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DESIGN OF PAVEMENT USING STEEL SLAG COMPARATIVE ANALYSIS BETWEEN AGGREGATE PAVEMENT & STEEL SLAG PAVEMENT

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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, gravel, bricks, stones, etc.., has been used for construction of all categories of roads in our country. Although those are good construction materials, due to scarcity they increase the construction cost 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.

In this study, a typical steel slag was collected from steel industry and its feasibility for use in different layers of road construction was investigated. To improve the geotechnical properties, the slag was mechanically stabilized with locally available soil. Geotechnical properties of these stabilized mixes were evaluated to investigate their stability in the construction of different layers of road. Technical specification of steel slag is developed for utilization in construction of embankment, sub grade and sub base layer of flexible pavement. Here, we also include the comparative analysis between stone aggregate and steel slag aggregate. We just try to utilize SSA instead of coarse aggregate to preserve our natural resources and also to establishing a new technique in pavement design.

Keywords:.

1. INTRODUCTION

Flexible pavements are so named because the total pavement structure deflects, or flexes, under loading. A flexible pavement structure is typically composed of several layers of materials. Each layer receives loads from the above layer, spreads them out, and passes on these loads to the next layer below. Thus the stresses will be reduced, which are maximum at the top layer and minimum on the top of subgrade. In order to take maximum advantage of this property, layers are usually arranged in the order of descending load bearing capacity with the highest load bearing capacity material (and most expensive) on the top and the lowest load bearing capacity material (and least expensive) on the bottom.

1. COMPONENTS OF FLEXIBLE PAVEMENT:

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

2. FUNCTIONS OF FLEXIBLE PAVEMENT:

2.1Subgrade:

It is the top of the ground or formation on which the road rests. It should have sufficient strength, good drainage, case of compaction and permanency of compaction and strength. Its functions are

- To support the road structure.
- To form a bed for the road at the designed level.

2.2Sub-base course:

It is a layer of cheap material placed between the base course and subgrade. It is formed locally available cheap materials like sand, gravel, rubble, ashes or stabilized soil. If subgrade and its drainage are good it may be omitted. Its functions are

- To protect the subgrade.
- To reduce the intensity of loading on the subgrade
- To improve drainage.
- To prevent the base and wearing course from being affected by the poor qualities of subgrade such as swelling, shrinkage, settlement, etc.

3. Base course:

It is the layer below the wearing course. It is an important structural part of the road. It should be strong enough to bear the loads of the traffic. It is made of good materials like broken stone well compacted. Its functions are

- To support the wearing course and prevent distortions in it.
- To bear the loads of the traffic.
- To reduce the intensity of loading on the sub base and subgrade.

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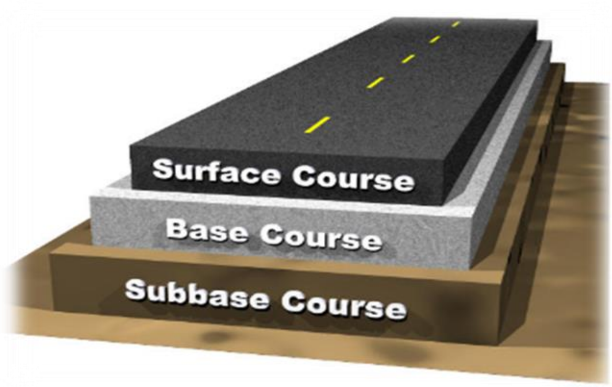
- To increase the structural strength of road.
- To prevent the volume changes in the poor subgrade.
- To reduce the thickness of wearing course.

4. Wearing course:

This is the top most layer of a road which is in direct contact with the traffic. It should be capable of withstanding the wearing effects of the traffic and also impervious. Its functions are

- To provide a smooth surface for traffic.
- To drain away the rain water and prevent the percolation of water.
- To give strength to the road structure.
- To act as a cushion between the wheels and base.



Cross section of flexible pavement

5. LABORATORY EXPERIMENTS

5.1 TESTS ON STEEL SLAG:

- Specific gravity test
- Grain size analysis
- Moisture absorption test
- Steel slag impact value test
- Los Angeles abrasion test

5.2 TESTS ON SOIL

- Compaction test

5.3 CALIFORNIA BEARING RATIO TEST (Slag & Soil)

Slag and soil were blended manually as per percentage by weight in the laboratory for investigation.

Table no: 1 – Mix designations of steel slag and soil.

Mix Designation	Mixes
100LS	100% local soil
15S + 85LS	15% steel slag & 85% local soil
25S + 75LS	25% steel slag & 75% local soil
35S + 65LS	35% steel slag & 65% local soil
50S + 50LS	50% steel slag & 50% local soil
100S	100% steel slag

SPECIFIC GRAVITY TEST

Table no: 2 – Determination of specific gravity:-

Sample (steel slag)	Weight of bottle (gms) " W1"	Weight of bottle + half filled material (gms) " W2"	Weight of bottle + half filled material + distilled water (gms) " W3"	Weight of bottle + distilled water (gms) " W4"
1.	670	934	1750	1550

Calculations:

Specific gravity = W2-W1/ [(W2-W1) – (W3-W4)]
= 934-670/ [(934-670) – (1750-1550)]
= 4.125

Result:

Specific gravity of steel slag is 4.125

Generally specific gravity of a steel slag varies from 4.1 to 4.3

6. GRAIN SIZE ANALYSIS

IS sieve size (mm)	Weight retained (gms)	Percentage of retaining (%)	Cumulative % weight retained "X"	Cumulative percentage passing N = (100-X)
4.75	385	38.5	38.5	61.5
2.36	182	18.2	56.7	43.3
1.18	156	15.6	72.3	27.7
0.600	64	6.4	78.7	21.3
0.425	61	6.1	84.8	15.2
0.3	40	4.0	88.8	11.2
0.15	41	4.1	92.9	7.1
0.075	41	4.1	97.0	3.0
Pan	30	3.0	100.0	0

Table no: 3 – Determination of fineness modulus:

Initial weight of a sample = 1000g

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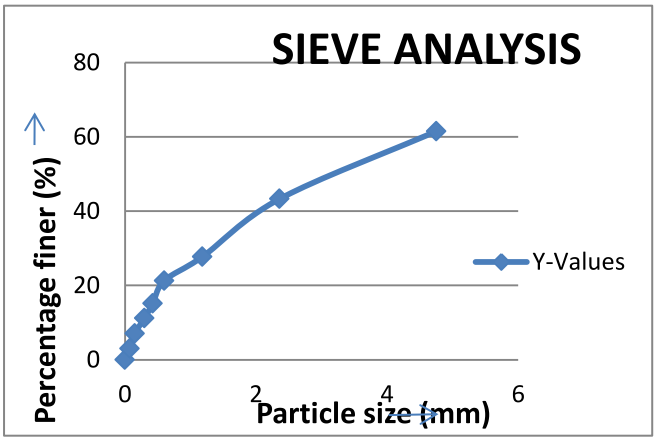
Calculations:

Fineness modulus = [(Sum of cumulative % weight retained) /100]

= [(38.5+56.7+72.3+78.7+87.8+88.8+92.9+97.0+100)/100]

= 709.7/100 = 7.09

Graph: 1- graphical representation of sieve analysis:



1. MOISTURE ABSORPTION TEST

Table no: 4 – Determination of water absorption value

S.no	Determination No.	I	II
1.	Weight of saturated surface dried sample in gms (A)	2663	1085
2.	Weight of oven-dried sample in gms (B)	2612	1072
3.	Water absorption = [(A-B) / B] × 100 (%)	1.95	1.21
Average value = [(1.95+1.21) ÷2] = 1.58%			

2. STEEL SLAG IMPACT VALUE TEST

Table no: 5- Determination of aggregate impact value:

Description of sample	Weight of sample taken (W1) gms	Weight of sample passing from 2.36mm sieve (W2) gms	Aggregate impact value = [(W2/ W1)]×100 (%)
Sample 1	345	96	27.8
Sample 2	340	102	30.0
Sample 3	350	94	26.8

3. LOS ANGELES ABRASION TEST

Calculations:

Weight of steel slag aggregate (W1) = 5000gms
Weight of aggregate passing through 1.7mm sieve (W2) = 986gms
Abrasion value = (W2 / W1) × 100
= (986 / 5000) × 100
= 19.7%

PAVEMENT DESIGN:

- **DESIGN OF FLEXIBLE PAVEMENT**

The flexible pavements has been modeled as a three layer structure and stresses and strains at critical locations have been computed 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:
Vertical compressive strain at the top of the sub-grade which can cause sub- grade deformation resulting in permanent deformation at the pavement surface.
Horizontal tensile strain or stress at the bottom of the bituminous layer which can cause fracture of the bituminous layer.
Pavement deformation within the bituminous layer.

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

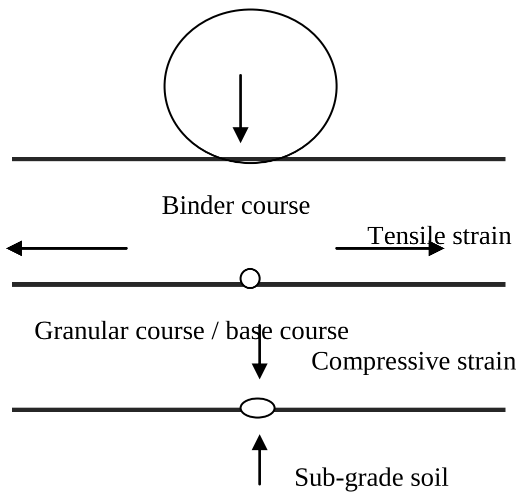


Fig:- critical locations in pavement

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DESIGN PROCEDURE:

Based on the performance of existing designs and using analytical approach, simple design charts and a catalogue of pavement designs are added in the code. The pavement designs are given for subgrade CBR values ranging from 2% to 10% and design traffic ranging from 1 msa to 150 msa for an average annual pavement temperature of 35 C. The later thicknesses obtained from the analysis have been slightly modified to adapt the designs to stage construction. Using the following simple input parameters, appropriate designs could be chosen for the given traffic and soil strength:

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

COMPARATIVE ANALYSIS

Better highway system provides varied 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.
- Reduction in accident rates.
- Improved level of service and ease of driving.
- Increased comfort to 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.

In the planning and design of highways there is increasing need for analysis to indicate the justification of the expenditure required and the comparative worth of proposed improvements, particularly when various alternatives are being compared.

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: 10- different test results for SSA & natural aggregate

Property	Conventional aggregate	Steel slag aggregate
Specific gravity	2.63	4.125
Bulk density	2.65g/cc	3.18g/cc
Aggregate impact value	34.50%	28.20%
Los Angles abrasion value	23.82%	19.70%

CONCLUSION

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

- SSA has a specific gravity more than conventional aggregate it leads to increase in weight of aggregate. The higher weight increases the cost of hauling 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 work site.
- From the experiments we are observed that the moisture absorption capacity of SSA is more than the natural aggregate, the problems were attributed to an excess of lime in the steel slag, which caused expansion when exposed to water. Note that the expansive nature of SSA was not considered in this study, it became a problem in some of their pavements. Especially it became a major problem in cement concrete pavements.
- The SSA was high bulk density than natural aggregate it results in more stable pavement. It is highly stable due to high angle of internal friction also.
- SSA is more angular and porous than conventional aggregate. High porosity of the 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.
- Natural aggregate results in low value as it 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 so it is proved that the pavement construct with SSA has more strength as compared to the pavement construct with natural aggregate. The higher CBR value also results that there is decrease in thickness of pavement hence the cost will be reduced.
- The Los Angeles (LA) abrasion test provides an indication of aggregate toughness and abrasion characteristics. Lower numbers indicate greater toughness and abrasion resistance. SSA has abrasion value close to the natural aggregate. Hence it is safely used as pavement material instead of natural aggregate.
- From the compressive test experiment it is observed that the Replacement of conventional

coarse aggregate by steel slag aggregate in pavement construction enhances the compressive strength when the replacement of level is up to 60%, for further replacement compressive strength is found to be decrease.
- SSA mix was more resistant to rutting and low temperature cracking than the basalt mix.

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