An Experimental Study of Modern Road Construction Using Steel Slag

Vedansh
Student, Department of Civil Engineering
Buddha Institute of Technology
Gorakhpur,U.P. India
avvishwakarma831@gmail.com

Jagrit kumar chaurasia
Student, Department of Civil Engineering
Buddha Institute of Technology
Gorakhpur U.P. India
Jkchaurasia77030@gmail.com

Israr Ali
Student, Department of Civil Engineering
Buddha Institute of Technology
Gorakhpur U.P. India
Ia708248@gmail.com

Manish yadav
Student, Department of Civil Engineering
Buddha Institute of Technology
Gorakhpur U.P. India
yadavkumarmanish@gmail.com

Ankit Srivastav
Assistant Professor, Department of Civil Engineering *Buddha Institute of Technology* Gorakhpur U.P. India
ankitsrivastav309@bit.ac.in

Abstract*— A by product of the steel production is steel slag. It is produced as a byproduct of the steelmaking process. For these reasons, most developed countries have declared steel slag to be a useful construction resource rather than an industrial waste, despite its high disposal cost as a waste item. It is subsequently recycled as an aggregate for base building, soil stabilization, road construction, and flexible pavement surface. Despite this, stockpiles continue to hold a sizable portion of the steel slag produced by the steel industry. Because of this, a huge tract of land is being sacrificed in order to get rid of this valuable resource. Numerous scholars have examined the application of steel slag.

***Keywords*— Life cycle evaluation, experimental testing, recycled materials, steel slag, and circular economy, etc**

1. Introduction

They have therefore investigated a range of recyclable materials that may be utilized as aggregate. Geiseler (1996) states that Aristotle mentioned around 350 BC that iron slag, a stone-like residue, is produced as a result of the purification process. It is quite good at drying the wounds and has many other benefits. The byproduct is produced when scrap metal is melted in an electric arc furnace (EAF) to manufacture steel, and when iron is turned into steel in a basic oxygen furnace (BOF). While the chemical composition of the steel slag obtained from these furnaces stays within the range, the characteristics may vary depending on the furnace and the grade of steel produced. In contrast with an electric arc furnace,

a suitable method to prevent volumetric expansion, as doing so could lead to pavement failure. Iron and steel slags have been employed in engineering buildings for more than 150 years, according to the National Slag Association. It is utilized as fill material, subgrade soil stabilization, rail road ballast, and aggregate in place of natural aggregate for bounding applications (BFS).

John Emery claims that throughout the Roman Empire, iron slag was also utilized to build roadways. Up to 97% of all steel slag produced in 1998 was utilized in various ways by Germany to build heavily traveled roadways. For surface layer, road base, and sub base applications, it is used as aggregate. It is also used in hydraulic structures and earthworks. Steel slag has a large proportion of free iron, which makes it dense and hard, giving it excellent resistance to abrasion. It is a sufficiently angular, vesicular, porous substance with a rough texture. It offers good stability and a particle interlock upon compaction. The ratio of steel slag to natural aggregate is not standardized, however if partially.

1.1 Objective of the study

A byproduct of the steel-making process is steel slag. Silica, alumina, titanium, iron sand, and various calcium and magnesium oxide combinations make up the majority of the slag's composition. Slag's job in the steelmaking process is to keep the molten iron at a consistent temperature

1.1 Scope of study

Decreased Dependence on Normal Assets: Customary street development vigorously depends on regular counterbalance and totals, exhausting valuable normal assets. The Steel Slag Street innovation dispenses with the requirement for normal materials, helping ration significant assets and save regular biological systems.

2. MATERIALS AND METHODS

2.1.1 Steel slag

Steel slag is a modern side-effect acquired from the steel producing industry. It is delivered in enormous amounts during steel-production tasks that utilization electric bend heaters. Steel slag can likewise be delivered by purifying iron mineral in a fundamental oxygen heater.

Fig-2.1.1

2.1.2 Property of steel slag

Steel slag totals are profoundly precise in shape and have unpleasant surface. They have high mass explicit gravity and moderate water ingestion (under 3%).

Degree, explicit gravity, dependability, toughness, destructiveness, and waste are a couple of the critical qualities of steel slag that are especially pertinent while utilizing steel slag as a total in granular establishment. As follows, these attributes are covered:

a) Degree: Steel slag is handily treated to meet the granular totals' graduation guidelines.

b) Explicit Gravity: Steel slag total is anticipated to deliver an item with a higher thickness contrasted with customary blends in light of the relatively high unambiguous gravity (3.2-3.6) of steel slag.

c) Security: Steel slag totals have a high California Bearing Proportion (CBR) worth of up to 300 percent and a high point of inner contact (40° to 45°).

d) Steel slag totals show great strength and protection from erosive enduring.

e) Destructiveness: In spite of the fact that leachate from steel slag can outperform a pH worth of 11, the pH scope of the steel slag total regularly lies somewhere in the range of 8 and 10.

f) Waste Qualities: Steel slag totals are free depleting and are not defenseless to ice.

2.1.3 Advantage of steel slag

- This strategy can keep the street from any harm caused during the rainstorm season.
- The thruways and different streets can turn out to be more grounded with this steel slag streets than ordinary regular streets.
- It can likewise decrease the expense of development by 30% than regular street development.
- Steel squander produce every year that normally go to landfills can get use now by this strategy for development.
- The utilization of Steel Slag to develop streets will work on the strength and nature of streets making them more secure.
- The utilization of Steel Slag on streets will help in decreasing the waste and reusing the misuse of the Steel businesses in India.
- The carbon impression in the Steel Slag Streets is lower than common streets worked with different materials.
- Steel-slag combination has ideal execution as far as interconnecting and bond

2.2.1 Aggregate

Total materials are acquired from regular mines of sand or sand and rock, quarries, stores, and underground residue. Instances of total materials include: Squashed rock – These items are gotten by removing rocks and pulverizing them to the ideal size and surface.

Fig-2.2.1

2.2.2 Advantage of aggregate

The advantage of utilizing aggregate planing include the following-

Minimizing staffing Fluctuations –

Through using total wanting to figure creation interest, organizations can foresee staffing necessities. Organizations that are needing extra representatives on an impermanent premise will generally fill these situations with laborers from transitory work offices. With legitimate estimating, a business will actually want to diminish or dispose of the need to employ additional laborers. Eventually, this will save the business both time and cash as it won't have to pay extra charges to the staffing office and it will not need to pay laborers to prepare the new increments.

Reduce overhead –

Inside an assembling office, having overabundance stock can cost large chunk of change. This is on the grounds that the office should guarantee that it has sufficient material close by to deliver the completed merchandise as well as the space to store those things. Moreover, having completed items laying around improves the probability that they will become harmed or become old before they are sold. Sticking to a total arranging model can assist creation offices with keeping lower levels of stock and diminish above costs.

Accommodate changes –

Most creation organizations can't adhere to a solitary arrangement consistently as creation orders can change frequently. Total arranging considers emergency courses of action to be taken care
of set up for creation offices to have the option to oblige for huge changes in client orders and creation. Refreshing conjectures and creation designs occasionally permits organizers to consider any progressions in expected request or supply and change plans.

2.2.3 Tests of aggregate

- Aggregate Crushing Test
- Aggregate Impact Test

A. Aggregate crushing test

The strength of total is charecherized as the obstraction of the total against show stacking. The strength of not set in stone by the devastating worth test on totals. The total going through a12.5 mm IS sifter are taken . these Total are exposed to steady staching of 40 tons with the assistance of an unclogger

Calculation

ACV = (W2 / W1) *100

W1 = 2010g

W2 = 306g

ACV = (306/2010)*100 = 15.22 %

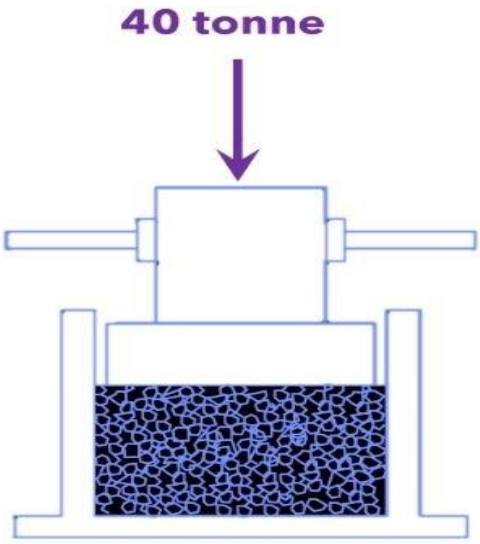

Fig-2.2.3(A)

The squashed totals are then gone through a 2.36 mm sifter. The heaviness of the totals going through the 2.36 mm strainer, communicated as the level of the all out weight of totals, is alluded to as Total Pulverizing Worth (ACV). Lesser is the ACV, more will be the strength of total. ACV under 10 demonstrates major areas of strength for especially while, ACV more prominent than 35 shows feeble total.

Total Smashing Worth (ACV) =weight of material going through 2.36 mm strainer/weight of complete total.

Fig-2.2.3(A)

B. Aggregate impact test

The strength of the total is characterized as the capacity to oppose influence stacking. The durability of the not entirely set in stone by Effect Worth Test on totals. The totals going through a 12.5 mm IS strainer and held on a 10 mm IS sifter are taken. This example of total is exposed to 15 blows with the assistance of a metallic mallet having a mass of 13.5-14 kg, dropping from a level of 38 cm.

The totals after influence are gone through the sifter of size 2.36 mm. The heaviness of totals going through the 2.36 mm sifter, communicated as the level of the

Fig-2.2.3(B)

The totals after influence are gone through the sifter of size 2.36 mm. The heaviness of totals going through the 2.36 mm sifter, communicated as the level of the all out weight of totals is alluded to as Total Effect Worth (AIV). Lesser is the AIV, more will be the durability of the total. The AIV of total shouldn't

surpass 30% for wearing course, 35% for bituminous macadam and 40% for water-bound macadam.

Calculation –

AIV = W2 / W1 *100
W1 = 500g
W2 = 27.5g

AIV1 = 27.5/500*100 = 5.5 %

Total Effect Worth (AIV)=weight of material going through 2.36 mm strainer/weight of all out total.

Fig-2.2.3(B)

C. Elongation index test

The lengthening record of the totals is characterized as the rate by weight of the totals present in the example having their most noteworthy size more prominent than 1.8 seasons of their mean size. Stretching record test on totals is performed utilizing Length Measure.
This test doesn't have any significant bearing to totals with a size of under 6.3 mm. A total example having at least 200 pieces is thought of and each total is gone through the particular checks of the length measure. The heaviness of totals held over different checks is noted which when communicated as far as the absolute weight of the totals is alluded to as Extension List.

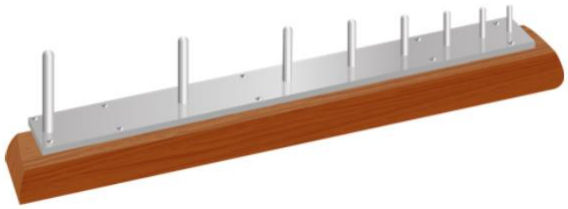

Fig-2.2.3(C)

Elongation Index value = weight of elongation aggregate/weight of non flaky

2.3.1 Bitumin

Bitumen is a blackish-earthy colored oil substance. Bitumen is the organization of oil based commodities and asphaltene tar. The regular beginning of bitumen happened a long time back while living creatures were covered under rocks in swamps and other oceanic environments. However, these days, raw petroleum is the primary wellspring of the age of bitumen.

Bitumen is a development material utilized for the development of adaptable asphalt. The term bitumen is utilized to depict a substance produced through the refining of raw petroleum. Bitumen has cement and waterproofing properties and can be utilized in developing streets and enterprises.
Bitumen stores can likewise be produced in old lakes.

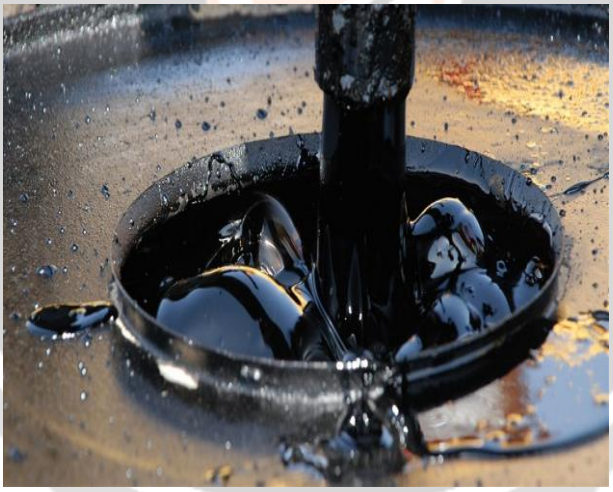

Fig-2.3.1

2.3.2 TYPES OF BITUMEN

Penetration Grade Bitumen
Oxidized Bitumen Grade
Cut Back Bitumen
Bitumen emulsion
Polymer Modified Bitumen

2.3.3 TESTS OF BITUMENS

Penetration Test
Softening Point Test
Ductility Test
Viscosity Test
Specific Gravity Test

Solubility Test
Flash And fire Point Test
Loss On Heating Test

A. Penetration Test

An entrance test, otherwise called a pen test, is a recreated digital assault against your PC framework to check for exploitable weaknesses. With regards to web application security, infiltration testing is usually used to expand a web application firewall.

Entrance analyzers are security experts gifted in the craft of moral hacking, which is the utilization of hacking devices and procedures to fix security shortcomings as opposed to actually hurt. Organizations recruit pen analyzers to send off reenacted assaults against their applications, organizations, and different resources. By organizing counterfeit assaults, pen analyzers help security groups reveal basic security weaknesses and further develop the general security pose.

Fig-2.3.3(A)

B. Softening Point Test

The conditioning point test is the temperature at which the substance accomplishes a specific level of mellowing under the predefined states of the test.The contraption used to decide relaxing mark of bitumen is RING AND BALL gathering.The conditioning point of different bitumen grades for the most part lies between 35°C to 70°C. Mellowing point of bitumen to be utilized for street development where the most extreme temperature is 40°C ought to be more noteworthy than the 40°C.

The conditioning point of bitumen or tar is the temperature at which the substance accomplishes a specific level of mellowing. According to IS:334-1982, it is the temperature (in o C) at which a standard ball goes through an example of bitumen in a shape and falls through a level of 2.5 cm, when warmed submerged or glycerin at determined states of test. The folio ought to have adequate ease before its applications in street utilizes. The assurance of relaxing point assists with knowing the temperature up to which a bituminous cover ought to be warmed for different street use applications. Mellowing not entirely settled by ring and ball contraption

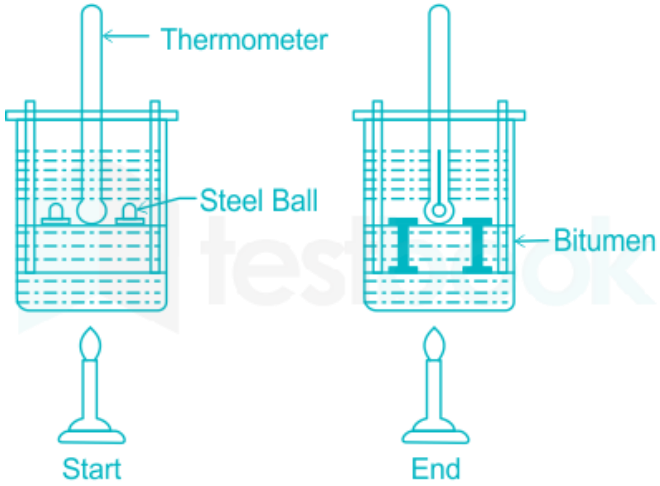

Fig-2.3.3(B)

C. Ductility test

A ductility test is a mechanical evaluation method used to quantify how much a material will plastically (and permanently) deform when subjected to tensile stress. It establishes the maximum amount of deformation the material can withstand before cracking or breaking.Ductility is a ability of a material to plastically deform without failure or fracture. In most applications higher ductility in a material is sought.Ductility test or bend test is very common test for welded joints, piping products and reinforcing (reo bars) materials.

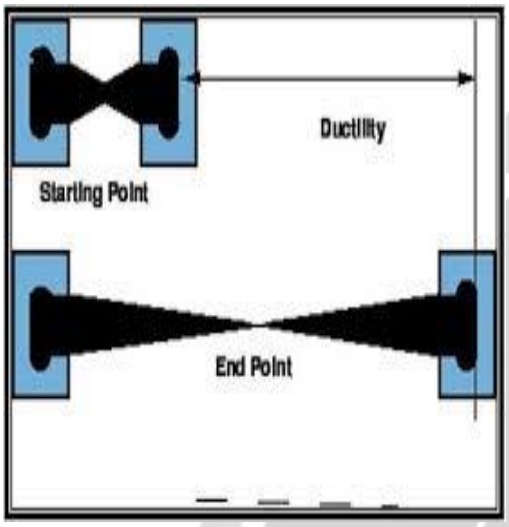

Fig-2.2.3(C)

D. Viscosity Test

The thickness of a fluid (see Consistency) is estimated utilizing a viscometer, and the best viscometers are those which can make and control straightforward stream fields. The most generally estimated thickness is the shear consistency, and here we will focus on its estimation, despite the fact that it ought to be noticed that different extensional viscosities can likewise be characterized and endeavors can be made to gauge them, albeit this is difficult.

2.4 PRODUCTION AND UTILIZATION OF STEEL SLAG

During the creation of three tons tempered steel around one ton of steel slag is produced. It has been seen that each year fifty million tons of steel slag is created from various steel enterprises all through the world. Just in Europe, around twelve huge number of steel slag is created consistently. Steel slag is a remaining material that creates during the development of treated steel by various assets either from the dissolving of scratch to deliver steel in electric bend heater (EAF), or by changing iron over completely to steel in essential oxygen heater (BOF). Hot fluid metal, scratch and motions along with lime and dolomite lime handled in essential oxygen heater. The debasements like carbon monoxide and silicon, manganese, phosphorous and iron in fluid state consolidates with lime is and dolomite lime are isolated by infusing oxygen with high strain to frame steel slag. Electric curve heater is a pot molded plan used to handle cold steel scratch rather than hot fluid metal. The piece is dissolved through high electric flow going through graphite terminals by shaping a circular segment. A few different metals like Ferro, compounds are added to adjust the necessary synthetic organization of steel and oxygen is blown to filter the steel. Toward the end, the drifting steel slag is isolated from the outer layer of liquid steel. The leftover steel slag is then squashed into 8 crawls with the assistance of a huge steel ball or a strong steel chamber by dropping it to the slags. The cycle for squashing and reviewing is rehashed until to get the necessary grade of totals. Recuperation of metallic particles is helped out through transport lines electromagnetically in a similar plant.

Then, at that point, provided as development total to the development offices. It is rivaling normal total, where elite execution total is restricted. This shows the significance of elective totals like steel slag are important items not the squanders, additionally giving ecological advantage.

2.5 Chemical And Mineral Composition Of Steel Slag

Generally steel slag consist of CaO, MgO, SiO2 and FeO oxides, which found within the range of about 88% to 90 %. The total concentration of these oxides in liquid slags is in the range of 88%– 92%. Though these oxides fluctuate based on the material used, type of steel being manufactured and condition of furnace. Use of dolomite instead of lime as a flex, highly influence the chemical composition which provides higher content of MgO . The chemical composition of steel slag are given in Table 1. Both BOF and EAF slags are dicalciumsilicate, dicalciumferrite and wustite. Dicalciumsilicate provides stability, which prevents disintegration of steel slag. Several studies show that the dissolved lime and MgO does not affect the volume of steel slag, but the excess amount of "spongy free lime" and MgO may cause the volume instability.

2.6 Physical And Mechanical Property Of Steel Slag

Streets are exposed to static and dynamic powers, including the unforgiving climate like downpour, temperature, freezing and defrosting. The proposed material ought to give satisfactory physical and mechanical properties to oppose and perform well. The physical and mechanical properties are given as: total smashing worth, misfortune points scraped area, total effect esteem, sufficiency, cleaned stone worth, water retention, surface, stripping, explicit gravity and flakiness. The physical and mechanical properties of steel slag gainfully meet the prerequisites of a posh material. As contrast with regular total, it gives an optimal solidness, penetrability, security and opposition against scraped spot, breaking and super durable twisting.

A. Specific Gravity

Steel slag contains sufficient amount of iron oxide, therefore it has greater value of specific gravity as compare to the natural aggregates. Number of researchers have evaluated the specific gravity of other construction materials and that of steel slag fall within the range of 3 to 4. Steel slag is about 20 % heavier than the lime stone and granite. This may be an economic disadvantage, but is not considered, as it provides more advantages like high strength and durability.

B. Grain size distribution

Grain size appropriation, a significant element which is exceptionally impacted the mechanical properties of the material. It is challenging to break it in to particles of various sizes during its age in the steel plant. During the cooling system, it separates into various molecule size containing bigger size as rocks up to the measures of residue. Further it is handled to acquire legitimate grade of steel slag by smashing plants as examined before. The coarse degree particles tracked down in the scope of around 64mm to 200mm, correspondingly the medium size particles ultimately depend on 64mm. The fine degree resembles all around reviewed sand comprising of fluctuating sizes of rock up to the residue size particles, held at No. 4 sieve;

C. composition chacteristic

Restricted examinations have been completed on the compaction of general steel slag. The consequences of past investigates show higher upsides of greatest dry unit weight of steel slag then normal total. Rohde et al., (2003) have concentrated on the compaction attributes of EAF steel slag of various grades by standard delegate compaction test technique. The ideal dampness content and most extreme dry load of EAF steel slag were in the scope of 3%-6% and 23-26kN/m3 .

D. Shear resistance

Steel slags are unpleasant in surface, cubical and precise as contrast with the normal material. It gives better interlocking and erosion which results solidness, protection from rutting and higher pallet opposition. The erosion point of steel slag is accounted for 40º to 50. As a result of its better shear opposition, can be utilize every one of the layers of asphalts.

E. Thermal Properties

It has been seen that steel slag, can possibly hold the intensity as longer than normal total. The intensity maintenance property of steel slag total is a benefit. It assists with getting ready warm blend black-top cement to cover the totals appropriately exceptionally fixing of asphalts surface in chilly climate.

2.7 UTILIZTION OF STEEL SLAG IN THE ROAD CONSTRUCTION

Steel slags have been effectively used for the development of streets in wearing course, base and sub base also. Particularly Europe, Canada, Australia and USA have not regarded it as a modern waste but rather a valuable development material, and effectively utilizing steel slag as total in surfacing and base of adaptable asphalts. Steel slag is created in 29 provinces of US by 17 organizations. Exceptional determination, adequate record of its purposes and execution on significant undertakings all over the planet show that both steel (BOF or EAF) slag is a material of decision. In Batlimore as per Khan et al., (2002) the remarkable attributes exhibiting one of the upsides of utilizing steel slag bituminous cement is high pallet opposition (under wet or dry circumstances) gave all through the servicelife of the asphalts. SSA and black-top combinations were utilized to give 1 to 1.25 inch thick surface layer for various streets in Indiana somewhere in the range of 1979 and 1981. Bituminous test segments were developed utilizing six unique mix of coarse and fine total to deliver combinations with a large number of degrees and extents of steel slag coarse totals. Slip obstruction numbers estimated utilizing ASTM E274 demonstrate that the utilization of steel slag total in black-top surface blends furnish asphalt surfaces with great pallet opposition. Asphaltic clearing combinations utilizing steel slag total showed astoundingly high security, which might further develop the groove safe when utilized in asphalt surface layers. Blend delivered using steel slag total and regular sand showed incredibly enormous solidness modulus values. An enormous solidness esteem is a sign of the chance of utilizing a decreased asphalt thickness. This more slender layer assumes a significant part in making up for the high-thickness detriment of steel slag black-top blends. Stock and Ibberson, (1996) revealed the utilization of steel slag in bituminous street development in South Yorkshire and its environs for the beyond 60 years. Over 300,000 tons of steel slag each year was used for street development. As an evaluation of slide opposition of black-top surfaces consolidating steel slag, side power coefficient Routine Examination Machine (SCRIM) was estimated on different classifications of streets (100 mm and 14 mm surface dressings). The overviews show that steel slag street surfaces have to some extent as great long haul slip obstruction properties as those of tantamount normal total street surfaces under comparable traffic conditions. SSA has additionally been effectively used in nations with high encompassing temperatures that cause serious issues in black-top surfaces. Among the different nations all over the planet with blistering environments, like Singapore, Malaysia, Australia, South Africa, Saudi Arabia and Italy, have previously understood the unrivaled properties of steel slag black-top. Super durable misshapening can happen at a beginning phase in the existence of black-top surfacing material, when the street surface temperature starts to move toward the conditioning point of the bitumen. The high surface temperature makes the black-top become plastic and afterward twist effectively bringing about rutting.

It is seen that the utilization of EAF steel slag for low volume streets practical as contrast with the normal totals. Appropriately endured EAF steel slag has been examined for the development of low volume streets as a base material. Agreeable aftereffects of versatile modulus were gotten from EAF steel slag as contrast with the regular totals. Aiban and Abdul Wahhab (2006) consolidated a combination of marl and sand with 30% to 85% of steel slag by weight for street base and got CBR values up to 455%. For the utilization of base and sub base courses, properties of concrete settled steel slag have been concentrated too. The outcomes showed high qualities then normal total concrete adjustment. A combination of fly debris and phosphogypsum with steel slag intended for street base. At the point when the properties of this blend researched, the came about upsides of long haul shear strength and water soundness files were a lot higher than concrete balanced out granular materials. It is additionally proposed by Mymrin et al., (2005) that the development cost of street base can decreased by the utilization of concrete initiated steel slag with regular soil blend, since it furnishes greatest strength and

dependability with a more limited thickness as contrast with the ordinary material.

3. RESULT AND DISCUSSION

The result shows that when steel slag percentage that used with hot asphalt mixing mix according the (ASTM D 1559 – 82) increased the Marshal stability and Marshal Index were increased too. The Marshal stability increased from 8 to 12.2 KN for samples prepared by using hot asphalt mix with 10 % of steel slag due to increase its bulk density from 2.23 to 2.40 and Marshal Index increased from 2.93 to 4.42. On the other hand, when the steel slag increase to 20%, marshal stability and marshal index were increased to be 13.65 KN and 5.42, respectively. Furthermore, marshal stability and index increased to be 15.85 KN and 5.82 when the percentage of steel slag increased to be 30%. However, when steel slag increased to be 40 %, Marshall Stability and Marshall Index were decreased to be15.25 and 5.62, respectively as shown in table 9. Therefore, the optimum percentage of steel slag that suitable for Iraqi weather with high temperature reach to 50 °C or more in summer is 30%

3.1 Desire Outcomes

To create the sustainable development modal: Using the steel slag in flexible pavement it utilizes the industrial waste from steel industry so that it reduces the metallurgical pollution hence it creates the sustainable development modal in front of MORTH.
Providing less rutting deformation: The addition higher rutting resistance occurred because of the higher creep stiffness of the mixtures with steel slag aggregate.
Making easy to maintenance: The flexible pavement easy to maintenance because after constructing the flexible pavement do not take much more time for strengthening the layer and hence traffic density do not jam for large duration time.
Giving eco-friendly results: Instead of keeping the stock pile in the dumped area nearby it can be used in road construction pavement so that it reduces the pollution. hence it creates eco-friendly example in front government of India.

4. CONCLUSION

This paper investigated the designing properties of steel slag. Steel slag has various benefits with high designing properties. It has been pronounced a helpful development material not a modern waste. The general end drawn in view of the writing survey is as followed; past examinations have stressed on use of steel slag in concrete and substantial industry. Thus, the vast majority of the trial concentrates on investigated the compound arrangement not the physical or mechanical properties of steel slag. The concentrate further, steel slag blend requires higher worth of bitumen content, which doesn't meet the rules of ideal bitumen content for normal total. There isn't any rule or determination overall for steel slag to be followed, for the various extents of steel slag mixed with regular total to get satisfactory blend plan. Writing showed that steel slag has sufficient potential and can be used in subgrade or banks, yet extremely uncommon examination have been finished around here. It is finished up in view of synthetic and mineralogical sythesis, the properties of steel slag are different contrasted with the normal total. Thus, the rules of normal total are being kept for steel slag isn't suitable. Monetarily the steel slag might be less expensive whenever used in metropolitan streets yet it would be costly for country streets because of the transportation charges

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