974). The results of Standard Proctor test have been reported in Table 4.2 and 4.2-4.9.

3.2.2 Swell Pressure Using Consolidometer

3.2.2.1 Composition of Specimen : Specimens of parent soil and soil treated with 4%, 8%, 12%, 16% and 20% of Mild Steel Sludge by dry weight of soil were prepared at maximum dry density and optimum moisture content as per IS: 2720(1974).

3.2.2.2 Mixing : Oven dry sample was dry mixed with various percentages of additives. Sufficient quantity of distilled water was then added to bring the moisture content to the desired level. The mixture was then thoroughly mixed with a spatula. All the specimens were kept in polythene bags for maturing for three days.

3.2.2.3 Compaction : Specimens were compacted by static compaction in 10 cm diameter consolidation ring to the required height of 2.5cm. The inner surface of the ring was smeared with mobile oil to minimize friction between inner surfaces of the ring and the soil sample. The wet homogeneous mixture was then placed inside the specimen ring using the spoon in three layers, leveled and top compacted by 5cm diameter ram. Sample was placed in specimen ring with extension collar attached to it and both the external surfaces of the specimen were covered with saturated filter paper. After that porous stone and pressure pad was inserted into the extension collar and the whole assembly was statically compacted in loading frame to the desired density. The sample was kept under static load for not less than 10 minutes in order to account any subsequent increase in height of sample due to swelling.

3.2.3 Testing Program : A series of swell pressure tests were conducted by consolidometer method to determine the swell pressure of untreated expansive soil and soil treated with industrial waste to evaluate the effect of addition of industrial waste on swell pressure. In consolidometer method, the volume change of soil is permitted and corresponding pressure required to bring back the soil to its original position is measured. A consolidometer provides means for submerging the sample, for applying the vertical load and for measuring the change in thickness of specimen.

3.2.4 Apparatus Used

1. Three-gang fixed ring, one way drained one dimensional consolidometer.
2. Fixed ring cell with specimen ring of 100mm diameter, 25mm height, with an extension collar, a bottom porous stone-120mm in diameter and a top porous stone with 100mm diameter.
3. For applying vertical pressure, lever arm loading mechanism with a lever arm constant of 10.
4. For measurement of vertical deformation in the sample, deformation dial gauge with a least count of 0.01 mm.

3.2.5 Procedure :A series of well pressure tests were conducts by consolidated method on parent soil and soil treated with various percentage of additives. Statically compacted specimen was placed in fixed ring consolidometer where only the top porous stone is permitted to move downwards as the specimen compressed .Consolidometer was assembled with the ring having the soil specimen and saturated porous stone at the top. Filter paper was placed between soil specimen and porous stone. Assembly was the mounted on the loading frame. The holder with the dial gauge to record the progressive vertical heave (swelling)of the specimen under no load, was then screwed in place and adjusted in such a way for the compression of the soil, if any. Lever arm loading beam was leveled in a horizontal position with appropriate loading transmitting member in contact with pressure pad through a ball seating before applying load. Steel ball was placed on the space provided on the pressure pad to maintain vertically of loads. While mounting the assembly in consolidometer, specimen ring with collar is placed first and then outer ring of tough is place in order to avoid any gap resulting from improper assembly procedure. All the three test samples were mounted simultaneously in order to avoid any disturbance in dial gauge reading of a previously mounted specimen due to mounting of subsequent specimen. A seating load of 0.06 kg/cm^2 was applied and initial reading of dial gauge was noted at this stage. The system was then connected to a water reservoir with the level of water in reservoir at about the same level as that of soil specimen and water allowed to follow in the sample. A Time gap of 5 minutes will be maintained for connecting the sample to water reservoir and commencement of swelling in the three sample. The consolidometer tough was also completely filled with water to keep the specimen saturated during the test. The test specimen were allowed to swell under a seating load of 0.06 kg /cm^2 for period of 6-7 days or still swelling get became constant. The free swell reading shown by the dial gauge under the seating load was recorded at different time intervals. The dial gauges reading were taken till equilibrium is reached. This was ensured by making a plot of swelling dial reading versus time in hours till the plot becomes asymptotic with abscissa(time scale).The vertical expansion of the specimen was measured by means of a deformation dial gauge, and dial reading were taking at elapsed time of 0,1/2,4,8,20,24, 32,44,56 and 64 Hrs and greater if required. The equilibrium swelling get is normally reached over a period of 5-7days in general for all expensive so list. The swollen same was then subjected to consolidations under different pressures of 0.11,0.26, 0.51, 1.02, 2.015 and 4.002 kg/cm^2.The compression dial reading was recorded till the dial reading became constant or for maximum period of 24 hours for each load applied over the specimen. The consolidation load was applied till the specimen attained is original volume.

3.2.6 Precautions

1. Porous stone should be fully saturated by boiling in water for about 25 minutes.
2. Load applied should be axial.
3. Throughout the test, container trough should be kept filled with water.
4. Grease should be applied at all the joints in order to prevent leakage of water from the consolidometer.
5. Water in the consolidometer trough and reservoir is kept at same level in order to avoid any pressure difference.
6. In case of level arm loading system, the apparatus shall be properly counterbalanced by ensuring that the yoke is horizontal position
7. Weight of loading pad should be included while calculating pressure value.

3.2.7 Evaluation of swell pressure: The observed swelling dial gauge reading have been recorded in Table 4.3 to 4.9 and plotted with elapsed time as abscissa and specimen have (H) as ordinate on natural scale in Fig 4.10 to 4.17 for Virgin soil and soil treated with various percentage of granulated mild steel sludge. A smooth curve is drawn joining these points. As the curve so drawn becomes asymptotic with the abscissa, the swelling reaches its maximum and hence the swelling phase in stopped and the consolidation phase is started.

The compression reading have been recorded in Table 4.10 to 4.16 and plots of change in thickness of expanded specimen as ordinate and consolidation pressure applied as abscissa as abscissa of semi-logarithmic scale have been shown in Fig 4.18 to 4.25.Initially, a flat curve is obtained as the sample preparation and thereafter it changes to a straight line for normally consolidated condition. The swelling pressure executed by the soil specimen under soil specimen under zero swelling condition will be obtained by interpolation.

Table 3.1 Index Properties of Parent soil

Physical Properties		Value
Grain Size Distribution Data	Gravel (%)	0
	Sand (%)	0
	Clay + Silt(%)	100
Specific Gravity		2.91
Liquid Limit		68
Plastic Limit		28
Plasticity Index		42
IS Classification		CH
OMC (%)		27
MDD (%)		1.603

Table 3.2 Compaction Characteristics of Stabilized Soil

Sample Description	Compaction Properties	Percentage of Stabilizer (Granulated Mild Steel Sludge)				
		4%	8%	12%	16%	20%
Parent Soil+ Mild Steel Sludge	OMC (%)	25.1	24.8	24.3	23.5	22.5
	MDD (g/cc)	1.65	1.71	1.76	1.79	1.83

Variation of Specimen Heave with Time (Table 4.3-4.9)

Table 3.3 Sample -1 (Parent Soil)

Time (hrs)	Initial Dial Gauge Reading (mm)	Final Dial Gauge Reading (mm)	Expansion (mm)
0	11.01	11.01	0
0.5	11.01	11.16	0.15
1	11.16	11.31	0.35

2	11.31	11.43	0.42
4	11.43	11.65	0.64
8	11.65	11.70	0.69
20	11.70	11.73	0.72
24	11.73	11.80	0.79
32	11.80	11.80	0.79
44	11.80	11.80	0.79
56	11.80	11.82	0.81
68	11.82	11.82	0.81
80	11.82	11.82	0.81
92	11.82	11.82	0.81

Table 3.4 Sample-2 (Parent Soil + 4% MSS)

Time (hrs)	Initial Dial Gauge Reading (mm)	Final Dial Gauge Reading (mm)	Expansion (mm)
0	11.20	11.20	0
0.5	11.20	11.28	0.08
1	11.28	11.38	0.18
2	11.38	11.47	0.27
4	11.47	11.57	0.37
8	11.57	11.57	0.37
20	11.57	11.58	0.38
24	11.58	11.65	0.45
32	11.65	11.67	0.47
44	11.67	11.68	0.48
56	11.68	11.70	0.50
68	11.70	11.72	0.52
80	11.72	11.80	0.60
92	11.80	11.80	0.60

Table 3.5 Sample-2 (Parent Soil + 8% MSS)

Time (hrs)	Initial Dial Gauge Reading (mm)	Final Dial Gauge Reading (mm)	Expansion (mm)
0	11.15	11.15	0
0.5	11.15	11.15	0
1	11.15	11.16	0.01
2	11.16	11.18	0.03
4	11.18	11.22	0.07
8	11.22	11.28	0.13
20	11.28	11.30	0.15
24	11.30	11.36	0.21
32	11.36	11.40	0.25
44	11.40	11.49	0.34
56	11.49	11.51	0.36
68	11.51	11.55	0.40
80	11.55	11.58	0.43
92	11.58	11.58	0.43

Table 3.6 Sample-2 (Parent Soil + 12% MSS)

Time (hrs)	Initial Dial Gauge Reading (mm)	Final Dial Gauge Reading (mm)	Expansion (mm)
0	12.20	12.20	0
0.5	12.20	12.20	0
1	12.20	12.21	0.01
2	12.21	12.23	0.03
4	12.23	12.30	0.10
8	12.30	12.32	0.12

20	12.32	12.38	0.18
24	12.38	12.41	0.21
32	12.41	12.42	0.22
44	12.42	12.45	0.25
56	12.45	12.48	0.28
68	12.48	12.49	0.29
80	12.49	12.49	0.29
92	12.49	12.49	0.29

Table 4.7 Sample-5 (Parent Soil + 16% MSS)

Time (hrs)	Initial Dial Gauge Reading (mm)	Final Dial Gauge Reading (mm)	Expansion (mm)
0	10.05	10.05	0
0.5	10.05	10.06	0.01
1	10.06	10.08	0.03
2	10.08	10.10	0.05
4	10.10	10.15	0.10
8	10.15	10.20	0.15
20	10.20	10.21	0.16
24	10.21	10.26	0.21
32	10.26	10.28	0.23
44	10.28	10.30	0.25
56	10.30	10.32	0.27
68	10.32	10.33	0.28
80	10.33	10.35	0.30
92	10.35	10.37	0.32

Table 4.8 Sample-2 (Parent Soil + 20% MSS)

Time (hrs)	Initial Dial Gauge Reading (mm)	Final Dial Gauge Reading (mm)	Expansion (mm)
0	9.39	9.39	0
0.5	9.39	9.39	0
1	9.39	9.40	0.01
2	9.40	9.42	0.02
4	9.42	9.45	0.06
8	9.45	9.50	0.11
20	9.50	9.51	0.12
24	9.51	9.52	0.13
32	9.52	9.52	0.13
44	9.52	9.53	0.14
56	9.53	9.53	0.14
68	9.53	9.53	0.14
80	9.53	9.53	0.14
92	9.53	9.54	0.15

Compression of Expanded Specimens w.r.t Load Intensity (Table 4.10-4.16)

Table 4.10 Sample-1 (Parent Soil)

Load Intensity (kg/cm2)	Compression (mm)
0.06	0.90
0.11	0.87
0.26	0.83
0.51	0.66
1.02	0.27
2.015	-0.69

Table 4.11 Sample-2 (Parent Soil + 4% MSS)

Load Intensity (kg/cm2)	Compression (mm)
0.06	0.51
0.11	0.50
0.26	0.28
0.51	0.01
1.02	-0.45

Table 4.12 Sample-3 (Parent Soil + 8% MSS)

Load Intensity (kg/cm2)	Compression (mm)
0.06	0.30
0.11	0.28
0.26	0.19
0.51	-0.07

Table 4.13 Sample-4 (Parent Soil + 12% MSS)

Load Intensity (kg/cm2)	Compression (mm)
0.06	0.22
0.11	0.21
0.26	0.15
0.51	-0.15

Table 4.14 Sample-5 (Parent Soil + 16% MSS)

Load Intensity (kg/cm2)	Compression (mm)
0.06	0.13
0.11	0.13
0.26	0.05
0.51	-0.30

Table 4.15 Sample-6 (Parent Soil + 20% MSS)

Load Intensity (kg/cm2)	Compression (mm)
0.06	0.06
0.11	0.05
0.26	-0.17
0.51	-0.25

Tables for Change in Thickness and Total Heave time

Table 5.1 ΔH (mm) (Change in thickness) of treated Soil

Description Of Sample	Percentage of Stabilizer					
	0%	4%	8%	12%	16%	20%
Parent Soil +Mild Steel Sludge	0.87	0.52	0.23	0.21	0.11	0.08

Table 5.2 Total Heave time (hour) of Soil treated with various Percentages of Granulated Mild Steel Sludge

Description of Sample	Percentage of Stabilizer					
	0%	4%	8%	12%	16%	20%
Parent Soil+Mild Steel Sludge	56	44	56	44	20	8

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Table for Swell Potential and Swell Pressure

Table 5.3 Swell Potential (%) of Soil treated with various percentages of Mild Steel Sludge

Description Of Sample	Percentage of Stabilizer					
	0%	4%	8%	12%	16%	20%
Parent Soil+Mild Steel Sludge	3.48	2.08	0.92	0.84	0.44	0.32

Table 5.4 Swell Pressure of treated soil(kg/cm^2)

Description Of Sample	Percentage of Stabilizer					
	0%	4%	8%	12%	16%	20%
Parent Soil+ Mild Steel Sludge	1.32	0.55	0.43	0.39	0.29	0.18

APPENDIX-B: FIGURES

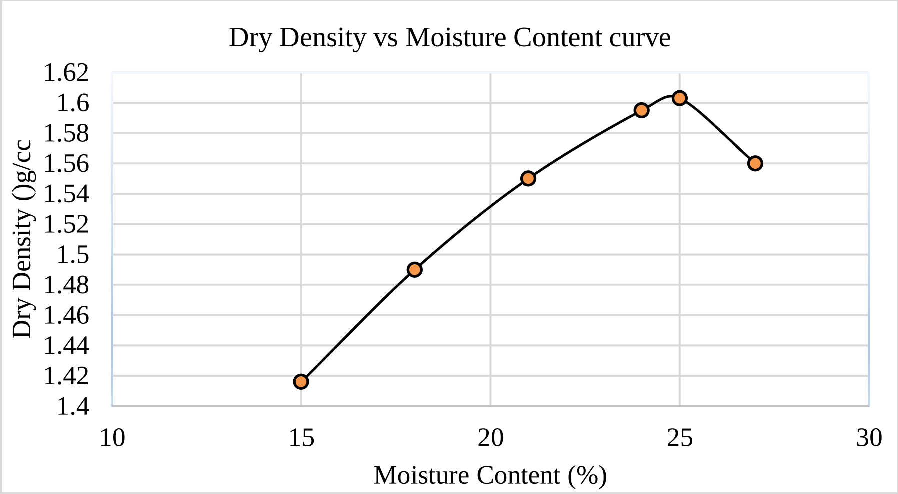

Fig 4.1 Compaction Curve for Parent Soil

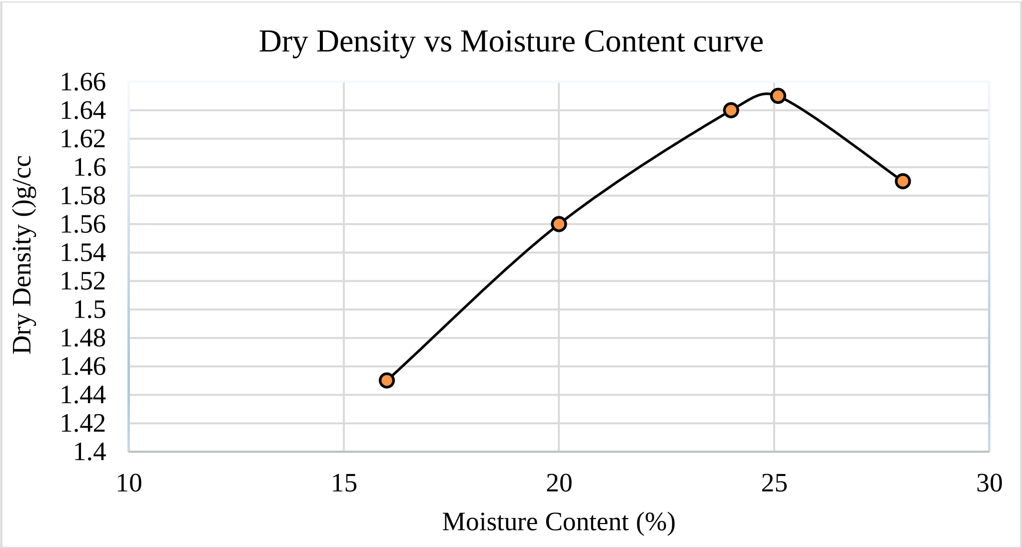

Fig 4.2Compaction Curve for Parent Soil + 4 % MSS

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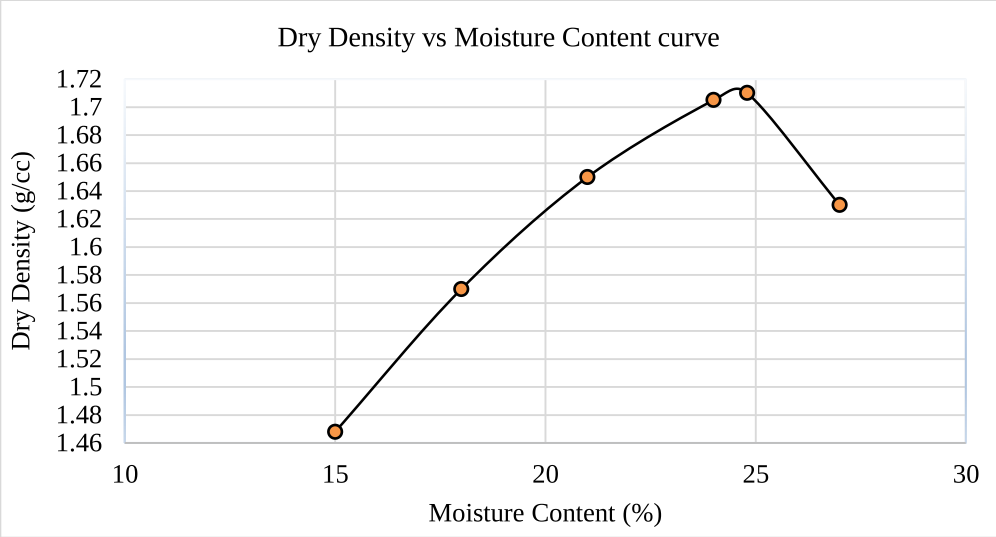

Fig. 4.3 Compaction Curve for Parent soil + 8% MSS

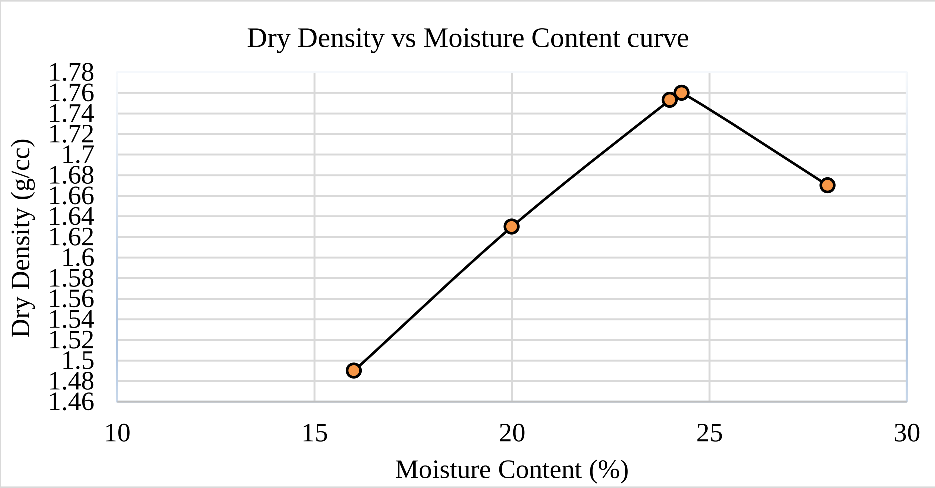

Fig. 4.4 Compaction Curve for Parent soil + 12% MSS

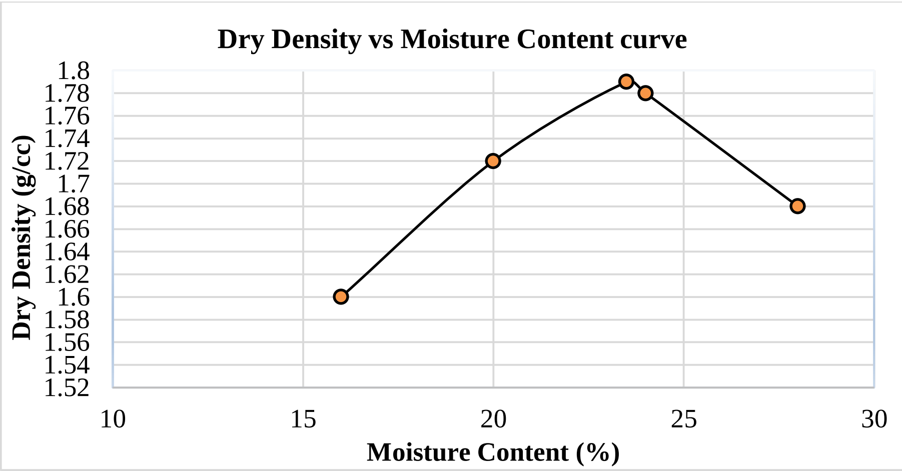

Fig. 4.5 Compaction Curve for Parent Soil + 16% MSS

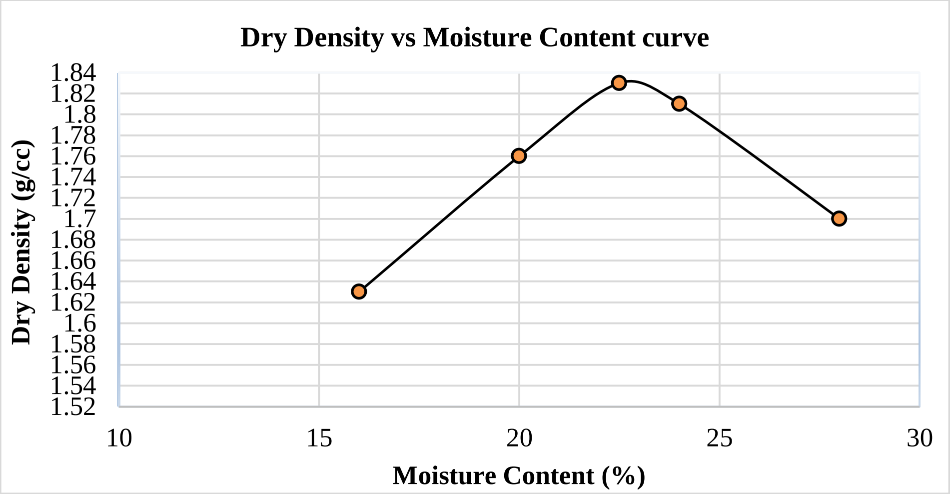

Fig 4.6 Compaction Curve for Parent Soil + 20 % MSS

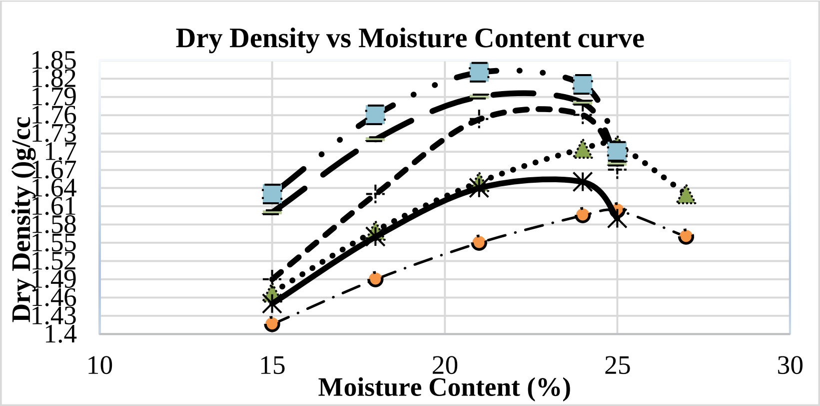

Fig. 4.7 Comparison of Compaction Curves

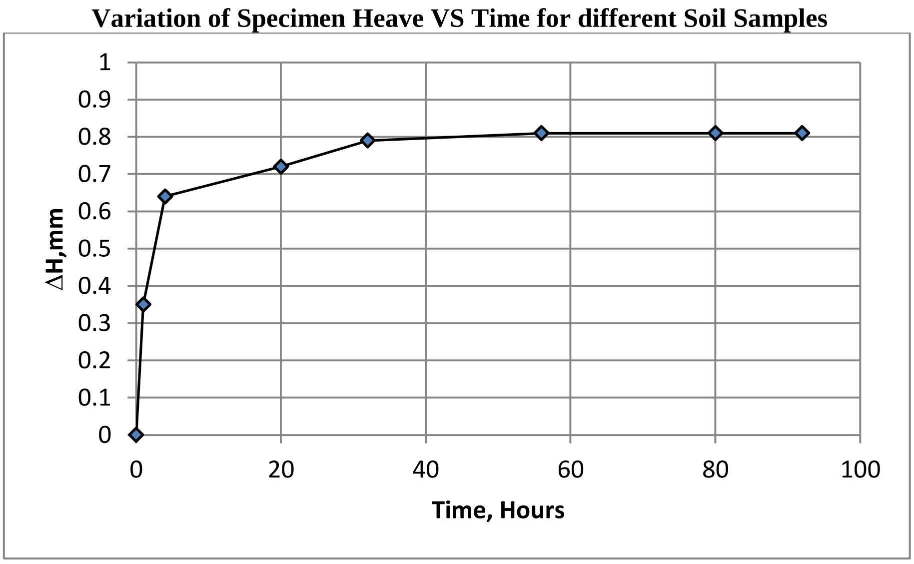

Fig 4.8 Specimen Heave VS Time curve for Parent Soil

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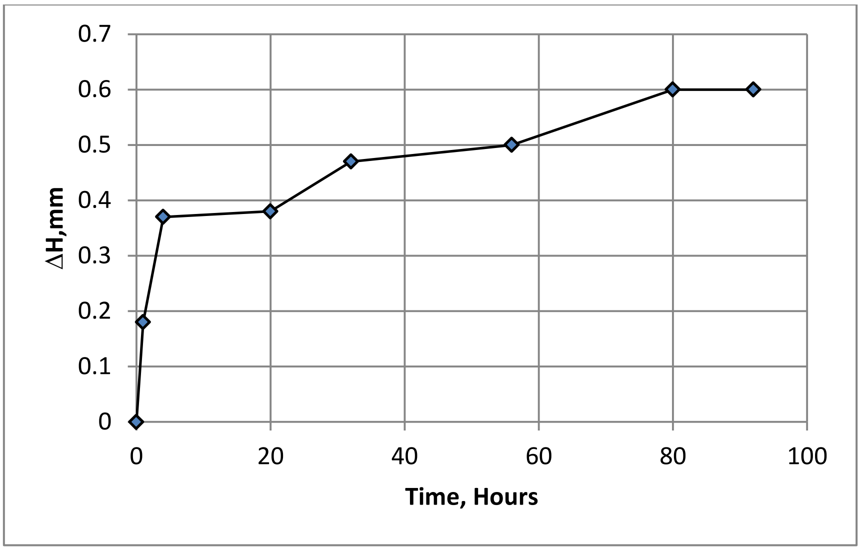

Fig 4.9 Specimen Heave VS Time curve for Parent Soil + 4% MSS

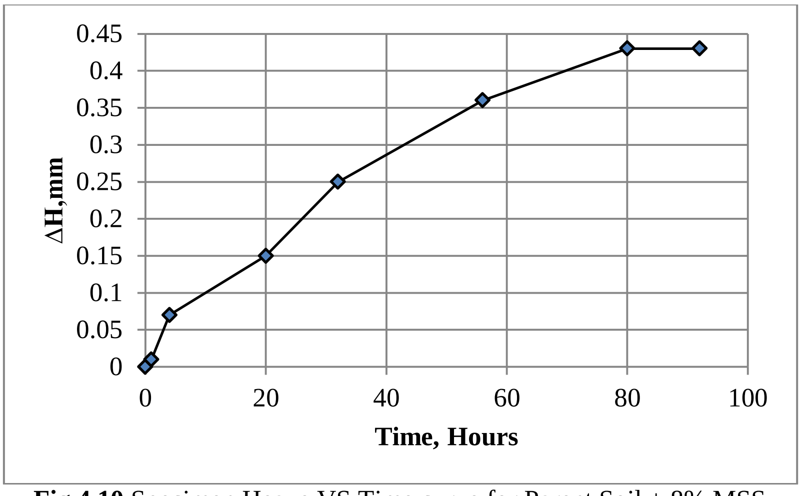

Fig 4.10 Specimen Heave VS Time curve for Parent Soil + 8% MSS

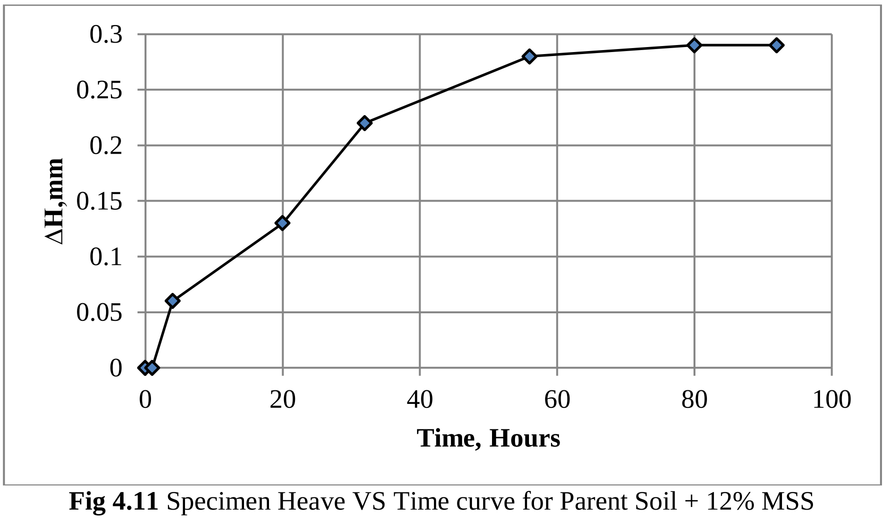

Fig 4.11 Specimen Heave VS Time curve for Parent Soil + 12% MSS

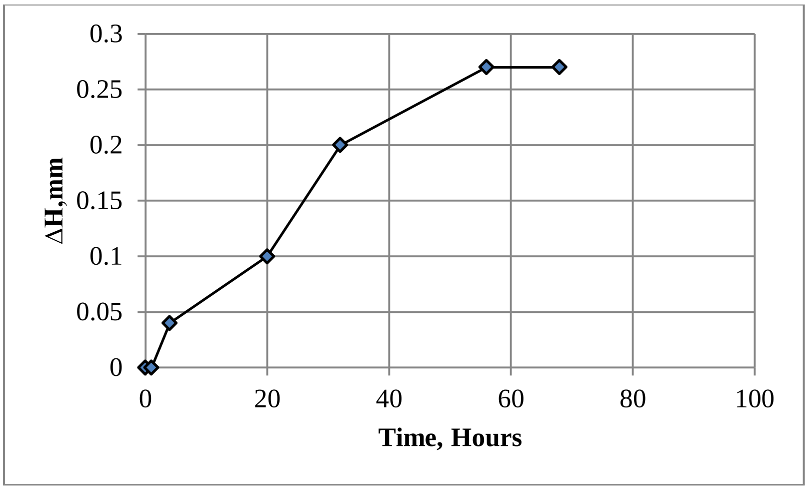

Fig 4.12 Specimen Heave VS Time curve for Parent Soil + 16% MSS

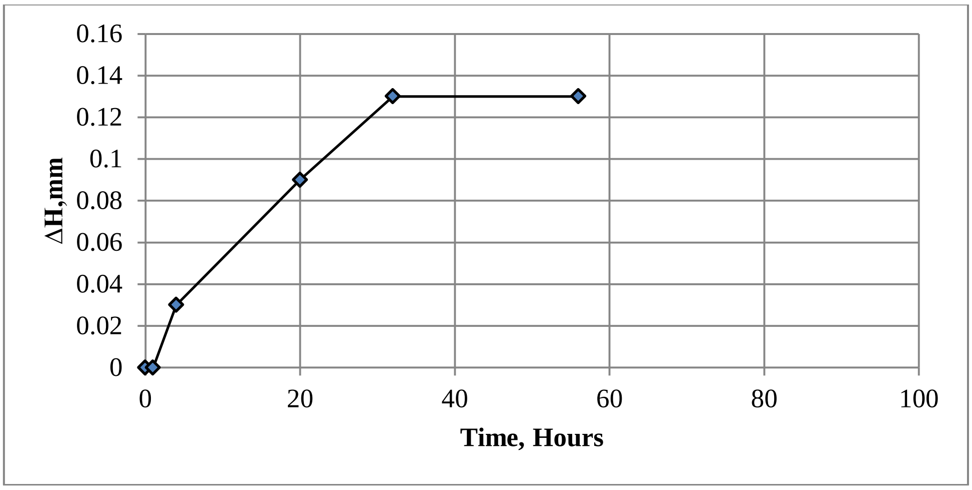

Fig 4.13 Specimen Heave VS Time curve for Parent Soil + 20% MSS

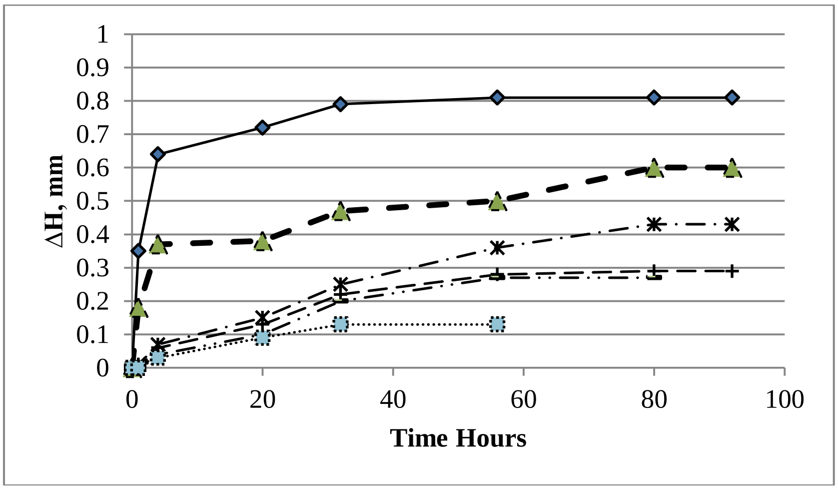

Fig. 4.14 Specimen Heave VS Time Curves for Parent Soil and Soils Treated with different percentages of MSS

Chapter 4 Analysis Of Test Result And Discussion

4.1 General: The objective of this study is to investigate the swelling behavior of a black cotton soil treated with 4%, 8%, 12%, 16%, and 20% by weight of granulated mild steel sludge. A series of swell pressure tests have been conducted by consolidometer method to determine the swell pressure of untreated black cotton soil and black cotton soil treated with granulated mild steel sludge to evaluate the effect of granulated mild steel sludge on swell behavior of soil. Specimen heave of the soil has been permitted and it has been observed that it occurs with the passage of time. A series of consolidation pressure of 0.11, 0.26, 0.51, 1.02, 2.015 and 4.002 kg/cm^2 have been applied and consolidation pressure to bring the soil back to its original volume has been determined which is reported as swell pressure. The results of these tests have been analyzed under following headings.

4.2 Moisture-Density Relationship : Standard proctor tests have been conducted to determine optimum moisture content (OMC) and maximum dry density (MDD) of parent soil and soil treated with various percentages of granulated mild steel sludge. Fig. 5.1 shows the comparison of OMC and MDD for parent soil and soil treated with various percentages of granulated mild steel sludge. For parent soil OMC and MDD have been observed as 27% and 1.603 g/cc respectively. OMC varies from 25.1% to 22.5% and MDD varies from 1.65 g/cc to 1.83 g/cc with the increase in sludge content from 4 to 20%. Moreover it is observed that there is a decrease in OMC and increase in MDD due to an increase in percentage of mild steel sludge. The presence of mild steel sludge having high specific gravity may be the cause for increase in MDD. The decrease in OMC of the soil with the increase in percentage of mild steel sludge may be attributed to non-plastic silty and granulated nature of sludge. However for the parent soil, OMC value is observed to be on lower side as compared to soil with low additive content of 4%, through the variation is not very significant.

4.3 Specimen Heave Versus Time: In one dimensional consolidometer the soil is allowed to free swell under seating load with respect to time. The free swell readings shown by the dial gauge under the seating load are recorded at different time intervals. The dial gauge readings are taken till equilibrium is reached. This is ensured by making a plot of swelling dial reading versus time in hour still the plot become asymptotic with abscissa (time scale). The total time for specimen heave can be found out by locating a point on the curve at which the curve become asymptotic with abscissa.

Based on the analysis of results, total time for specimen heave of parent soil and soil treated with various percentages of granulated steel sludge have been determined and the results have been tabulated in Table 5.2. A graph showing variation of total heave time with various percentages of granulated steel sludge has also shown in Fig. 5.3.

For parent soil, the value of the time for total expansion has been observed as 56 hr. It has been observed that with the increase in percentage of granulated mild steel sludge from 4% to 20% in the soil, the value of total time for specimen heave from 44 to 8 hr.

A general decreasing trend has been observed in the value of total time for specimen heave due to increase in percentage of granulated mild steel sludge. This may be attributed to the addition of non-plastic material to the parent soil.

4.4 Swell Potential: Increase in thickness of soil sample was noted after saturation. Swell potential (S%) is defined as the ratio of increase in thickness (H) of soil specimen compacted in consolidometer and allowed to freely on soaking under a token surcharge to the original thickness (H) after being compacted to maximum density at optimum moisture content according to Standard Proctor Test and expressed as percent value.

Table 5.1 and Fig. 5.2 show record of change in thickness (H) of untreated and soil treated with various percentages of granulated steel sludge.
For parent soil, the total expansion has been observed as 0.81 mm. It has been observed that with the increase in percentage of granulated mild steel sludge from 4% to 20% in the soil, the value of total specimen heave decrease from 0.60 mm to 0.13 mm.

Based on the analysis of results, swell potential values of parent soil and soil treated with granulated mild steel sludge have been determined steel and results have been tabulated in Table 5.3. A graph for the variation of swell potential with varying percentages of mild steel sludge has shown in Fig. 5.4.

For parent soil the value of swell potential has been observed as 3.48%. It has been observed that with the increase in percentage of granulated steel sludge from 4% to 20% in the soil, the value of swell potential decreases from 2.08% to 0.32%.

It has been observed that due to increase in percentage of granulated steel sludge, the value of swell potential of the soil decreases which may be attributed to non-plasticity silty granular nature of sludge. For the percentage of granulated steel sludge in the soil at 16% or higher, the value of swell potential of the treated soil reduces to acceptable level, i.e. below 0.5%.

4.5 Swell Pressure

Based on the analysis of results, swell pressure values of parent soil and soil treated with granulated mild steel sludge have been determined and the results have been tabulated in Table 5.4. A graph for variation of swell pressure with the varying percentage of granulated mild steel sludge has been shown in Fig. 5.5.

For the parent soil the value of swell pressure has been observed as 1.32 kg/cm^2. With the increase in the percentage of granulated mild steel sludge from 4% to 20%, it has been observed that the value of swell pressure decreases from 0.55 to 0.18 kg/cm^2. It has been observed that due to increase in percentage of granulated steel sludge the swell pressures of soil decreases. It may be attributed to the non-plastic material of the soil. For the percentage of granulated mild steel sludge in the soil at 20%, the value of swell pressure of the treated soil reduces to an acceptable level, i.e. below 0.2 kg/cm^2.The results will help in arriving at economical proportion of the additive in soil-stabilizer mixture.

Chapter 5 Conclusion And Scope Of Further Research

5.1 General: The study demonstrates the influence of granulated mild steel sludge on selling behavior of an expansive soil collected from village near Pattan located in Srinagar (J&K). The black cotton soil has been mixed with 4%, 8%, 12%, 16%, and 20% by weight of granulated mild steel sludge. A number of standard proctor tests have been conducted to find the maximum dry density and the optimum moisture content values of untreated soil and treated soil for preparing sample for consolidometer method to determine the swell pressure of untreated black cotton soil and black cotton soil treated with granulated mild steel sludge to evaluate the effect of addition granulated mild steel sludge on swell pressure of soil. The following conclusions have been dawn based on the laboratory investigations carried out in this study.

5.2 Conclusion

1. It has been observed that there is a decrease in optimum moisture content (OMC) and an increase in maximum dry density (MDD) due to an increase in percentage of mild steel sludge. The presence of mild steel sludge having high specific gravity may be the cause for increase in MDD. The decrease in OMC of the soil with increase in mild steel sludge content may be attributed to non-plasticity and granular nature of sludge.
2. A general decreasing trend has been observed in the value of total time for specimen to heave due to increase in percentage of granulated mild steel sludge. This may be attributed to the addition of non-plastic material to the parent soil.
3. It has been observed that due to increase in percentage of granulated mild steel sludge, the value of swell potential of the soil decreases which may be attributed to non-plastic silty and granulated mild steel sludge in the soil at 20% or higher, the value of swell potential of the treated soil reduces to an acceptable level, i.e. below 0.5%.
4. It has been observed that due to increase in percentage of granulated mild steel sludge, swell pressure of the soil decreases. It may be due to the addition of non-plastic material to the soil. For the percentage of granulated mild steel sludge in the soil at 20%, the value of swell pressure of the treated soil reduces to an acceptable level, i.e. below 0.2 kg/cm^2.
5. The study shows treatment of soil with granulated mild steel sludge is an effective method of reducing swell potential and swell pressure of expansive soils. To summarize, use of industry waste is a beneficial proposition which is economic and environmental friendly as well, and is an alternative to other expansive techniques like use of geo-textiles and stone columns, thereby reducing construction costs particularly in developing countries. The results of this study will help in arriving at economical proportion of industrial waste material in designing foundation and pavements on compacted stabilized clay beds.

5.3 Scope of Further Research

A number of general research suggestions are listed herein that should increase the knowledge and enable the soil granulated mild steel sludge mixtures to become most useful engineering materials.

1. For advance research, it is recommended that the effect of cementing material in soil granulated mild steel sludge mixture may be explored to see whether it can better improve the properties of the soil.
2. Study on soil treated with other industrial wastes like rice husk ash, fly ash, stone dust, cement kiln dust, blast furnace slag may be done.
3. Further research may be done to study the effect on swell characteristics of soil stabilized with various industrial wastes.
4. Research can be done to study durability characterized of stabilized soils.

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