APPLICATION OF STEEL SLAG AS AN EFFECTIVE CONSTRUCTION MATERIAL IN PAVEMENTS

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ABSTRACT

The large amount of Industrial wastes as increased year by year and disposal becomes a very serious problem. It is necessary to utilize the steel slag waste affectively with technical development in each field. Commonly murrum soil has been used for construction of all categories of roads in our country. Although murrum is a good construction material, due to scarcity they increase the construction cost at some parts of the country, several types of murrum soils are found to be unsuitable for road construction in view of higher finer fraction and excessive plasticity properties. Such as used as industrial material like steel slag in construction of road pavement. Its disposal causing severe health and environmental hazards in road construction industries is gradually gaining significant importance in India considering the disposal, environmental problems and gradual depletion of natural resources like soil and aggregates. Steel slag is a waste material generated as a by-product during the manufacturing of steel from steel industries. The quantity of generation is around 24 lacs MT per year from (Ref.Report.CRRI-2010) different steel industries in the India. Presently, it has no applications and dumped haphazardly on the costly land available near the plants. In this study, a typical steel slag was collected from an M/s Jindal Steel Industry Pvt.Ltd Sinner MIDC, (M.S) in India and its feasibility for use in different layers of road construction was investigated. To improve its Geotechnical engineering properties, the Steel Slag material was mechanically stabilized with locally available soil in the range of 5 – 25%. Geotechnical parameters of these stabilized mixes were evaluated to investigate their suitability in the construction of different layers of road Technical specification of steel slag is developed for utilization in the construction of embankment, sub grade and sub base layer of Flexible pavement.

Key word*- Compaction test, CBR test, Index Properties, Moisture Absorption test.*

1.0 INTRODUCTION

Slags are by-products of metallurgical processes. Steel- and iron making industries generate different types of slag’s. Blast furnace slag which is a by-product of iron making process has a high SiO2 content and hence, rapidly-cooled blast-furnace slag has an amorphous structure and pozzolanic properties. Due to its beneficial cementations properties, blast-furnace slag generated each year is fully utilized by the cement and concrete industry. In contrast to blast- furnace slag, steel slag’s that generate from steelmaking and refining operations are not widely known and fully utilized in practice. Typically, steel slag’s have a very crystalline structure (due to the slow cooling conditions applied during processing and their chemical composition that lack SiO2), and hence, they only show weak cementations properties. In addition they can possess volumetric instability in presence of moisture. Coarse fraction (gravel-sizes) of steel slag is mainly used as road aggregates; however the problems related to its volumetric instability and lack of studies that explore the engineering properties of steel slag have impeded the utilization of steel slag in other applications in construction industry, specifically for the finer fraction (sand- and silt-sizes) of steel slag. In 2006, steel slag generation was estimated to be in 10-15 million metric ton (Mt) range in the U.S. and approximately 15 to 40% of the total steel slag output was not utilized. Traditionally unutilized steel slag is stockpiled in the steel plants, and eventually land filled at slag disposal sites. Since the current methods of stockpiling and land filling are not sustainable, disposal of steel slag has become a significant concern both to slag processer companies and to environmental agencies in the last decades. Use of steel slag in geotechnical engineering projects, such as in the construction of highway embankments or in sub grade stabilization projects, is advantageous because large volumes of steel slag can be utilized. Sustainability of steel slag in geotechnical applications will not only alleviate the steel slag disposal problem but also will offer a cost-effective substitute for conventional materials. In order to identify new applications for steel slag in the construction industry, there is a significant need to characterize steel slag's, and to determine their engineering properties and long-term swelling potential.

1.1 STEEL SLAG

'Iron' from ores is a complex process requiring a number of other materials which are added as flux or catalysts. After making steel these ingredients forming a matrix are to be periodically cleaned up. Removed in bulk, it is known as steel –slag.. For industrial use, different grades of steel are required. With varying grades of steel produced, the resulting slag's also assume various characteristics and hence strength properties. Grades of steel are classified from high to medium and low depending on their carbon content. Higher grades of steel have higher carbon contents.

Steel slag's are the byproducts of the companies which are very cost low for that we can make them as the additional sources for the pavements to use as the ingredients of the constructional materials. They are obtained by the de oxidation of the products of cast iron in the industrial usage. They are the byproducts of the companies making them economical in the construction practice.

The steel slag produced during the primary stage of steel making is known as furnace slag or tap slag which is the major share of the total slag produced in the operation. After the first operation, when molten steel is poured into ladle, additional; flux is charged for further refining. It helps the in absorbing of DE oxidation products, simultaneously providing heat insulation and protection of ladle refractoriness'. Slag produced on this operation is known as raker and ladle slag.

The steel slag is used as aggregates. Natural aggregate resources are becoming more difficult to develop or remove aggregate from the ground when slag can be used as a substitute which reduce waste and conserve resources. It protects and preserves our environment. Benefit from technical advantages offered by many of the steel making slag's. High performance products not necessarily low grade applications.

1.2 GGBS

GGBS is obtained from the byproduct of the all industries of steel manufacturing companies.. The main chemical composition of GGBFS is SiO2 Al2O3 and CaO. When GGBFS is added to concrete in powered form it accelerates the pozzolanic reaction. The benefits of adding powered GGBFS in concrete can be grouped as follows

2.0 PROPERTIES

The impacts of GGBS are addition on the performance of new concrete are as follows: ¾ increased cohesion ¾ compact internal and external bleeding ¾ reduced risk of segregation ¾ Reduced washout for under water concrete ¾ Enables the production of self-compacting concrete. Improvement of hardened concrete properties: The impacts GGBS addition on hardened concrete performance is as follows: ¾ Increased tensile and flexure strength ¾ Enables production of high performance concrete ¾ Enhanced resistances to chloride attack, sulphateattack.

2.1Utilization of industrial by-products.

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3.0 OVERVIEW

Slag is produced during iron and steel making processes, originating from the gangue in the mineral raw materials such as iron ore, coal, and limestone as well as those in the flux used at steel refining processes to remove Si, P, S, and other impurities in molten pig iron or to control steel contents.

The production amount of BF slag is approximately 300 kg per ton of pig iron, and that of steelmaking slag is 100–150 kg per ton of molten steel. Overall, roughly 40 million tons of iron/steel slag is produce in Japan every year.

Slags are by-products of metallurgical processes of metal smelting from its ore or metal refining. The iron and steelmaking industry is the main source of slag generation both in the US and in the world. Iron is smelted from its ore in a blast furnace. There are two main types of steelmaking processes. The first is the basic-oxygen-furnace (BOF) steelmaking process by which iron is converted to steel. The second is the electric-arc furnace (EAF) steelmaking process, which recycles mainly steel scraps. The steel from BOF and EAF can also go through a ladle refining unit to produce high-grade steels. Each of these processes generates different types of slags.

3.1 Blast-Furnace Iron making and Slag Generation

A blast furnace is a type of metallurgical furnace that is used to produce a metal from its ore. The blast furnace is a tall vertical cylindrical structure that is lined internally wither factory brick and covered externally with a thick steel shell. Blast furnace plants are equipped with ore storage yards, bridges, rail hoppers and transfer cars to facilitate charging of the materials into the furnace. Figure show pictures of blast furnace and a blast-furnace slag pit, respectively. In the iron making process, blast furnace is continuously charged with iron bearing materials in the form of iron ore lumps, sinter and/or pellets, fluxing agents such as limestone and coke from the top of the furnace. An iron ore is an iron-rich rock from which iron is extracted for the production of steel. It contains a high concentration of iron oxides along with silica and alumina. The most common iron ores consist mainly of hematite (Fe_2O_3) with minor amounts of magnetite (Fe_3O_4). These iron oxides are chemically reduced and physically converted to liquid iron in the blast furnace. The fluxing agent – limestone ($CaCO_3$) – is added to the furnace to essentially remove the impurities present in the iron ore by converting these impurities into“slag”.

3.2 Basic-Oxygen-Furnace (BOF) Process of Steelmaking and SlagGeneration

Modern integrated steel mills are huge steelmaking plants which have all the functions of primary steel production. These functions include conversion of ore to liquid iron, conversion of liquid iron to steel, solidification of liquid steel (casting), size reduction of solidified blocks (roughing rolling/billet rolling) and production of finished shapes (product rolling). Basic-oxygen furnaces are located at integrated steel mills in association with blast furnaces as they are charged with the molten iron produced in the blast furnace. The basic- oxygen furnace process (also known as the Linz-Donawitzprocess) is one of the modern steelmaking processes by which molten iron is converted to steel. The process of converting molten iron to steel in a basic-oxygen furnace takes approximately 40 minutes and hence is much more efficient than the traditional open-hearth process of steelmaking. Furnaces are designed to be tilted during charging and tapping.

3.3 Electric-Arc-Furnace (EAF) Process of Steelmaking and SlagGeneration

Electric-arc furnaces use high-power electric arcs, instead of gaseous fuels, to produce heat which melts recycled steel scrap and converts it to high-quality steel. Electric-arc furnaces are sometimes referred to as “mini mills”. The electric-arc furnace steelmaking process is not dependent on the blast-furnace production. The main feed of electric-arc furnaces is steel scrap with some pig iron. Steel scrap, either as heavy melt (large slabs and beams) or in shredded form, are separated, graded and sorted into as many as 65 different classes of steel in scrap yards. Oxygen reacts with the hot scrap producing an intense heat for cutting the scrap. As the melting process progresses, a pool of liquid steel is generated at the bottom of the furnace, and the process is stopped to allow loading of an additional basket ofscrap.

3.4 Ladle Furnace Refining and SlagGeneration

After completion of primary steelmaking operations, steel produced from BOF or EAF can be further refined to obtain the desired chemical composition. These refining processes are called as “secondary steelmaking operations”. Depending on the quality of the desired steel some or all of these refining processes are applied to the molten steel produced in EAF or BOF process. Ladle furnaces also function as a storage unit for the steel before the initiation of casting operations. Hence, they reduce the cost of high-graded steel production and allow flexibility in steelmaking operations.

3.5 Slag Processing andTreatment

After being tapped out of the furnace, slag goes through several processes. The main slag processing steps are as follows:

- Cooling
- Metal recovery
- Crushing
- Sizing/screening
- Grounding
- Stockpiling

Cooling is an essential step in the processing of all types of slag. It is important because the method of cooling and hence the rate of cooling affect the physical and mineralogical properties of the material drastically. After cooling, depending on the type of slag and intended use, slag undergoes all or some of the processing steps listed above.

3.6 Processing and Types of Blast-FurnaceSlag

Several different techniques are used to process and generate different kinds of blast furnace slag. As the processing determines the crystal structure and the physical properties of the final product, blast-furnace slags are classified based on the processing technique used. Four main types of blast-furnace slags are:

- Air-cooled blast-furnace slag
- Expanded or foamed blast-furnaceslag
- Pelletized blast-furnaceslag
- Granulated blast-furnace slag

When liquid blast-furnace slag is poured into pits and air-cooled under current conditions, it solidifies very slowly developing a crystalline structure similar to igneous rock. This slowly cooled slag is called **air-cooled blast-furnace slag**. It has crystals with sizes ranging from macroscopic to as large as 3 mm. This slag, which is hard and lumpy, is subsequently crushed and screened.
Foamed or expanded blast-furnace slag is formed when water, air or steam is introduced under controlled conditions into the molten slag as it is tipped into a special pit or container. The sudden generation of occluded gases and steam generates foaming and, therefore, the slag cooled in this manner is called expanded or foamed blast-furnaceslag.

4.0 PROPERTIES AND UTILIZATION OF SLAG

Blast-furnace slag (BFS) is generated during the extraction of iron from its ore. Hence, it contains the impurities present in the iron ore that react with the CaO released during the decomposition of the fluxing agents (lime or dolomite). The oxide contents of blast-furnace slag vary with its source. TheCaO, SiO2, Al2O3 and MgO contents in blastfurnaceslag can vary between 33-45%, 27-39%, 8-22% and 3-16%, respectively. Blastfurnaceslag also contains other minor compounds such as TiO2, SO3, P2O5 and MnO. the engineering properties of blast-furnace slag is not only influenced by its chemical composition but also by the procedures followed during processing of the molten slag. The structure of blast-furnace slag can vary from crystalline to amorphous (glassy) depending on its processing. Based on the processing technique selected, blast-furnace slags.

4.1.1 Air-cooled blast-furnace slag

Air-cooled blast-furnace slag(ACBFS) has a very crystalline structure, as the Colin grateisfairlyslow.ThestructureofACBFSvariesfromvesiculartodense,withthe

presence of fractures. Particles have textures with different degrees of roughness and angular shapes. The typical unit weight of ACBFS is12-13 kN/m3, which is lower than that of most natural aggregates. The specific gravity of the blast-furnace slag ranges from 2 to 2.5, with an absorption value ranging from 1 to 6%. ACBFS is used as road stones, concrete aggregate, filter media and railway ballast. Compared to ACBFS, expanded blast-furnace slag (EBFS) has a more vesicular structure and hence a higher porosity. The compacted dry unit weight of expanded blast-furnace slag typically lies in the range of 8-10 kN/m3, which corresponds to 70% of the dry unit weight of ACBFS. The particles of EBFS are angular with a very rough texture. For these reasons, expanded blast-furnace slag is very suitable as an aggregate for lightweight concrete. It is also used as a structural element for roof screeds and bridge decks. In general, expanded blast-furnace slag is predominantly glassy and, therefore, when finely ground, it also possesses hydraulic properties similar to ground-granulated blast-furnace slag.

4.1.2 Ground-granulated blast-furnaceslag

Ground-granulated blast-furnace slag is obtained by quenching molten iron slag (a by- product of iron and steel-making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. is used as a supplementary cementations material in the production of high-quality cement that is known as Portland blast-furnace slag cement (PBFSC).

4.2 Chemical and Mineralogical Properties of Steel Slag

All ferrous slags that are generated from the iron and steelmaking industries (blast furnace, basic-oxygen-furnace, electric-arc-furnace and ladle slag's) contain a percentage of CaO (from the fluxing agents) along with undesirable impurities. However, the mineralogy and mechanical properties of steel slag depend on the proportion of the main chemical constituents in the steel slag and on the techniques used in slag processing. Therefore, the chemical, mineralogical and mechanical properties of steelmaking (EAF,BOF and ladle) slag's are very different from those of blast-furnace slag. Portland cement contains four significant mineral phases which are the source of their strong cementations reactions

Phases are tricalcium silicate (C3S), dicalcium silicate (C2S), tricalcium aluminate (C3A) and tetracalcium-alumino ferrite (C4AF). These important mineral phases are not present in sufficient quantities in steel slag. The main differences in the mineralogy of steel slag and cement result from the abundance of iron oxide and free lime and the lack of silica in the chemical composition of steel slag.

4.3 Utilization of Steel Slag

Utilization of Steel Slag in comparison to other recyclable materials, such as fly ash, bottom-ash, tire shreds, cement kiln dust or foundry sand, steel slag is underutilized.
Civil engineering applications:

- Cement production
- Concrete aggregate
- Asphalt aggregate
- Road bases and sub-bases
- Soil stabilization

Miscellaneous applications:

- Steelmaking
- Fertilizer production

- Linings for waterways
- Landfill dailycovers
- Railroad ballast
- Miscellaneous environmental applications

4.3 Leaching

Steel slags contain heavy metals (antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, nickel, selenium, thallium, vanadium, etc.) at concentrations higher than those in most soils. Even though these metals are available as minor constituents of steel slag, possible leaching of these heavy metals into groundwater have prevented the use of steel slags in various civil engineering applications. Steel slag samples with different aggregate sizes were crushed and combined together to obtain homogenous samples from each source. the slag leachates are unlikely to cause groundwater contamination at a level that exceeds the drinking water standards. Steel slag leachates are also characterized by their high alkalinity. Elevated values were observed in slag leachates and also in groundwater affected by steel slag disposal sites. pH levels are elevated in steel slag affected waters, mainly due to the leaching of alkaline substances from steel slag into thewater.

4.4 Corrosion

The deterioration or disintegration of a material by a chemical or electrochemical reaction with

TYPICAL PROPERTIES

CHARACTERISTICS	SPECIFICATIONS	SPECIFICATIONS	SPECIFICATIONS
	IMPORTED BITUMEN PRICE (IN RS.)/PMT+(VAT/CST)	IMPORTED BITUMEN PRICE (IN RS.)/PMT+(VAT/CST)	IMPORTED BITUMEN PRICE (IN RS.)/PMT+(VAT/CST)
	VG-30	VG-40	(60-70)
Absolute Viscosity at 60°C,poises, Min.	2400	3200	-
Kinematic Viscosity at 135 °C, cSt, Min.	350	400	-
Specific Gravity at 27 Degree C, Min	Min. 0.99	Min. 0.99	-
Water, percent by mass, max	Max. 2.0	Max. 2.0	-
Flash Point, Cleveland open cup, (degree C, Min)	Min. 220	Min. 220	>250°C
Softening Point (degree C)	40 to 55	50	49-56
Penetration at 25 degree centigrade. 100g, 5 sec., 1/10mm	50 to 70	40 to 60	60-70
Ductility at 25°C ,cm,	Min. 40	Min. 25	>100
Viscosity ratio @ 60 degree C	Max. 4.0	Max. 4.0	-
Matter Soluble in trichloroethylene, Percent by mass,	Min. 99.0	Min. 99.0	-
Density, 25°C,(kg/m3)	-	-	1.010/1.060
Loss On Heating (%)	-	-	0.2 Max
Drop in Penetration after Heating (%)	-	-	20 Max
Solubility in sc2 (WT%)	-	-	>99.5
Spot Test	-	-	Negative

its

environment is defined as corrosion. Metals loose electrons when they react with water and oxygen, leading to the occurrence of corrosion. The electrochemical corrosion reaction involves an anode and a cathode. At the anode, positively charged metal ions are formed, whereas negatively charged hydroxyl ions are formed from dissolved oxygen at the cathode. Flow of electricity between these two charged ends can be generated on a single metallic surface or between dissimilar meta

5.0 RESULTS AND CONCLUSIONS

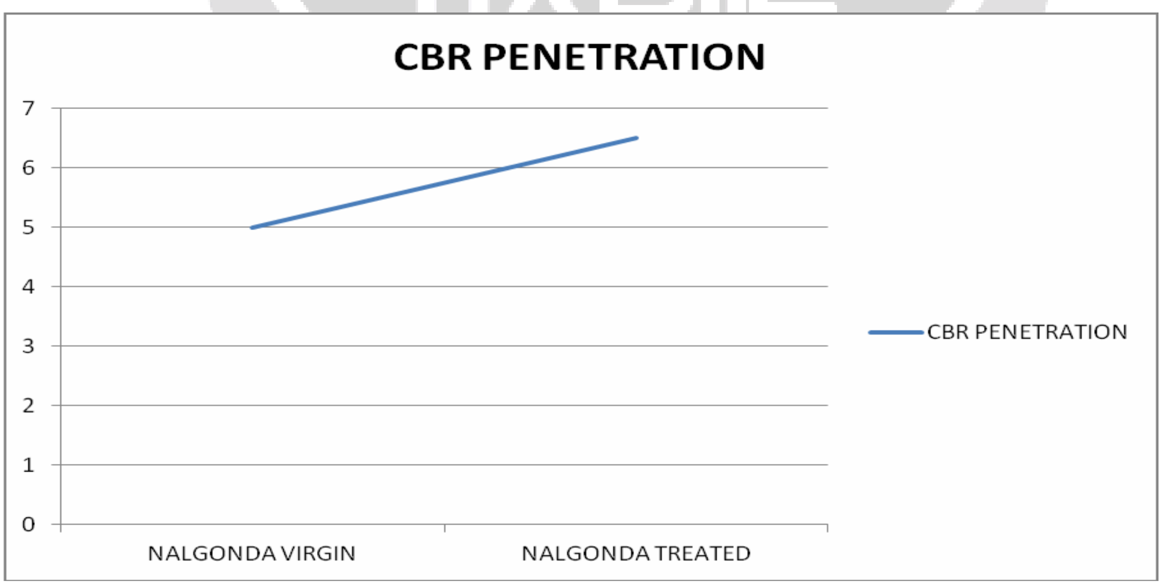
The following table gives the standard loads adopted for different penetrations for the standard material with a C.B.R. value of 100%

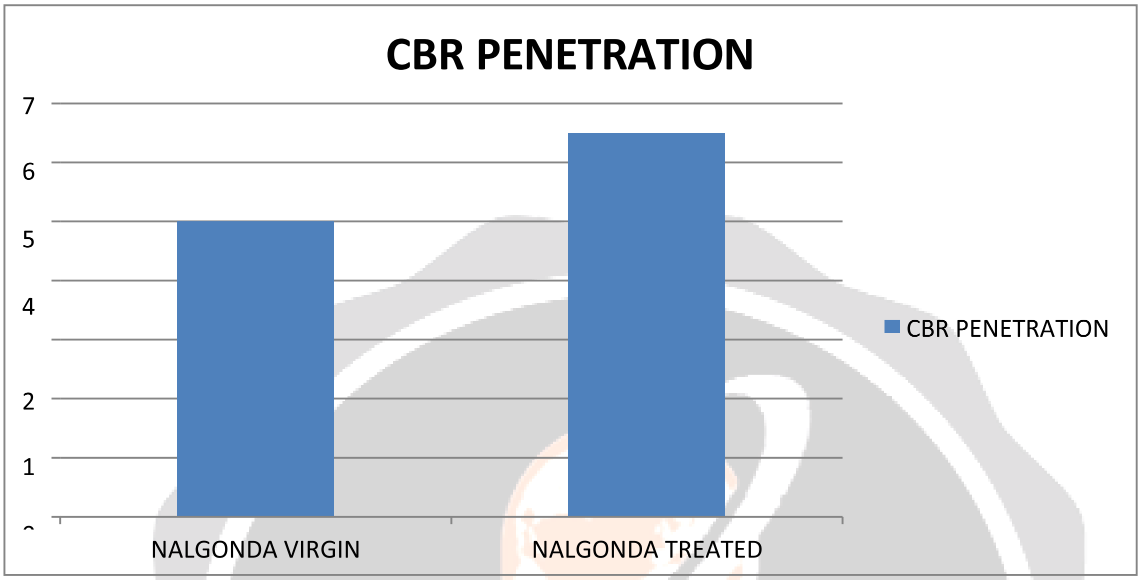
Penetration of plunger (mm)	Standard load (kg)
2.5	1370
5.0	2055
7.5	2630
10	3180
12.5	3600

CBR TEST RESULTS BEFORE ADDING STEEL SLAG

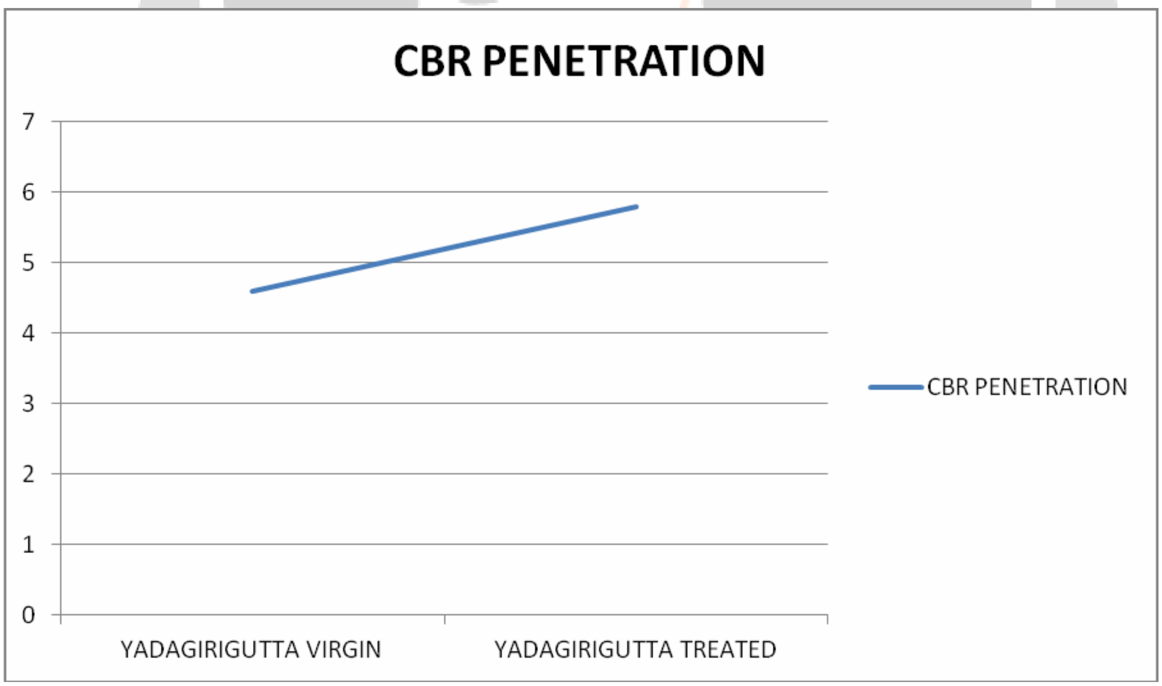
S. No	**Site**	**VIRGIN%**	**TREATED (%)**
1	NALGONDA	5	6.5
2	YADGIRIGUTTA	4.6	5.8
3	RANGAREDDY	5.2	6.3

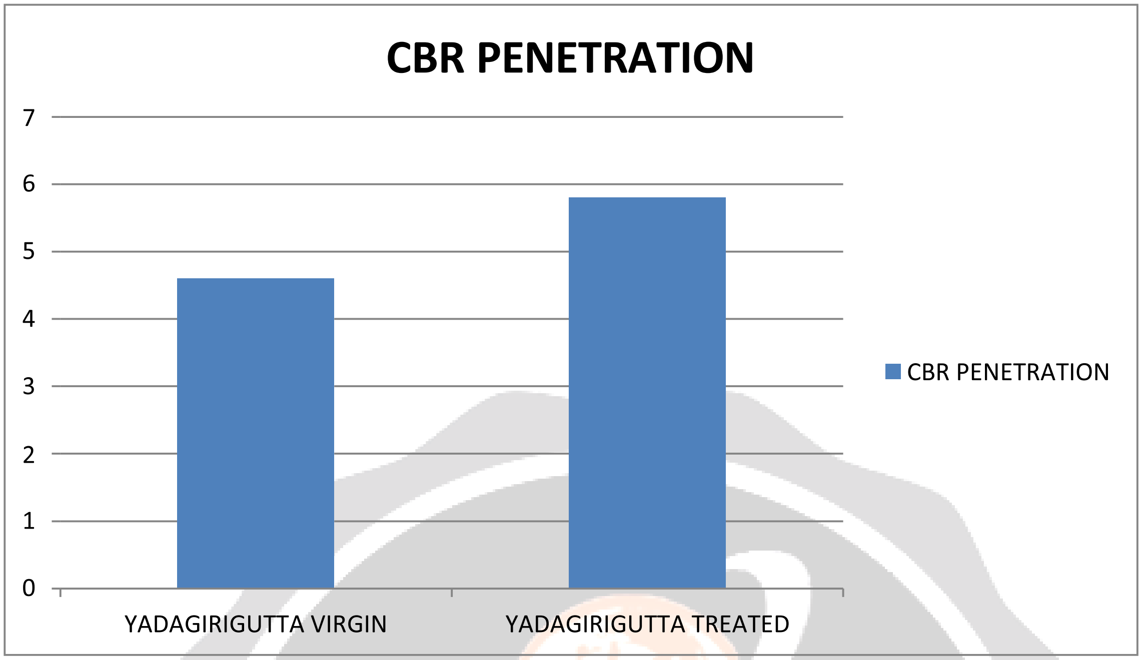
6.1 CBR RESULTS FOR NALGONDA REGION



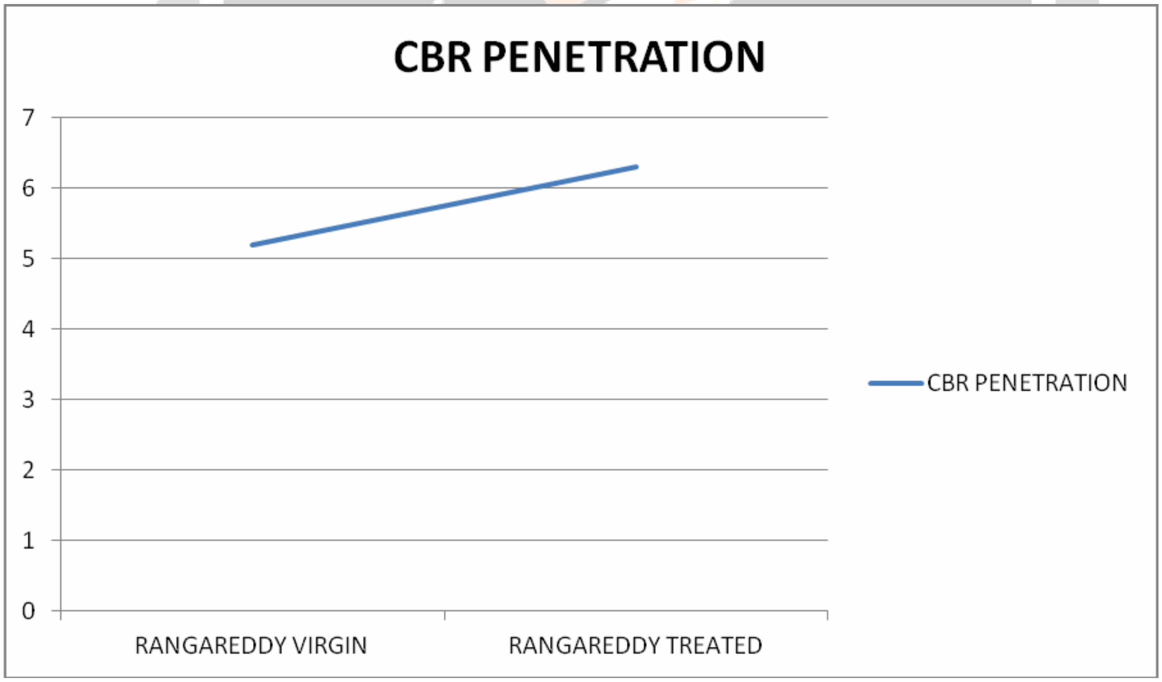


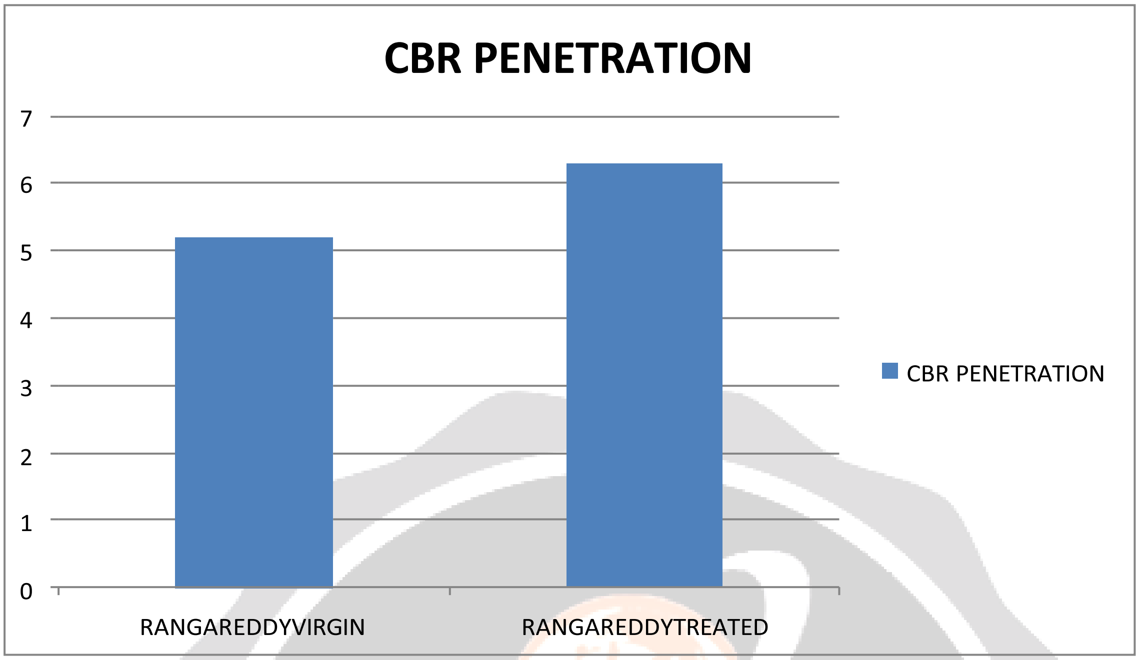
6.2 CBR TEST RESULTS YADAGIRIGUTTA REGION



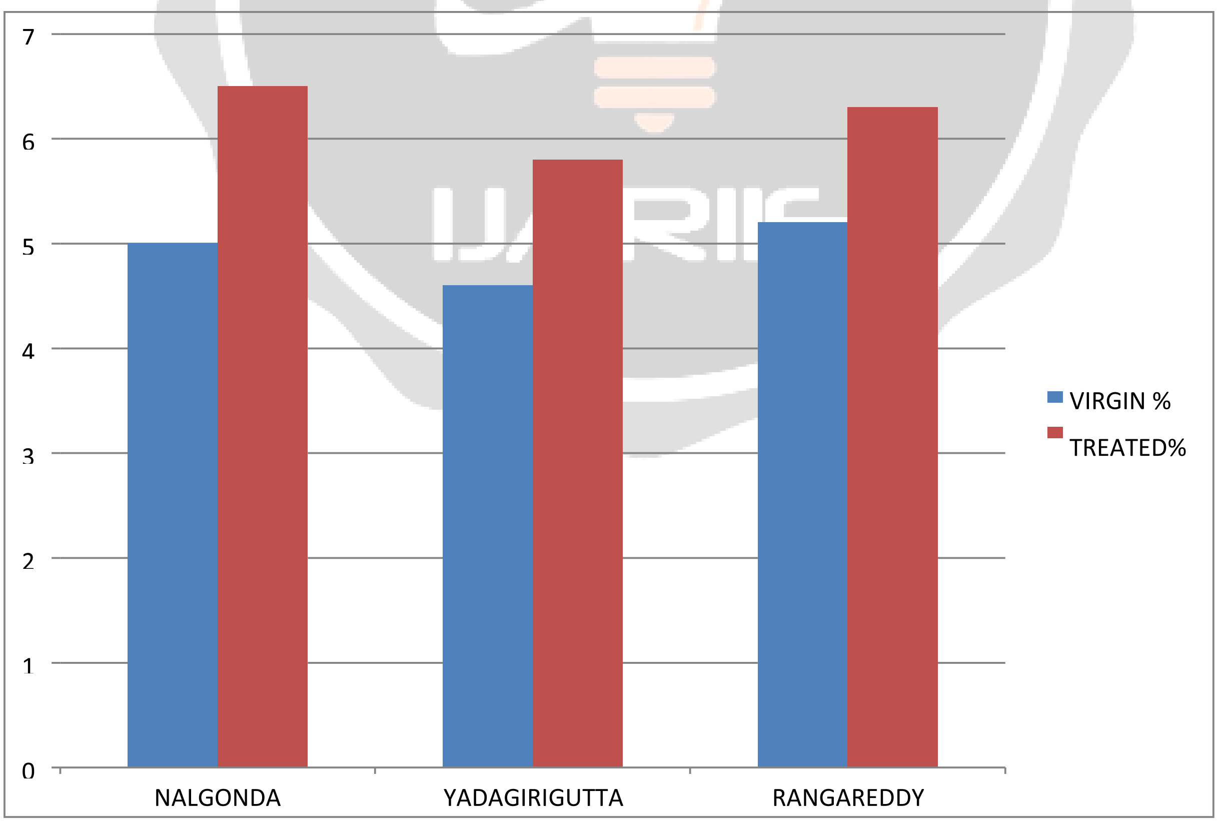


6.3 CBR TEST RESULTS FOR RANGA REDDYREGION





6.4 OVERALL TEST RESULTS COMPARING THREEREGIONS



6.5 CONCLUSIONS

6.1.1 The following table and graphs shows that the steel slag is an effective construction material in bituminouspavements.

6.1.2 The powdered steel slag acts as a good binding material in thepavements.

6.1.3 The steel slag is replacing the aggregates for about 20-30%, hence this makes the construction as an economical construction.

6.1.4 Since steel slag is a waste product of the major industries it can be obtained forlower cost.

6.1.5 Steel slag is giving more strength than the traditional construction pavement process and for an effective low costproduct.

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