Industrial Waste Materials Application in Highway Construction

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Abstract – *Present days' Industrial waste material disposal is a major problem. These materials effect to environmental pollution in the nearby areas because many of them are non-biodegradable. India has a more number of industries located in different places of the country and many more are planned for the near future. Every year several million metric tons industrial wastes are produced in these establishments. In developing countries like India Transportation is most important requirement for economic and social development. The use of these materials in road making is based on technical, economic, and ecological criteria. The pollution and disposal problems may be partly reduced. Road construction is an activity in which natural resources are utilized the most in comparison with other branches of civil engineering. Large quantities of natural materials, gravel, clay, rocks and sand are built into kilometers of newly-built roads or in reconstruction of decrepit roads. At the same time, the sustainable development concept requires a more efficient management of waste materials and preservation of environment.*

This paper clearly describes various industrial waste materials are being used in the construction of highway. The waste materials are Pond ash and slag. Which are satisfying MORTH-5th Rev. specifications requirements. Usage of these waste materials in highway works not only saves the construction cost but also preserves the Environment from Air Pollution, Water pollution and Minimize the land utilization for the disposal of these materials. This observation has been made from sambalpur-Rourkela road project, (Odisha) SH-10. So, all these internal parameters have been adopted in this project which is required to long term durability considering cost & safe environment. Slag obtained from Radharaman, Bajarangibali unit-1, Odisha. Pond ash samples from Suresh product & Agrasen sponge, Odisha. The samples collected from the site are tested under third party NABL laboratory and routine testing carried out in house laboratory. Characterize the geotechnical properties of both Slag & Pond ash individually. Tests are conducted to obtain optimum moisture content (OMC), Maximum dry density (MDD) using modified proctor's density test, Grain size distribution, Specific gravity ,direct shear test ,Field dry density test and CBR for finding out the suitability of subgrade material considering requirement of the IRC 37(2012) FOR EFFECTIVE CBR value as per MORTH 5th Revision Specifications and IS codes.

Key Words—*Pond Ash, slag, Embankment, Subgrade, Power plant, Steel Plant, Rewall back filling, MORTH 5th Rev.*

1. INTRODUCTION

To reduce the requirement of land for disposal of fly ash in ash ponds and to address the problem of pollution caused by fly ash, Ministry of Environment, Forests and Climate Change has issued various Notifications on fly ash utilization, first Notification was issued on 14th September, 1999 which was subsequently amended in 2003, 2009 and 2016 vide Notifications dated 27th August, 2003, 3rd November, 2009 and 25th January, 2016 respectively. Now a days Global warming and environmental destruction have become the major issues. Emission of host of greenhouse gases from industrial processes. Utilization of industrial wastes and conservation of natural resources. Preventing the depletion of natural resources and augmentation the usage of waste materials has become a challenge to all.

A few studies have been conducted concerning the protection of natural resources, prevention of environmental pollution and contribution to the economy by using this waste material. The two major by-products of industry are slag and pond ash. In India, the annual production of Pond ash is about 450 million tons, but about 35 percent of the total is being utilized, which is very low. Owing to its ultra-fineness, pozzolanic contribution and other properties, the use of pond ash makes a cost of disposal and to reduce environmental pollution, it is an imperative to increase the quantity of pond ash utilization. Similarly, the Steel industry in India is producing about 45 million tons of blast furnace slag and 22million tons of steel slag. There are three types of ash produced by thermal power plants viz. (i) fly ash (ii) bottom ash (iii) pond ash. The finer fraction of ashes which are collected in the electrostatic precipitators of thermal power plants is knows as fly ash. The heavier and coarser coal ash collected from furnace bottom is known as bottom ash and around 25% of the total coal ash production. Routinely, these two sorts of ashes are blended completely with water and sluiced to nearby storage ponds called ash ponds. The ash settled in the ash ponds is known as pond ash.

Steel slag is a byproduct obtained from steel industr y. It is generated as a residue during the production of steel. Because of the high disposal c ost as a waste material and the overall positive features of steel slag, it has been declared a Useful construction material, not an industrial wast e by most of the developed countries. Slag obtained from iron factories can be used for Granular sub base, Embankment, subgrade, Backfilling according to the satisfactory of the gradation properties in structures. An Experimental program was done to study the Characteristics, density and moisture content, Stress level on Pond Ash and Slag as per Morth 5th revision specifications.

SUMMARY OF FLY ASH GENERATION AND UTILIZATION

Description		1st Half Year 2014-15	1st Half Year 2015-16
Nos. of Thermal Power Stations from which data was received	:	146	132
Installed capacity (MW)	:	1,33,708.80	1,30,428.80
Coal consumed (Million-Ton)	:	272.70	251.69
Average Ash Content (%)	:	33.65	33.23
Fly Ash Generation (Million-Ton)	:	91.77	83.64
Fly Ash Utilization (Million-Ton)	:	48.65	46.87
Percentage Fly Ash Utilization	:	**53.01**	**56.04**

Table.1.Fly ash generation and Utilization

It can be seen from the above table that during current half year 132 thermal power stations have reported Fly Ash Generation & its Utilization data. Based on this, Fly Ash Utilization percentage has increased during 1st half of the year 2015-16 in comparison to the utilization during the 1st half of previous year (of 146 thermal power stations). The Fly ash wastage as well as utilization has generally been increasing since 1990.

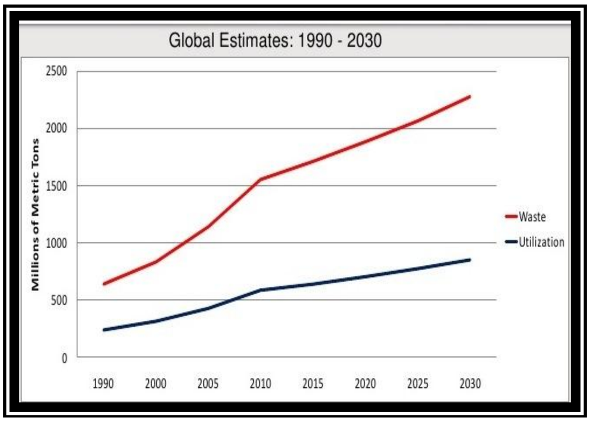


Fig.1 Fly ash Wastage and Utilization over the years

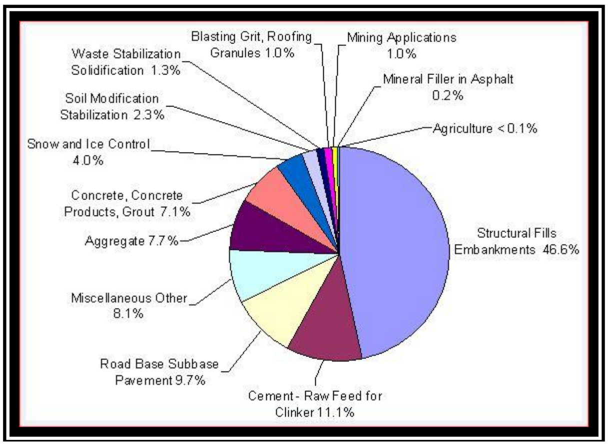


Fig.2.Slag Utilization in different areas

The above fig.2 shows the utilization of slag in different working areas.

2. LITERATURE REVIEW

Pond ash also Known as bottom ash is part of the non-combustible residue of combustion in a furnace or incinerator. In an industrial context, it usually refers to cold combustion and comprises trace of combustibles embedded informing clinkers and sticking to hot side walls of coal burning furnace during its operation(Santos et al. 2011).

Mathur et al. (1999) looked at the physical properties of blast furnace slag and steel slag and concluded that both materials were suitable to replace natural stone aggregates in base and sub base road layers, as long as the steel slag was adequately weathered. According to National Slag Association iron and steel slags have been used in engineering constructions for more than 150 years. It is being used as aggregate in replacement of natural aggregate, for bounding applications (BFS) instead of Portland cement, fill material, rail road ballast and sub grade soil stabilization.

According to John Emery iron slag were used for the construction of roads during the Romans Empire also. In 1998 up to 97% of the total generated steel slag has been used in different ways for the construction of high trafficked roads by Germany. It is utilized as aggregate for surface layer, road base and sub base. It is also utilized in earthworks and hydraulic structures as well. Because of significant amount of free iron, steel slag becomes hard and dense to provide high abrasion resistance. It is a rough textured, sufficient angular, vesicular and porous material. After compaction it provides a satisfactory particle interlock and high stability.

3. SCOPE OF THE PRESENT STUDY

Thus, through the appraisal of the literature review it is observed that several attempts have already been made by researchers to understand the procedure of slag, Pond ash making in highway construction. The objective of this study is to prevent the exhaustion of natural resources and enhancing the usage of waste materials, concern about global environmental issues, and a change over from the mass-production, mass-consumption, mass waste society to a zero-emission society.

1. To determine particle sizes and shapes.
2. To determine Modified proctor density test (OM &MDD) As per IS 2720 part 4.
3. To determine the field dry density as per IS 2720 part 28.
4. To determine shear strength, CBR as per IS 2720 Part 16.
5. To determine liquid limit and consolidation as per Morth (5th revision) clause 3014.

4. MATERIALS AND METHODS

In this present study a series of experiments have been done to evaluate the characteristic strength of slag and pond ash. It is beneficial quality/ durability norms pond ash and slag are non-plastic material, non-cohesive material having better shear strength.CBR values of slag and pond ash is much better than natural soil. Ultimately durability of road is good. The physical properties of the raw materials mentioned in below table No.2.

4.1 Materials used

4.1.1 Pond Ash

The pond ash used in the present investigation was collected from Suresh Product, Agrasen Sponge Ltd, Sundargarh district of Orissa.

4.1.2 Properties of Pond ash

The pond ash deposits are characterized by high compressibility. Pond ash high self-hardening and less settlement properties, it improves the pavement performance.The pond ash had Light grey colour. The following details as per IRC: SP: 58-2001requirements.

S. NO	Characteristics	Findings	Requirements as per IRC: SP:58-2001
1.	Specific Gravity	2.221	1.90-2.55
2.	Plasticity	Non-Plastic	Non-Plastic
3.	Maximum Dry Density, gm/cc	1.31	0.9-1.6
4.	Optimum Moisture Content, %	28.3	18-38
5.	Coefficient of uniformity	8.33	3.1-10.7
6.	Direct Shear		
	a. Cohesion(Kg /cm^2)	0.08	Negligible
	b. Angle of internal Friction(degrees)	34	30°-40°
7.	Coefficient of consolidation (Cv),cm^2/sec	1.19x 10^{-3}	1.75x10^{-5} to 2.01x10^{-3}
8.	Compression Index (Cc)	0.145	0.05 to 0.40
9.	Permeability, cm/sec	5.52x 10^{-4}	8x10^{-6} to 7x10^{-4}
10.	PH Value	7.6	3-9.1

Table 2. Properties of Pond Ash

4.1.3 Methods of Disposal of Pond ash

In India, most of the Thermal power plants adopt wet method of ash disposal. Pond ash will be collected from Thermal power plant at the bottom, in that it contains significant amount of relatively coarser particles (spanning from 150 microns to 2.36 mm). Pond ash utilization helps to reduce the consumption of natural resources. Also it is help to solve the problem of disposal of Pond ash.

Fig.3.Wet disposal of Pond ash

4.1.4 Utilization of Pond ash

Now a day's pond ash utilization in different work areas.

- In this Project mainly pond ash used in Road embankments, Rewall back filling material in structures. The below figures show the utilization of pond ash in different working areas.
- Use of Pond ash in Portland cement concrete for applications in highway construction.
- Use of Pond ash in stabilised base course for applications in highway construction.
- Use of Pond ash in soil improvement for applications in highway construction.
- Use of pond ash in asphalt pavements for applications in Highway construction.

Fig.4.Pond ash dumping at Rewall

Fig.5.Pond ash spreading with Grader

Fig.6.Pond ash rolling at Rewall back filling.

4.2.1 Steel slag

The steel slag used in the present investigation was collected from Radharaman, Bajarangabali Unit-1, Agrasen Factory, Sundargarh district of Orissa.

4.2.2 Properties of slag

Slag contains good strength, drainage and plasticity characteristics to act as a potential material for highway embankment construction. The pond ash had Light grey colour. The high specific gravity and the proper interlocking due to angularity of steel slag result better stability and resistance against rutting as well. The tests on slag requirements as per MORTH (5^{th} revision) clause 3104.

S. NO	Characteristics	Findings	Requirements as per IRC: SP:58-2001
1.	Specific Gravity	3.2 to 3.9	Not Specified
2.	Liquid Limit (%)	15.20	Maximum 25*
3.	Plastic Limit (%)	Nill	Not specified
4.	Plasticity Index	Non-Plastic	≤6
5.	**Direct Shear**		
	a. Cohesion(Kg/cm²)	0.25	Not specified
	b. Angle of internal Friction(degrees)	43°	Not less than 30°
6.	PH Value	7.50	3 – 9 (For geosynthetic reinforcement)

*for granular sub base

Table 3. Properties of Slag

4.2.3 Methods of Disposal of slag

It has been noticed that per year several million tons of slag is generated from different steel industries throughout the world. These waste materials disposal at outside of the industries (Open areas).

Fig.7. Disposal of Slag

4.2.4 Utilization of slag

- In this project slag mainly used in Embankment, subgrade, backfilling in structure works.
- The surveys show that steel slag road surfaces have at least as good long-term skid resistance properties as those of comparable natural aggregate road surfaces under similar traffic conditions.
- Road byproducts, such as reclaimed concrete pavement materials, and reclaimed asphalt pavement materials.
- Slag utilized in good stabilizer and binder material.
- Slag was used as fertilizers in agro-technical measures.

Fig.8.Slag rolling

Fig.9.Slag used in structure back filling

Fig.10.slag used in sub grade

4.3 Test Methods

The following test methods conducted for both Pond ash and slag individually as per MORTH 5^{Th} Revision specifications and.

1. Specific gravity.
2. Grain Size Distribution.
3. Modified Proctor's Density Test.
4. Direct Shear Test.

5. CBR test.
6. Liquid limit for slag.
7. Consolidation test for pond ash.
8. Field dry density by using NDG.

5.0. EXPERIMENTAL WORK

In this present study, a series of experiments have been done to evaluate the characteristics of steel slag and pond ash. Pond ash collected from Agrasen sponge Ltd, Scan steel, Suresh product. Slag collected from Radharaman Factory, Bajarangbali Unit-I near to Rourkela, Sundargarh, Odisha. The specimens were oven dried at the temperature of 105-110 degrees. Then it was sieved by utilizing required sieves as per IS: 2720, (Part 4)]. The material passing through the sieve was utilized as a part of experimental work.

Specific gravity of pond ash and slag samples were determined by density bottle following the standard method prescribed in IS 2720 (Part III/Section 1). Pond ash comprises both coarse and fine grained particles. For determination of grain size distribution, the pond ash was passed through an IS test sieve having an opening size 75μ.The slag was passed through an IS sieve having an opening size 10mm. Sieve analysis was performed for coarser particles as per IS: 2720 part (4), 1975 and hydrometer analysis was performed for finer particles as per IS: 2720 part (4) and IRC: SP: 58-2001.

6. RESULTS

6.1 Specific gravity:

Specific gravity of pond ash was found to be 2. 221. Specific gravity of slag was found to be 3.2. Steel slag contains sufficient amount of iron oxide; therefore, it has greater value of specific gravity as compare to the natural materials. It provides high strength and durability.

6.2 Grain Size Distribution

Grain size distribution, an important factor which is highly

Influenced the mechanical properties of the material. Grain size distribution by using dry sieve analysis method for pond ash and slag individually as per IS: 2720, (Part 4).

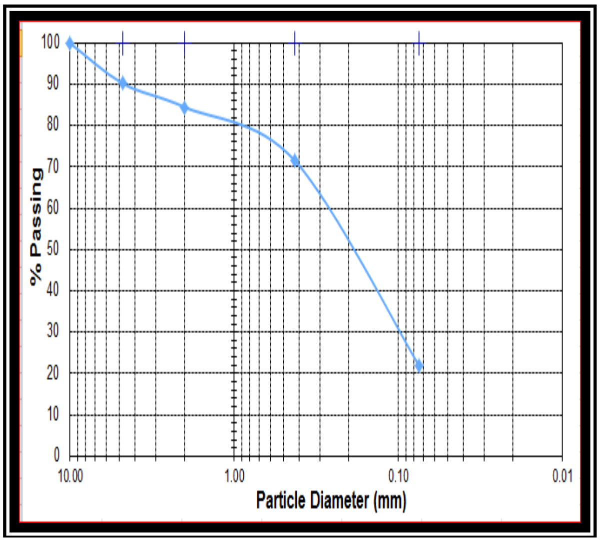


Chart- 1: Grain-size distribution curve of Pond ash

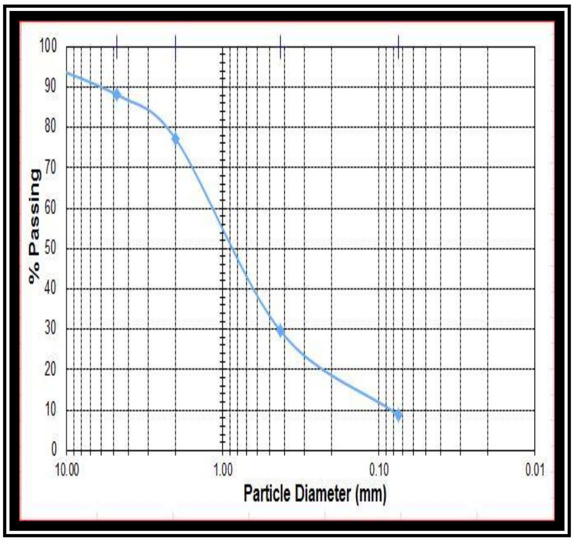


Chart- 2: Grain-size distribution curve of Slag

6.3 Compaction test

Modified proctor' density tests were carried out to determine the maximum dry density (MDD) and optimum moisture content (OMC) of given pond ash sample that is 1.31 gm/cc and 28.30 %. For slag that is 2 gm/cc and 9.70%.As per IS 2720, (Part-8). Maximum dry density of pond ash and slag is increasing with increase in compaction energy whereas optimum moisture content is diminishing with increase in compaction. [As per IS 2720, (Part-8)]

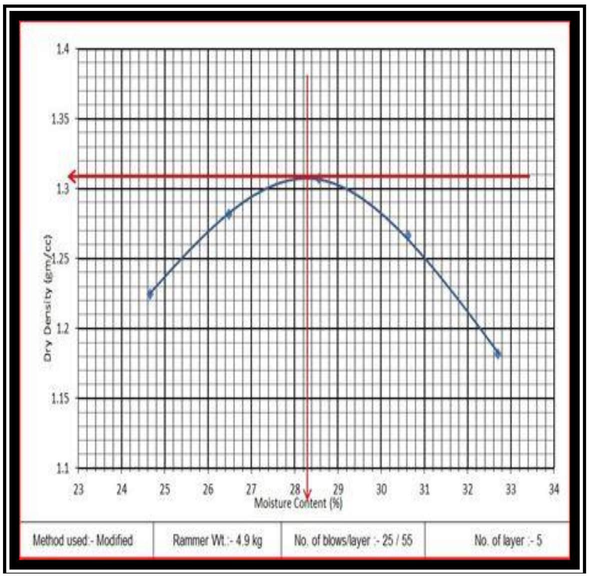


Chart- 3: Compaction curve of Pond ash

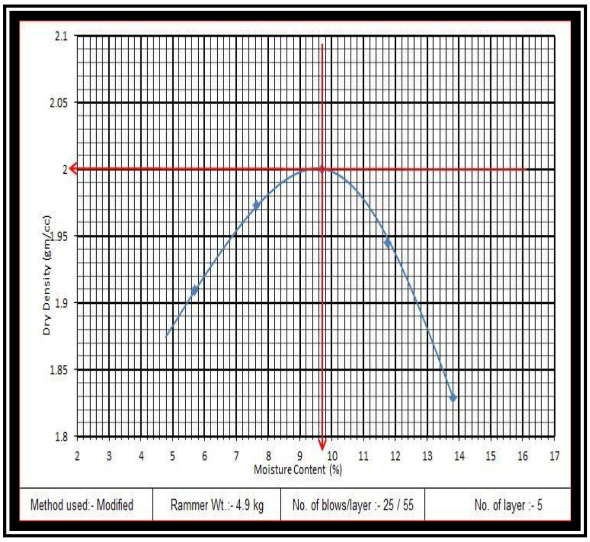
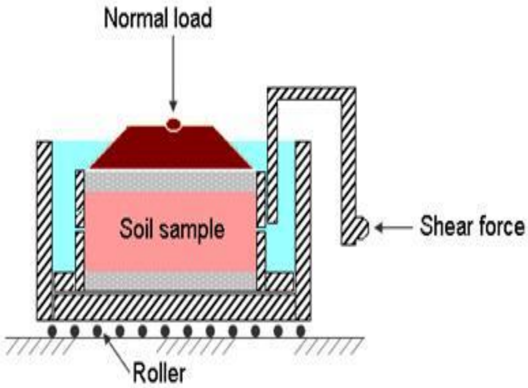


Chart- 4: Compaction curve of slag

6.4 Direct shear test

Direct shear test was directed for pond ash at OMC and MDD corresponding to Modified proctor' density test. Shear parameters was calculated from the graph between normal stresses vs. shear stress. Chart-5 shows the graph related to direct shear test. When the soil was compacted at Modified proctor' density test and moisture content, the unit cohesion (Ø) 0.08 and angle of friction 34^0. Steel slags are rough in surface texture, cubical and angular as compare to the natural material. It provides better interlocking and friction which results stability, resistance to rutting and higher skid resistance. The friction angle of steel slag is reported 43^0 and cohesion 0.25. Because of its better shear resistance, can be use all the layers of pavements. (As per IS: 2720 Part-XIII).



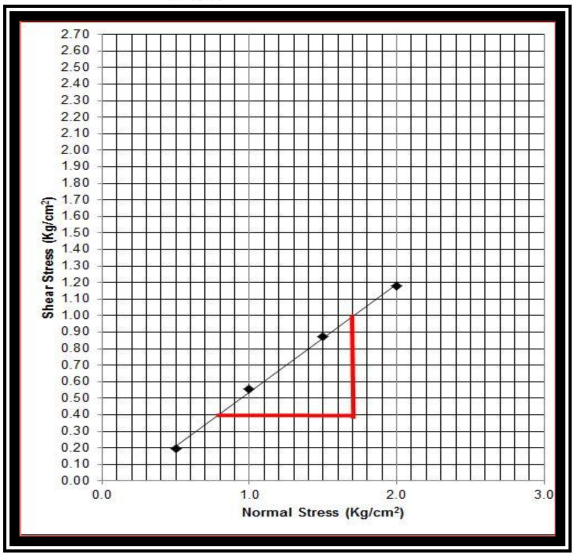


Chart- 5: Compaction curve of pond ash

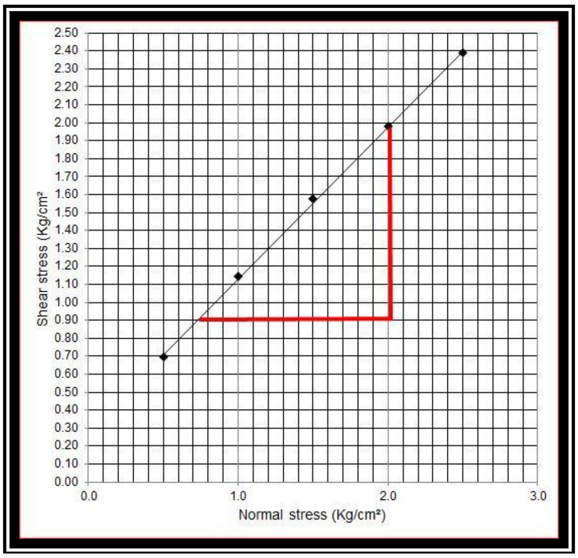


Chart- 6: Compaction curve of Slag

6.5 Liquid limit test for slag

Liquid limit is defined as "the moisture content at which soil changes from liquid state to plastic state". The boundary between the liquid and plastic states.Liquid limit of the slag is 15.20. The strength of connections between soil particles changes with water content in soils containing clay minerals. Therefore, these soils behave differently with different water content depending on the (quantitative and qualitative) clay mineral content. The liquid limit can be determined using the so-called Casagrande method. Colloidal clays have higher liquid limit. A soil with high clay content usually has high liquid limit

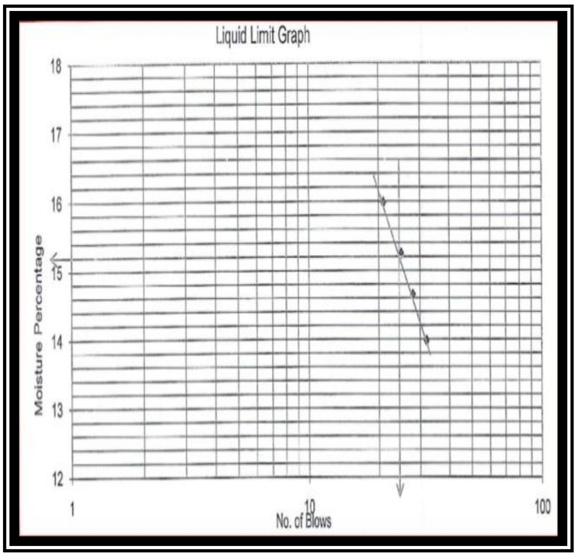


Chart- 6: Liquid limit graph for Slag

6.6 Consolidation test for pond ash

Consolidation is a process in which saturated soil is compressed due to steady and static pressure. Consolidation is a process by which soils decrease in volume. According to Karl von Terzaghi "consolidation is any process which involves a decrease in water content of saturated soil without replacement of water by air." This can be used to predict the amount of consolidation. The graph between stress (Kg/cm2) to percentage finer. The value of consolidation (Cc) of pond ash is 0.145.

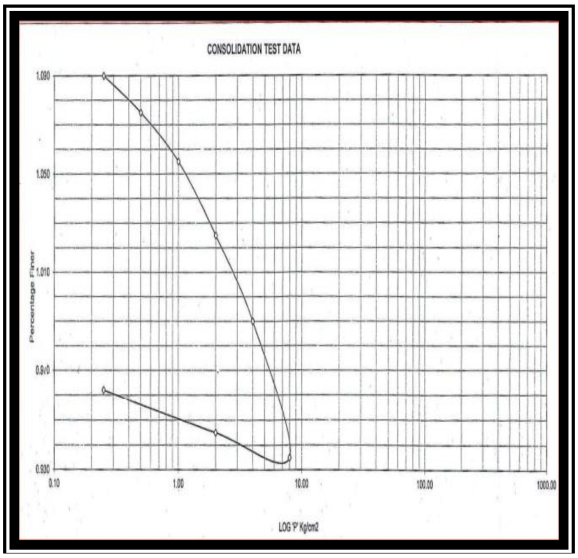


Chart- 6: Consolidation graph for pond ash

6.7 CBR test

CBR (California bearing ratio) test is one of the most commonly used methods to evaluate the strength of sub grade soil, sub base, and base course material for design of thickness of highways. The determination of C.B.R. of undisturbed and remoulded/compacted soil specimen, both in soaked as well as unsoaked state.CBR value of slag is 48.2% and for pond ash is 17.1%. For finding out the suitability of subgrade material considering the requirement of IRC 37(2012) for effective CBR value. CBR test conducted for slag and pond ash as per IS 2720(Part-16)

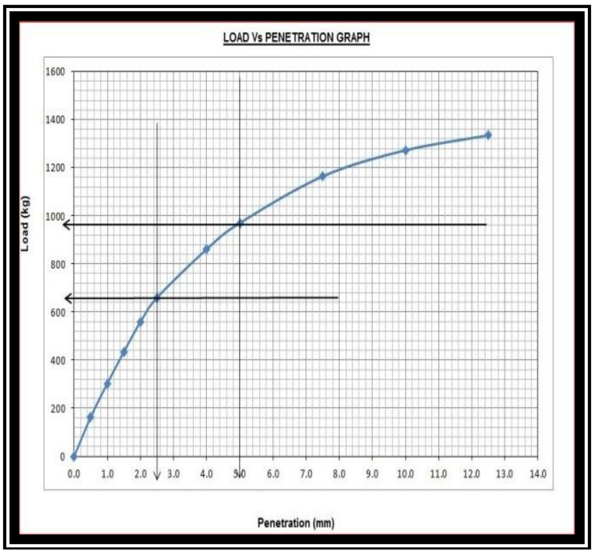


Chart- 6: CBR curve for slag

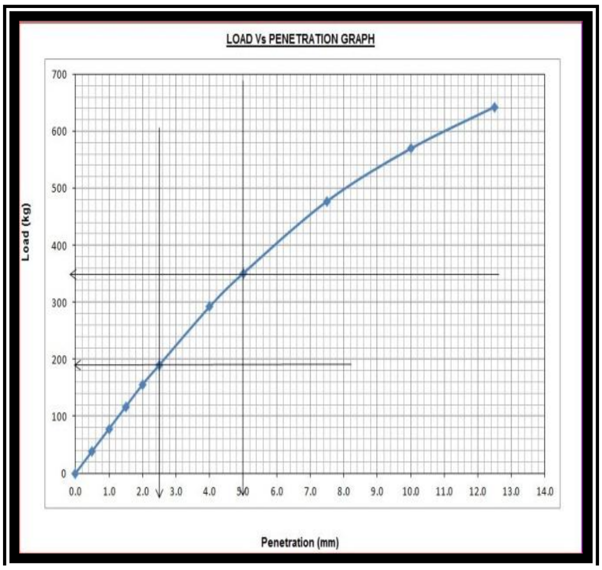


Chart- 6: CBR curve for Pond ash

6.8 Field Dry Density Test

The dry density of the compacted soil or pavement material is a common measure of the amount of the compaction achieved during the construction. Knowing the field density and field moisture content, the dry density is calculated. Field dry density test by using NDG (Nuclear Density Gauge).For embankment 95%, sub grade 98%, rewall back filling 97% obtained as per AASHTO T310.

7. CONCLUSION

This paper reviewed the high engineering properties of Pond ash and slag. It has been declared a useful construction material not an industrial waste. Different tests conducted for slag and pond ash as per IS codes and Morth specifications. It gives better results as per specifications. Here mainly slag and pond ash used in highway embankment, subgrade, and backfilling in structures. In this project pond ash and slag 7.45 lac MT used. Based on experimental results and observations presented in this paper, the following conclusions can be drawn:

1. Environmental pollution has been minimized by utilized the steel industrial waste and thermal power plant waste in road sector.
2. The expansion of slag is very less so we can replace the
   expansive soil by utilizing this industrial slag rather than utilizing murum.
3. Thermal Power Stations have to ensure the utilization of fly ash and fly ash based building products within the thermal power station for the development of infrastructure like construction of buildings & roads, reclamation of low lying areas, the raising of ash dyke etc.
4. There is a need to encourage 'Industry–Institute Interactions' for entrepreneur development, creating awareness and organizing training programmes and workshops.
5. Induction of 'Fly Ash' as a subject in academic curriculum of Engineering and Architecture is needed.

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