Characterisation and Utilisation of Steel Slag over A Subgrade in Design of A Flexible Pavement

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Abstract: **The large amount of industrial wastes are increasing year by year and its disposal becomes a very serious problem to the environment. It is necessary the utilization of industrial waste which is obtained by electric arc furnace the steel slag waste affectively with technical development in each field. Commonly the materials like murrum soil, gravel, bricks, stones, etc.., of different materials has been using for different types of construction of all categories of roads in our country. Although those are good construction materials, but sometimes due to scarcity of materials and the cost also increases at some parts of country, and also some types of materials are found to be unsuitable for road construction in view of higher finer fraction and excessive plastic properties. So that industrial material like steel slag is used in construction of road pavement. The steel slag disposal causing severe health problems and environmental hazards in road construction 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 industries. In this paper, a typical steel slag was collected from steel industry and its feasibility for use in different layers of road construction was investigated. Technical specification of steel slag is developed for utilization in construction of embankment, sub grade and sub base layer of flexible pavement. The steel slag when mixing with water in place of cement it gives a good result in slump concrete test. That result shows how much influencing the steel slag in concrete structures. The slag is mechanically stabilized with different types of soils available in different places to improve the geotechnical properties of soil to improve the geotechnical properties, the slag was mechanically stabilized with locally available soil.**

Keywords: Industrial wastes, Disposal, Concrete Mixes, Steel Sag and Environment.

I. INTRODUCTION

A. Flexible Pavement**:**

Flexible pavements are so named because the total pavement structure deflects, or flexes, under loading. A flexible pavement structure is constructed with different materials in layers. Each layer receives the load from the above layer to the next layer below and the load spreads uniformly. Therefore the stresses will be reduced, and the stress which are maximum at the top layer and minimum on bottom layer. Due to this advantage, the layers are usually arranged in the descending order the load bearing capacity the layers should be laid with maximum thickness at the top and lees thickness should be laid in bottom layers. The materials of highest cost should be used for top layer when compared to bottom layers.

Components Of Flexible Pavement**:**

A flexible pavement consists of four layers: (i) soil subgrade (ii) sub-base course (iii) base course (iv) surface course or wearing course. The flexible pavement of this layers transmit the vertical loads from the top layer to the lower layers by grain to grain transfer through the point of contact in the granular structure.

Fig-1.1 Cross section of flexible pavement

B. Pavement Materials**:**

The flexible pavement constructed with different materials and the layers transmit the vertical or compressive loads tor wheel loads the lower layers by grain to grain contact of aggregate through granular structure. A well compacted granular structure consists of strong graded aggregate can transfer of different wheel stresses through a large area and thus forms a layer of good flexible pavement. The load spreading characteristics of these layers depends on the type of materials which are used for road construction. These materials are classified into different categories:

- Subgrade soil
- Stone aggregate

- Bituminous materials

C. Steel Slag:

It is a bi product obtained from the manufacturing of steel in an electric arc furnace. The steel slag consists of high iron oxide content of and the result of the aggregate is very hard and dense (SSA is 20-40% heavier than natural aggregates). This steel slag also contains high content of calcium and magnesium, due to this the steel slag can expand when it comes with contact of water. The steel slag is also porous and angular in shape.

The main use of this SSA is substituting for natural aggregates in the production of hot-mix asphalt (HMA). It is used less often in supporting courses (bases and sub bases) beneath HMA or bituminous surface treatment (BST) wearing courses. It should not be used in cement concrete roads or any other cement concrete applications due to the expanding nature of the slag therefore expansion causes the concrete pavement to crack. Different users mention that the aggregate should be cured in water under saturated condition for a period of 3-6 months. Many states require an expansion test to this steel slag aggregate along with curing test.

Fig-1.2 Pictorial view of steel slag

1. Classification of steel slag**:**

The iron and steel slag are the bi products which are coming from manufacture of copper and steel making process in blast furnace slag and electric arc furnace slag

- Blast furnace slag and
- Steel making slag.

Blast furnace slag is recovered by separation of slag from blast furnaces for producing molten pig iron. The molten pig iron consists of non-ferrous components contained an iron ore and lime stone as an auxiliary materials and ash from coke. The air cooled slag process or granulates slag process is used for cooling of hot liquid slag.

Steel making slag consists of basic oxygen furnace arc or electric arc furnace and it is generated by a converter and electric arc furnace slag that is generated from the electric arc furnace in steel making process that uses steel scrap as its raw material.

2. Advantages of steel slag aggregate:

The advantages of SSA in bituminous applications are as follows:

Advantages when used in bituminous pavements

- Resistance to skidding
- Resistant to wear and tear.
- High stability.
- Resistant to covering in the presence of moisture.
- Rutting resistant

3. Disadvantages of steel slag aggregate:

Disadvantages of SSA used in bituminous pavements

- High volume expanding in the presence of moisture.
- Increasing binder demand (25% to 35%) due to its porous nature.
- High specific gravity resulting in lower volumes of pavement mix and transportation costs high.
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II. LITERATURE REVIEW

Wu et.al, (2007) documented a study done in China to assess the necessity of using SSA in Stone Mastic Asphalt (SMA). China was in searching an alternative material or any other sources to supplement diminishing natural stone sources. Due to its priority and usage of steel slag it was cured for 3 years. The SSA mix was compared to one of its basalt aggregate. The SSA mixes used 80% SSA, limestone powder, and short- chopped polyester fibers. The SSA had a porous structure that required 24% more asphalt binder than the basalt aggregate. Expansion rates were below 1% confirming the use of the extended moist curing process.

Kehagia, (2009) reported on a Greek study indicates the skidding resistance of HMA wearing courses built with SSAs. The British Pendulum Tester is used to measure the pavements performance built with SSA and SSA with limestone mixes. Tests conducting over a one year period showing that the mixes with SSA having better anti-skidding performance as compared with conventional aggregates. The high bulk density, angular in shape and the irregularities in the steel slag surfaces were reported to ensure that pavements built with these aggregates would be resistant to deformation under traffic loading.

Khanna (2011) describes the design of flexible pavements by using group index method and California bearing ratio test. By using CBR method the thickness of pavement is obtained based on the soil tests, the curves are plotted between CBR percent and depth of construction. Khanna the state highway of engineering also describes the tests for different materials which are used for pavement construction.

Pasetto&Baldo, (2011) they performed a laboratory test on SSA for use in HMA. One limestone aggregate mix are compared to three SSA mix. SSAs were compared with the asphalt binders normally which used in HMA mixes. No excessive permanent deformation was predicted by the two mix design methods. The overall performance of SSA was predicted in terms of stiffness and fatigue due to its moisture damage. Mixes with the highest percentage of SSA (90%) performed the best as compared to the 60, 30, and zero percent SSA mixes.

NCHRP Synthesis 435 entitled **"Recycled Materials and By-products in Highway Applications"** gathered the experiences of transportation agencies and the beneficial use of SSA for highway applications (Stroup-Gardiner & Wattenberg-Komas, 2013). Issues identified included the expansive nature of the fresh slag, the higher specific gravities that result in lower yields of paving mixes and higher transportation costs, and the need to use locally available sources to reduce these haul costs.

International Journal of Engineering and Technology Volume 5 No. 8, August, 2015 Flexible Pavement Assessment of Selected Highways in Ifelodun Local Government, Ikirun-Osun, South – Western, Nigeria The study represents the adequacy of the highway it is often judged by the smoothness or roughness of the pavement; deficient pavement conditions can results in increased the vehicular characteristics and static characteritics and probability of increased crashes. In this study the following processes were carried out: interview sessions with relevant parties, site observations, site pictures were collected during observation, the geotechnical properties of soil subgrade and Manual survey was carried out in this study to B.S 1377.

International Journal of Engineering Inventions Volume 4, Issue 9 [May 2015]Mechanical Properties of Concrete Using Steel Slag Aggregate J. Saravanan and N.Suganya This study presents an establishment of steel slag aggregate and comparative analysis between steel slag concrete and conventional natural aggregate concrete. The high demand of hardened concrete is more than 70% in building construction and the amount of disposed waste material is also increasing, suppliers and researchers are exploring the use of alternative materials which could preserve our natural sources and to protect the environment.

International Journal of Engineering and Innovative Technology (IJEIT), volume 5, issue 11 (May 2016) this study presents that concept of steel slag used in flexible pavement design and its properties and different tests conducted on steel slag required to investigate the suitability of steel slag for different layers of pavement.

International Journal of Advanced Research in Civil, Structural, Environmental and Infrastructure Engineering and Developing Mar,2017 Experimental programs and Studies conducted On Steel Slag In Concretee. Vijay,M.VishalBy its an orthogonal design, this study helps the replacement of sand with the steel slag and slags of Handan to compare the concrete made of steel slag and slag with standard concrete. The results shows the performance of compressive strength of steel slag concrete is very close to that of ordinary concrete on 7th day and 28th day respectively

International Research Journal of Engineering and Technology (IRJET) 04 | -2015 this study helps for constructing of flexible pavements by using design charts Sanjeev Gill* ,Dr.D.K.Maharaj number of methods for development of design charts have been discussed. In Group Index Method the pavement total thickness (surfacing, base and sub base) Also the thickness of sub-base is determined. The CBR method is widely used for the design of flexible pavement. The CBR method is based on strength parameter of the soil material and this method is more rational than the Group Index Method. North Dakota Method is similar to the CBR method. The thickness of pavement is found from the design curve.

III. METHODOLOGY

A. Tests on Steel Sag

Procedure:

- Take 2 kg of aggregate sample is washed thoroughly to remove fines, and placed in wire basket and immersed in distilled water at a room temperature between 22- 32º C and should cover at least 5cm of water above the top of basket.
- After immersion the entrapped air is removed from the aggregate sample by lifting the wire basket containing 25 mm above the base of the water tank and allowing it to drop at the rate of about one drop per second. The wire basket and aggregate sample should remain completely immersed in water for 24 hours..
- The wire basket and the aggregate sample are weighed when suspended in water at a temperature of 22° – 32°C. And the weight should be notes as W_1 g.
- The wire basket and aggregates sample are removed from water and allowed it to drain for few minutes, after which the aggregates are transferred to the dry absorbent clothes. The empty basket is returned to the tank of water jolted 25 times and the weight noted as W_2 g.
- The aggregates placed on the dry absorbent clothes till no further moisture could be removed by this cloth. Then the aggregates should be transferred to the second dried cloth spread in single layer and allowed it to dry for at least 10 minutes till the aggregates are completely dry. The surface dried aggregate weight is noted as W_3 g.
- The aggregate sample is placed in empty tray and kept in an oven and maintained at a temperature of 110° C for 24 hrs. then the aggregate sample is removed from the oven, cooled in an air tight container and weighed as W_4 g.

Fig-3.1 wire basket and water container

Table 1 – Determination of specific gravity

S.No.	Description of item	Sample 1
1.	Weight of saturated aggregate suspended in water with basket (W_1 g)	5100
2.	Weight of basket suspended in water (W_2 g)	2695
3.	Weight of basket suspended in water (W_2 g)	3405
4.	Weight of oven dry aggregate (W_4 g)	3286
5.	Specific gravity = $W_3 / (W_3 – (W_1 – W_2))$	**3.405**

Result: The specific gravity of a given aggregate sample is 3.405

Conclusion: The higher specific gravity results weight of aggregate is high. The SSA of higher weight mix means that a given weight of mix will not cover the same volume of pavement as a conventional mix with natural aggregate; therefore more amount of mix is required to cover the length, width and depth of pavement with conventional HMA (hot-mix asphalt). This requires the need of more asphalt binder, it raises costs of the pavement

B. Grain Size Analysis**:**

Grain size analysis is an index number equal to the sum of cumulative percentages of retained material on a set of sieves divided with 100.

The fineness modulus is an numerical index number giving some idea about mean size of particles present in the aggregate. Fineness modulus can be calculated as a weighted average size in set of sieves on which material is retained and the sieves being counted from bottom to top.

Fig-3.2 Set of sieves & Sieve analysis

Procedure:

- Dry the given steel slag sample by keeping in oven at a temperature of 100^0C to 110^0C for a period of 24 hours.
- Take the weight of steel slag sample. Keep the weight of sample of slag in the top most sieve of the set with larger size at top and lower size at bottom. Care should be taken to ensure that all the sieves are clean before use.
- Each sieve shall be shaken separately and it should be placed for a period of not less than 2minutes.
- The shaking is done with a varied motion forwards and backwards, left and right, clockwise and anti-clockwise so that the material is kept moving in set of sieves and frequently changing directions.
- Find the weight of steel slag retained on each sieve taken in order from top to bottom

If sieving is carried out with the help of machine, 10minutes sieving will be required for each test.

We can also implement same tests to following methods like Moisture absorption, Steel slag impact value, Los Angeles abrasion, Shape test on steel slag and Crushing strength of steel slag

C. Tests on Soil

Compaction Test:

Compaction is a process of reducing or removing of air voids in a soil sample. This test is used to determine at which the soil is having more dense and at that point achieving its maximum dry density of the soil. The graph is plot between water content and maximum dry density of soil to obtain its optimum water content.

Fig- 3.3: Compaction test apparatus

Procedure:

1. Take about 3kg of soil sample which is passing from 20mm sieve and retained on 4.75mm sieve.
2. Place the soil sample in large metal tray and add the water content of 4% to the weight of soil sample.
3. Before filling the mould with soil it should be cleaned thoroughly and grease should be applied.
4. Take the empty weight of a mould along with base plate,
5. Firm the collar and place the mould on a solid base.
6. Fill the first layer of soil sample in the mould and compact the soil sample with a rammer of weight 2.6kg, and the layer should be compacted by 25 blows.
7. Now fill the second layer of the soil sample inside the mould and repeat the same procedure as first layer. After that fill the third layer with soil and given 25 blows of the standard rammer weighing 2.6kg and having drop of 310mm.
8. Remove the collar of compaction equipment and trim the excess soil sample with sharp knife and then weight the mould with compacted sample.
9. Take the soil sample from the mould for determining the water content.
10. Repeat the above procedure for different soil sample to find different water content values.

Observations and tabulation:

- Diameter of the mould = 10cm
- Height of the mould = 13cm
- Volume of the mould = area X height = $[(\pi/4) \times 10^2] \times 13 = 1020.01 cm^3$

Table: 2- Determination of optimum moisture content:

Empty weight of a mould (gms) W_1	**Added water content (%)**	**Weight of mould + sample (gms) W_2**	**Weight of sample in the mould $=W_2-W_1$**	**Bulk density= Weight/volume (gm/cc) (ρ)**	**Dry density= $\rho_d=[\rho\div(1+w)]$**
5740	4	8060	2320	2.27	2.18
5740	6	8456	2716	2.66	2.50
5740	8	8987	3247	3.18	2.94
5740	10	8760	3020	2.97	2.70
5740	12	8410	2670	2.61	2.33

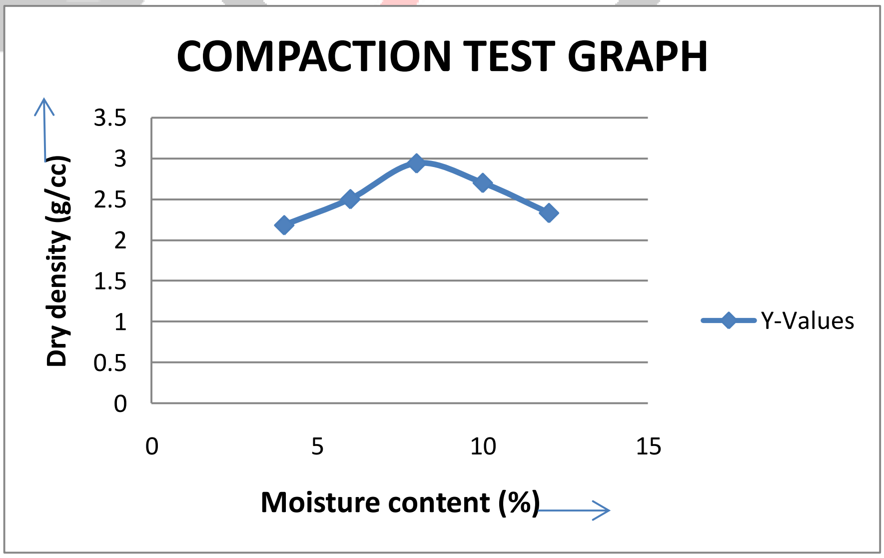

Fig-3.4 Graphical representation of modified proctor's compaction test

Result: Maximum dry density of soil = 2.94g/cc**,** Optimum moisture content in soil = 8%

IV. PAVEMENT DESIGN

A. Introduction

The flexible pavements has been designed as a layer structure and the stresses and strains have been calculated at different critical locations by using the linear elastic model. To give proper consideration to the aspects of performance, the following three types of pavement distress resulting from repeated (cyclic) application of traffic loads are considered:

- At the top of sub grade the vertical compressive strain which can cause sub-grade deformation resulting in permanent deformation occurring at the pavement surface.
- At the bottom of bituminous layer the horizontal tensile stress or strain which can cause fracture of the bituminous layer.
- Tensile stresses causes pavement deformation with in the bituminous layer.

While the permanent deformation in flexible pavement within the bituminous layer shall be controlled by satisfying the mix design requirements, thickness of granular and compact structure of bituminous layers are selected using the analytical design approach so that the tensile strains at the critical points are within the allowable limits. For calculating tensile strains at the bottom of the bituminous layer, the unyielding of dense bituminous macadam (DBM) layer with 60/70 bitumen has been used in this analysis.

The below figure 4.1 shows that the critical location of flexible pavement in different layers

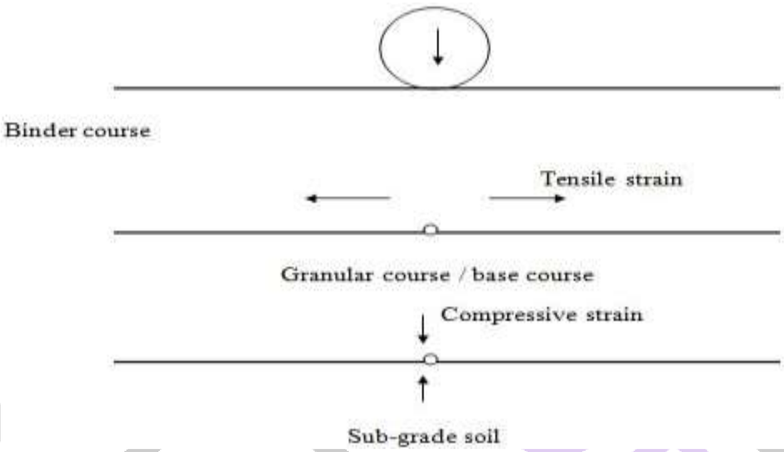

Fig 4.1 critical locations in pavement

B. Design of Flexible Pavement Methods:

The various design approaches for flexible pavement may be classified in to three groups.

- Empirical methods
- Semi-empirical methods or semi theoretical methods
- Theoretical methods

Empirical methods are either based on physical properties of soil or strength parameters of soil sub-grade. When the design is based on stress-strain relation and modified is based on experience, may be called as semi-empirical methods or semi theoretical. There are design methods based on theoretical analysis and mathematical computations. Each one of the design approaches has its own advantages and disadvantages.

Out of the various flexible pavement design methods available, the following are discussed here.

- Group index method
- California bearing ratio method
- California R value or stabilometer method
- Triaxial test method
- McLeod method
- Burmister method

From the above design methods, the empirical methods are group index method, CBR, stabilometer and McLeod method. The Tri axial test method is a theoretical method using empirical modifications as suggested by Kansas state highway department and therefore may be considered as semi-empirical method. Burmister method is a theoretical approach using elastic two layer theory.

1. Group index method:

The group index method for flexible pavement is essentially an empirical based method on the physical properties of the soil sub grade. The GI values of different soils varies in the range of 0 to 20. The higher the GI value, the soil sub-grade is weaker and lower value indicates the soil sub grade is strong which used for thickness of pavement.

To design the thickness of pavement by this method, first GI value of the soil is found. Based in this value the anticipated traffic is estimated as light, medium and heavy and the total thickness of flexible pavement (surface, base and sub base course) is found by using group index design chart recommended by IRC corresponding to the GI values of the soil.

2. California bearing ratio method:

In order to design thickness of pavement by using CBR method, in this method first soaked CBR value of the soil sub-grade is evaluated. Based on this value the appropriate design curve is chosen by taking the anticipated traffic into consideration, therefore the total thickness of flexible pavement is needed to cover the subgrade of the known CBR value is obtained. In case is there any material superior than the soil subgrade, such that it may be used as sub base course then the thickness of construction over this material could be obtained from the design chart knowing the CBR value of the sub base. Thickness of the sub base course is the total thickness minus the thickness over the sub base.

Thus CBR method for flexible pavement design is based on strength parameter of soil sub grade and pavement material.

C. Design Procedure

The performance is based on existing designs and using analytical approach, based on these the simple design charts and a thesaurus of pavement designs are added in the code. In this code the pavement designs for subgrade, the CBR values ranging from 2% to 10% and estimated design traffic ranging from 1 msa to 150 msa for an average annual pavement temperature of 35ºC. The thicknesses obtained later from the analysis has been slightly modified to adopt the desired construction. By using the following simple parameters which are obtained, appropriate designs and charts could be chosen for the given strength of soil and given traffic

- Design traffic in terms of cumulative number of standard axles; and
- CBR value of subgrade.

1. Design traffic:

This method consider the anticipated traffic in terms of the cumulative number of standard axles (8160 kg) is to be carried by the flexible pavement during the design life. This requires the following information for design of pavement:

- Initial traffic in terms of CVPD
- Design life in number of years
- Traffic growth rate during the design life
- Design life in number of years
- Vehicle damage factor (VDF)
- Distribution of commercial traffic over the carriage way

Initial traffic: Initial traffic is estimated in terms of commercial vehicles per day (CVPD). For this structural design of flexible pavement only the commercial vehicles are considered assuming laden weight of four tonnes or more and their standard axle loading will be considered for initial traffic. Estimate the average traffic flow for any road should normally is based on 7-days or 24-hour classified traffic counts (ADT). In case of new roads, the traffic estimates can be made on the basis of land usage and traffic existing in different routes routes in that area.

Traffic growth rate: It can be estimated by (i) studying the past trends of traffic growth, and (ii) by establishing new statistic models. If sufficient data is not available, it is recommended that an average annual traffic growth rate of 7.5 percent may be adopted.

Design life: For the purpose of design of flexible pavement, the design life is based on the cumulative number of standard axles that can be carried before strengthening of the flexible pavement is necessary. The IRC is recommended that all pavements for arterial roads or semi arterial roads like NH, SH should be designed for a life of 15 years, EH and urban roads for a life of 20 years and other categories of roads are designed for a life of 10 to 15 years.

Vehicle damage factor: The vehicle damage factor (VDF) is a multiplier for converting the number of commercial vehicles of different vehicles of their axle loads and axle configurations to the number of standard axle-load repetitions. It is defined as equivalent number of standard axles to the commercial vehicle. The VDF varies with the axle configuration, axle loading, type of terrain, type of road, and from region to other region. The axle loads of different vehicles are used to convert different axle load repetitions into equivalent standard axle load repetitions. For these equivalency factors refer IRC: 37-2001. The exact VDF values are arrived after extensive field surveys.

Table 3 – VDF values based on traffic volume

Initial traffic volume in terms of no. of commercial vehicles per day	Terrain	
	Rolling / plain	Hilly
0-150	1.5	0.5
150-1500	3.5	1.5
More than 1500	4.5	2.5

2. Vehicle distribution factor:

A vehicle distribution factor for commercial traffic is estimated by different directions and by traffic lane is necessary as it directly affects the total equivalent standard axle load application used in the design. Until sufficient data is available, the following distribution may be assumed.

- **Single lane roads:** Traffic roads or tends to be more channelized or un channelized on single roads than two lane roads and to allow for this concentration of wheel load repetitions, the design should be based on total number of commercial vehicles in both directions for vehicle distribution factor
- **Two-lane single carriageway roads:** The design of these roads should be based on 75 % of the total number of commercial vehicles in both directions.
- **Four-lane single carriageway roads:** The design of these roads should be based on 40 % of the total number of commercial vehicles in both directions.
- **Dual carriageway roads:** For the design of these roads the dual two-lane carriageway roads should be based on 75 % of the number of commercial vehicles travelling in each direction. For both dual three-lane carriageway and dual four-lane carriage way the distribution factor will be 60 % and 45 % respectively.

3. Pavement thickness design charts:
The design of flexible pavements thickness is to carry traffic in the range of 1 to 10 msa, use chart 1 and for traffic in the range 10 to 150 msa, use chart 2 of IRC:37 2001. The design curves relate pavement thickness to the cumulative number of standard axles is to be carried over the design life for different sub-grade CBR values ranging from 2 % to 10%. Based on this CBR value the design charts will give the total thickness of the pavement for the above inputs. The total thickness of pavement consists of granular sub-base, granular base and bituminous surfacing. The individual layers are designed based on the recommendations given below and the subsequent tables.

Flexible pavement design chart (IRC) design traffic is between 1-10msa:

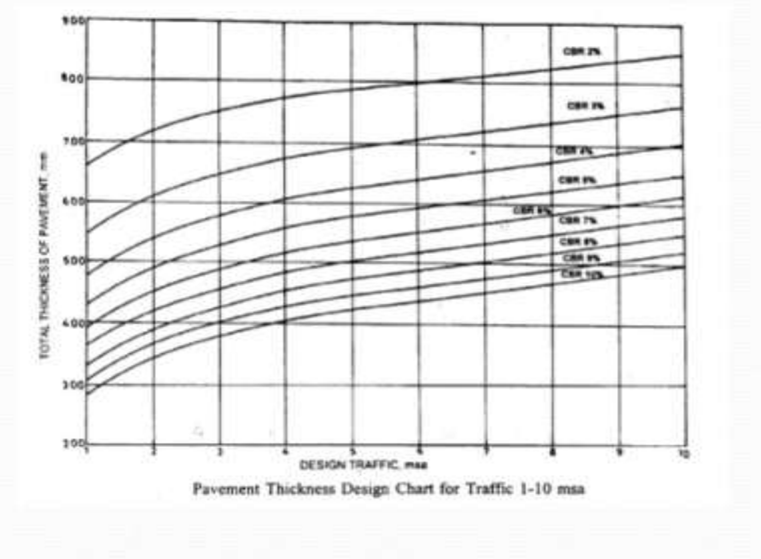

Fig: 4.2- Pavement thickness design chart

Flexible pavement design chart (IRC) design traffic is between 10-150msa:

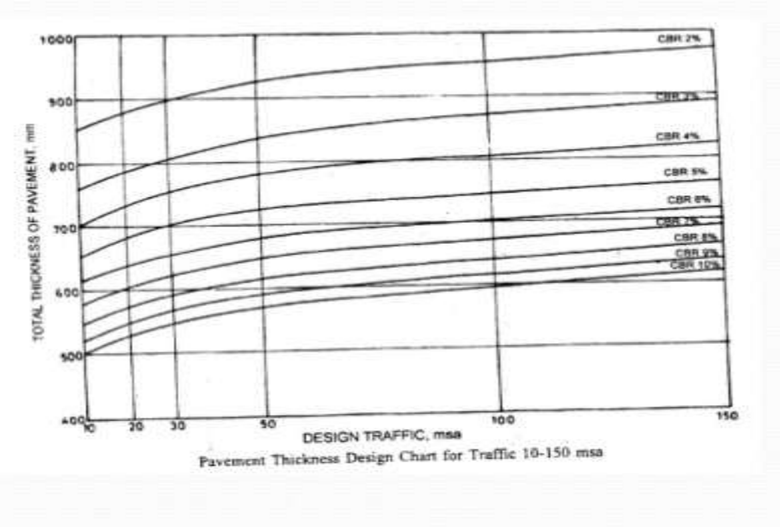

Fig: 4.3- Pavement thickness design chart

D. Pavement Design:

Design the pavement for construction of a new bypass with the following data:

- Two lane carriage way
- Initial traffic in the year of completion of construction = 500 CVPD (sum of both directions)
- Traffic growth rate = 7.5 %
- Design life =20 years
- Vehicle damage factor based on axle load survey = 3.5 standard axle per commercial vehicle
- Design CBR of subgrade soil = 6.79% nearly equal to 7%
- Distribution factor = 0.75

Solution:-

i. **Design traffic:** The design traffic is considered in terms of cumulative no. of standard axles to be carried during design life of the road.
$N = \{365\times [(1+r)^n -1] \times A\times D\times F\} / r = \{365\times [(1+0.075)^{20} -1] \times 500\times 0.75\times 3.5\} / 0.075 = 20.74$msa

ii. **CBR value:** CBR value for a sample which is a mix of 25% of slag and 75% of soil is equal to 6.79%

iii. **Thickness of pavement:** From IRC: 37-2001, for CBR value 6.79% and design traffic 20.74msa the thickness of pavement is equal to 620mm.

iv. **Pavement composition:** Pavement composition can be obtained by interpolation from Pavement Design Catalogue (IRC: 37-2001).

(a) Bituminous surfacing = 40mm BC + 100 mm DBM , (b) Road-base = 250 mm & (c) Sub-base = 230mm

Design the pavement for construction of a new bypass with the following data:
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3. Traffic growth rate = 7.5 %
4. Design life =20 years
5. Vehicle damage factor based on axle load survey = 3.5 standard axle per commercial vehicle
6. Design CBR of subgrade soil = 9.09% take it as 9%
7. Distribution factor = 0.75

Solution:-

i. **Design traffic:** The design traffic is considered in terms of cumulative no. of standard axles to be carried during design life of the road.

$N = \{365\times[(1+r)^n -1]\times A\times D\times F\} / r = \{365\times[(1+0.075)^{20} -1]\times 500\times 0.75\times 3.5\} / 0.075 = 20.74\text{msa}$

ii. **CBR value:** CBR value for a sample which is a mix of 25% of slag and 75% of soil is equal to 9%

iii. **Thickness of pavement:** From IRC: 37-2001, for CBR value 9% and design traffic 20.74msa the thickness of pavement is equal to 575mm.

iv. **Pavement composition:** Pavement composition can be obtained by interpolation from Pavement Design Catalogue (IRC: 37-2001).

(a) Bituminous surfacing = 40mm BC + 85 mm DBM , (b) Road-base = 250 mm & (c) Sub-base = 200mm

V. COMPARATIVE ANALYSIS

A. Introduction:

Better highway system gives benefits to the society. Improvements in highway results in several benefits to the road users such as:

- Reduction in vehicle operational cost per unit length of road.
- Saving in travel time and resultant benefits in terms of time cost of vehicles and the passengers.
- Cost of accidents should be reduced.
- Improved level of service concept and ease of driving.
- Increased comfort to road users and passengers.

Therefore the level of service of a road system may be assessed from the benefits to the road users.

The cost of improvement in the highway of land, materials, construction work and for the other facilities should be worked out. From the point of view of economic justification for the improvements, the cost reductions to the highway users and other beneficiaries of the improvements during the estimated period should be higher than the investments made for the improvement.

B. Experimental Program

Using of conventional aggregate in the field of construction increase rapidly and looking for alternative source in place of conventional aggregate assumed is to be more important. The objective of this research at first is to study the effect of using steel slag aggregates in place of conventional aggregate in the properties of asphalt concrete mixtures. Secondly make comparative study or comparative analysis of using steel slag aggregate and conventional aggregate in asphalt concrete mixtures. Slag is a bi product from industrial waste for the production of iron, which causes serious problem to environment as well as reduces the energy needed to search for natural aggregates and prepared for use in asphalt concrete mixtures. In this research the percentages of steel slag used in concrete mixtures and conduct the tests of impact value, Los Angeles abrasion test, specific gravity for conventional aggregate and steel slag aggregate individually, compare the results which are obtained. From the result it can be seen that using steel slag aggregate is useful for resist rutting and suitable for pavement in hot climate area.

1. Aggregate tests: Traditional tests of aggregates were done to determine specific gravity, bulk density, impact value and Los Angles Abrasion. A physical and mechanical property of Crushed Limestone and steel slag aggregate was presented in the table below.

Table: 4- different test results for SSA & natural aggregate

Property	Conventional aggregate	Steel slag aggregate
1.	Specific gravity	2.67
2.	Moisture Absorption capacity	< 1%
3.	Impact value	34.50%
4.	Los Angeles abrasion value	23.82%
5.	Crushing strength	20%
6.	Flakiness Index	35%
7.	Elongation Index	30%
8.	Bulk density	2.65g/cc
9.	Optimum moisture content	8-12%

VI. RESULTS AND CONCLUSION

Table 5 Tests conducted on steel slag

S.NO	NAME OF THE TEST	OBTAINED VALUE	RECOMMENDED VALUE
1	Specific gravity	3.405	3.15-3.5
2	Moisture absorption capacity	1.58%	1-2%
3	Crushing strength	32.4%	35%
4	Impact value	29.4%	30%
5	Flakiness index	19.4%	<25%
6	Elongation index	18.6%	<25%
7	Los angles abrasion	26.8%	<30%

Table 6 COMPARATIVE ANALYSIS:

S.NO	Property	Conventional Aggregate	Steel Slag Aggregate
1	Specific gravity	2.6-2.9	3.405
2	Moisture absorption capacity	1-2%	1.58%
3	Crushing strength	30-45%	32.4%
4	Impact value	30-35%	29.4%
5	Los angles abrasion	<30%	26.8%
6	Flakiness index	15-25%	19.4%
7	Elongation index	15-25%	18.6%

VII. CONCLUSION

This paper presents and discusses the results of using steel slag aggregate Instead of conventional aggregate, to evaluate the effectiveness of using steel slag aggregate in highway construction works. The presented results and discussions reveal the following main conclusions.

- The specific gravity of steel slag is more than conventional aggregate it leads to increase in weight of steel slag aggregate. The higher weight increases the hauling cost of the aggregate from the source to the job site. Hence we are concluded that SSA is a useful material, if the steel manufacturing industry is near the job site.
- From the experiments we are observed that the moisture absorption capacity of SSA is more than the natural aggregate, the problems were erected due to an excess of lime content in the steel slag, which caused expansion when it is exposed to water. Note that the expansive nature of this SSA was not considered in this study, it became a problem in some of their pavements. Especially it becomes a major problem in cement concrete pavements or roads
- The bulk density of steel slag is more than natural aggregate it results pavement more stable. It is highly stable due to high angle of internal friction also.
- SSA is more angular in shape and porous in nature than conventional aggregate. High porosity of the slag aggregate results in a demand for more asphalt binder than mixes using natural aggregates. The higher weight of the SSA mix means that a given weight of mix will not cover the same volume of pavement as a conventional mix with natural aggregate; therefore more tons of mix is required to cover the same length, width and depth of pavement than conventional HMA. This, along with the need for more asphalt binder, raises costs.
- Conventional aggregate results in low value when it is measured by CBR test but the SSA gives high value when it is measured by CBR test. Higher CBR value indicates that high load carrying capacity of the pavement is high so it is clearly that the pavement construct with SSA has more strength as compared to the pavement construct with natural aggregate. The higher CBR value also indicates that there is decrease in thickness of pavement hence the cost will be reduced.
- The Los Angeles (LA) abrasion test provides a better toughness and abrasion characteristics to the steel slag. The less numbers indicate a greater toughness and abrasion resistance. SSA has a good abrasion and the value is very close to the conventional aggregate. Hence the steel slag aggregate used as pavement material instead of conventional aggregate.

In summary we are concluded that SSA is angular and porous, has a high specific gravity, it is more resistant to abrasion and weathering, is highly stable due to high angles of internal friction, and has high load carrying capacity as measured by the CBR. So it will be used as pavement material. If the pavement is constructed in moisture absorbing places where the pavement mix is highly susceptible to moisture damage, in such a places it was required that the slag aggregate be moist cured under sprayed water conditions in a controlled stockpile for six months to alleviate the expansion potential.

REFERENCES

Wu et.al, (2007) documented a study done in China to assess the necessity of using SSA in Stone Mastic Asphalt (SMA). China was in searching an alternative material or any other sources to supplement diminishing natural stone sources. Due to its priority and usage of steel slag it was cured for 3 years

Kehagia, (2009) reported on a Greek study indicates the skidding resistance of HMA wearing courses built with SSAs. The British Pendulum Tester is used to measure the pavements performance built with SSA and SSA with limestone mixes. Tests conducting over a one year period showing that the mixes with SSA having better anti-skidding performance as compared with conventional aggregates

Khanna (2011) describes the design of flexible pavements by using group index method and California bearing ratio test. By using CBR method the thickness of pavement is obtained based on the soil tests, the curves are plotted between CBR percent and depth of construction. Khanna the state highway of engineering also describes the tests for different materials which are used for pavement construction.

Pasetto&Baldo, (2011) they performed a laboratory test on SSA for use in HMA. One limestone aggregate mix are compared to three SSA mix. SSAs were compared with the asphalt binders normally which used in HMA mixes. No excessive permanent deformation was predicted by the two mix design methods. The overall performance of SSA was predicted in terms of stiffness and fatigue due to its moisture damage. Mixes with the highest percentage of SSA (90%) performed the best as compared to the 60, 30, and zero percent SSA mixes
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International Journal of Engineering and Technology Volume 5 No. 8, August, 2015 Flexible Pavement Assessment of Selected Highways in Ifelodun Local Government, Ikirun-Osun, South – Western, Nigeria The study represents the adequacy of the highway it is often judged by the smoothness or roughness of the pavement; deficient pavement conditions can results in increased the vehicular characteristics and static characteritics and probability of increased crashes. In this study the following processes were carried out: interview sessions with relevant parties, site observations, site pictures were collected during observation, the geotechnical properties of soil subgrade and Manual survey was carried out in this study to B.S 1377.

International Journal of Engineering Inventions Volume 4, Issue 9 [May 2015]Mechanical Properties of Concrete Using Steel Slag Aggregate J. Saravanan and N.Suganya This study presents an establishment of steel slag aggregate and comparative analysis between steel slag concrete and conventional natural aggregate concrete. The high demand of hardened concrete is more than 70% in building construction and the amount of disposed waste material is also increasing, suppliers and researchers are exploring the use of alternative materials which could preserve our natural sources and to protect the environment

International Journal of Engineering and Innovative Technology (IJEIT), volume 5, issue 11 (May 2016) this study presents that concept of steel slag used in flexible pavement design and its properties and different tests conducted on steel slag required to investigate the suitability of steel slag for different layers of pavement