

**A REVIEW OF USE STEEL SLAG IN CONCRETE MIXES FOR RIGID
PAVEMENT**¹GATESI JEAN DE DIEU, ²Prof. M.H.Lunagaria¹*Master's candidate in Civil (Transportation Engineering), L.D.College of Engineering, Ahmedabad 3800-15*²*Associate professor in Civil (CASAD), Government Engineering College Godhra*¹²*Gujarat Technological University, India*

Abstract: Steel slag is an industrial by-product obtained from the steel manufacturing industry. It is produced in large quantities during the steel-making operations which utilize Electric Arc Furnaces (EAF). Steel slag can also be produced by melting iron ore in the Basic Oxygen Furnace (BOF). Steel slag is currently used as aggregate in concrete mix slab applications, but there is a need for some additional work to determine the feasibility of utilizing this industrial by-product more wisely as a replacement for both fine and coarse aggregates in a conventional concrete mixture. Concrete mix volume is up to 75% of aggregates. Replacing all or some portion of natural aggregates by steel slag would lead to considerable strength and environmental benefits.

Target of this research also is to check the strength of steel slag concrete if it is suitable in rigid pavement in place of natural aggregate concrete. In order to know suitability of steel slag concrete, laboratory experiments have been carried out for checking the different properties of fresh and hardened concrete for workability, compressive, flexural and split tensile strength. The cube, beams and cylinders have been made, cured for 7 and 28 days, after that they have been tested by using loading machine (equipment). The results from the laboratory were analyzed according to the Indian standard specification. All experimental results for fresh and hardened concrete showed that the increasing the steel slag % in concrete mix, could improve the properties of concrete. The coarse steel slag aggregates showed good workability as well as strength of concrete as shown in the laboratory results in this research.

Keywords: Rigid pavement, Steel slag, Concrete mix, Strength, Natural aggregates, Environment benefit.

I. INTRODUCTION

Concrete is prepared by mixing various constituents like cement, aggregates, water, etc. which are economically available. Concrete plays a critical role in the design and construction of the nation's infrastructure. Almost three quarters of the volume of concrete is composed of aggregates. The coarse aggregate fraction is that retained on 4.75 mm sieve and fine aggregates fraction is that passing 4.75 mm sieve. To meet the global demand of concrete in the future, it is becoming a more challenging task to find suitable alternatives to natural aggregates for preparing concrete. Therefore the use of alternative sources for natural aggregates is becoming increasingly important. Steel slag is a co-product of the steel making process in which steel cannot be prepared in the Basic Oxygen Furnace (BOF) or in an Electric Arc furnace (EAF) without making its co-product; steel slag. The use of steel slag aggregates in concrete by replacing natural aggregates is a most promising concept. Steel slag aggregates are already being used as aggregates in concrete paving road mixes due to their mechanical strength, stiffness, porosity, wear resistance and water absorption capacity. Studies and tests are being conducted on ways to use this steel slag as an aggregate in concrete by different researchers. However there were no serious attempts to investigate the performance of fresh steel slag aggregate against aged aggregate in concrete. Also the data regarding long term concrete performance are limited and inconclusive. Especially concerning the expansive characteristics of steel slag aggregates. Much research remains to be done in this regard.

I.1 Needs of research

The problem of steel slag utilization is not confined to India alone but is being experienced all over the world. However this problem is particularly acute in countries like India, where utilization of steel slag has not received much attention. The degree of its utilization varies among different countries. In India, the present rate of utilization is only about 10 percent, which is below the world average of about 16 percent. Hence in this research, it is aimed to describe the use of steel slag in rigid pavement road works and its improvement of strength with compare to the conventional concrete. The only potential problem with steel slag aggregate is its expansive characteristics and undesirable reactions between slag and components of concrete.

In this research, several experiments have been conducted to study the effect of adding (replacing) steel making slag to concrete composite and measuring the effect of slag content on the mechanical behavior of hardened concrete in order to

overcome such problem mentioned above. The percentages of replacement in the concrete mix were ranging from 0 to 40%. The following ratio will be reported in this study: 0, 10, 20, 30 and 40% by weight.

I.2 Objectives of research

The aim of this research was to explore the feasibility of utilizing the steel slag produced by steel mills industry as a replacement for natural aggregates in the concrete.

- To study the effect of using steel slag in concrete mixture by different ratios on improving properties of hardened concrete.
- To investigate the properties of concrete with steel slag aggregates.
- To check the suitability of steel slag for concrete production and then to develop concrete mixtures with high volume industrial by-products for environmentally friendly applications.
- The Comparison between the strength of steel slag in concrete and conventional concrete.
- To encourage the engineers for using industrial Co-products in rigid pavement application.

II. LITERATURE REVIEW

II.1 Pavement

Pavement is the structural members consisting of superimposed layers of processed or natural materials above the natural soil sub grade, whose primary function is to distribute the applied vehicle loads to the sub grade. The pavement structure should be able to provide a surface of acceptable riding quality, adequate skid resistance, favorable light reflecting characteristics and low noise. The ultimate aim is to ensure that the transmitted stresses due to wheel load are sufficiently reduced, so that they will not exceed bearing capacity of the sub grade. Pavement is classified in different types such as flexible, rigid, semi-rigid and composite pavement (**ARVO Tinni, 2013 et al**). In this research, it will be focused on the concrete pavement which is known as rigid pavement. The following requirements should be fulfilled by good pavement:

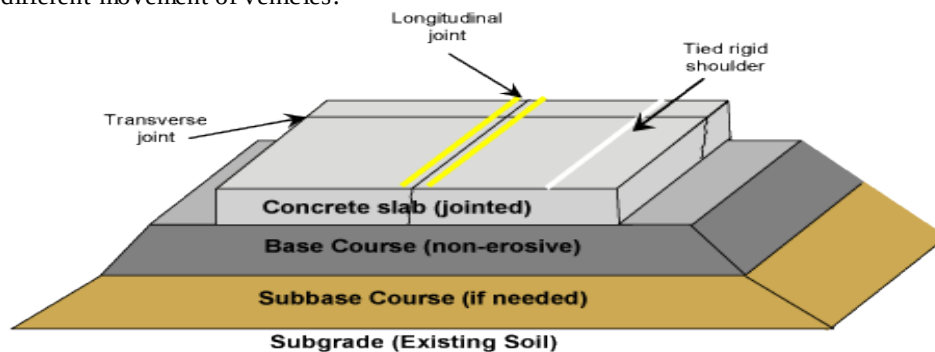
- It should be strong enough to resist the stress imposed on it.
- It should be sufficiently thick to distribute the loads and stresses to sub grade.
- It should be dust proof so that the traffic safety is not impaired etc.

A rigid pavement structure is typically composed of PPC (mostly) surface course built on top of either, the sub grade and underplaying base.

It is consisted the following parts:

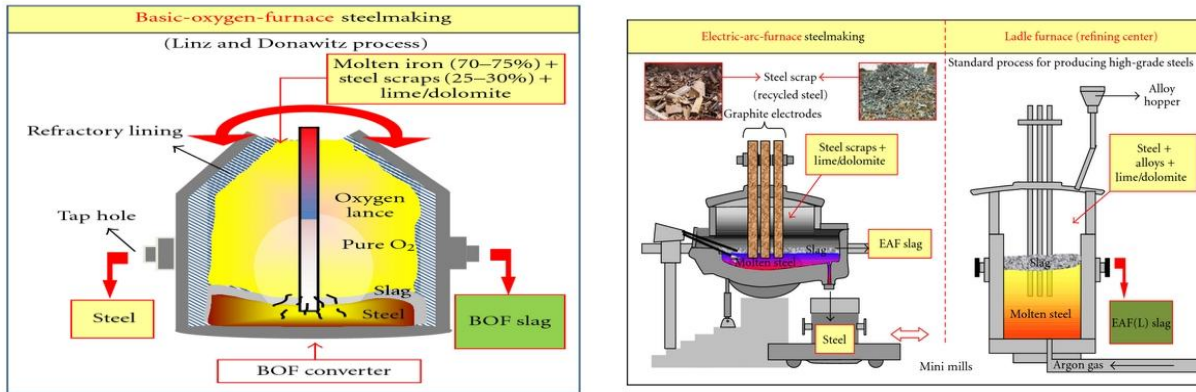
- Surface course: this is the top layer, which consists the Portland cement concrete slab
- Base course: this is the layer directly below the PCC layer and generally consists of aggregate or stabilized sub grade.
- Sub base: this layer under the base layer but it is not always needed and therefore may often be omitted.
- Sub grade layer: is the leveled surface and compacted plays the role of receiving the all upper layers(slab)

The below figure shows the different parts of rigid pavement structure and the different joints provided for controlling the defects which can be caused by stresses from the loads. The top layer as slab is playing the big important for receiving the heavy wheel loads and the different movement of vehicles.



II.2 Formation of steel slag

The formation of steel slag and its composition as defined, Steel slag is a byproduct obtained either from conversion of iron to steel in a Basic Oxygen Furnace (BOF), or by the melting of scrap to make steel in the Electric Arc Furnace (EAF). Slag are named based on the furnaces from which they are generated (**Iren Zeynep Yildirim, 2011**)



Chemical and mineral composition of slag, especially from their experiments, showed the steel slag composition and its percentage. The steel making slag are composed principally of calcium silicate, calcium alumino-ferrite and fused of oxide calcium lime, iron, magnesium and manganese. The compositions vary with the type of furnace. Composition of furnace charges, grades of steel produced and with individual furnace operating practice. Material added to the melt just before the end of the heat may be completely incorporated in slag. Therefore some free oxide, including CaO, may be found in some slag (Praveen Mathew, Leni Stephen and J. George).

Name of compound	Oxide composition	BOF Slag %	EAF Slag %
Iron oxide	FeO	10-35	15-30
Silicate oxide	SiO ₂	8-20	9-20
Metallic ferrous	Mettalic Fe	-	-
Manganese	MnO	2-15	3-10
Aluminate oxide	Al ₂ O ₃	1-6	2-9
Calcium oxide	CaO	30-55	35-60
Magnesium oxide	MgO	5-15	5-15
Phosphorous oxide	P ₂ O ₅	0.2-3	0.1-2
Sulfur	S	1-1.5	Less than 2

Physical properties of iron and steel slag, they found that the properties depend upon the chemistry as well as the cooling condition and can be influenced by processing once the slag is removed from furnace. All measures including processing of solid crystalline slag for example crushing and screening is done to ensure that the produced aggregates and mixture conform to requirement given by any nation standard and regulations. In this research they found that chemical, mineralogical and physical properties of iron and steel slag are similar to those natural aggregate rocks. Though the high density, the low impact value, the high compressive strength as well as the good polishing and freezing thaw resistance. All these unique properties make iron and steel slag ideally suitable for use in road construction. Furthermore, the cubical shapes, rough surface texture of slag provide excellent resistance to the formation of ruts in surface course of pavement. Some properties of iron and steel slag aggregate with compare to the natural rock aggregate (EUROSLAG, 2014)

Properties	Steel slag	basalt
Particles density in g/cm ³	3.6	3.0
Compressive strength in N/mm ²	200	300
Aggregate impact value in %	17	17
Resistance to polishing(PSV)	57	50
Water absorption in %	1	Less than 0.5
Resistance to freeze and thaw in %	Less than 0.5	Less than 0.5

The steel slag can be stored in order to use it with the good quality without any problem of some contains compound which should be disappeared in determined period. Steel slag must be allowed to undergo weathering process before using as aggregate in construction because of it expensive nature. This is done in order to reduce the quantity of free lime acceptable limits. The steel slag is allowed to stand in stockpile for a period at least 4 months and exposed to weather. During this weathering process the steel slag is required to be in contact with water so that the hydration process between lime and water

take place. Hydration of free lime (CaO) or free magnesia (MgO) is responsible for expansive nature of steel slag (**Stein Inc 2008**)



II.3 Past studies on steel slag as aggregates

Anastasiou and Papayianni, 2006 had studied the utilization of steel slag in construction works, as described earlier the steel slag is an industrial by product and instead of disposing it in the land fill, the use of such product in construction market would increase the efficiency and economic. The physical, mechanical and chemical characteristics have been extensively examined by the above researchers. Due to its potentially expansive properties, it requires the special carefully if it is applicable in construction works (eg concrete pavement). The possibility of using the steel slag as aggregate concrete without any problem was studied by the above researchers. **Manso and Gonzalez, 2004**, they have determined the durability of steel slag concrete and they found that the results are acceptable. They conducted also the test for mix design by using EAF slag and the result showed that the workability of fresh and the strength of hardened concrete were very good. After that the result showed that the behavior of mixed concrete against aggressive environment condition is acceptable. **Maslehuddin, et al, 2003**, they made some experiments to compare the difference between the steel slag aggregate concrete and natural aggregate concrete. After the results from the laboratory, they observed that:

- Durability and physical properties of steel slag aggregate concrete was better than natural aggregate concrete.
- They suggested that the use of steel aggregate in concrete is beneficial and economical.
- Abrasion resistance, specific gravity, water absorption, chemical soundness, alkalinity and concentration of chloride and sulfate have been tested.
- The compressive strength of steel slag aggregate concrete increased with the portion of coarse aggregate from 31.4MPa up to 42.7 MPa.
- Flexural and split tensile strength also increased while water absorption capacity reduced.

Manso, Polanco et al, 2006, they conducted also the tests on the durability and mechanical properties of steel slag concrete and they concluded that: By proper mix proportion, both mechanical strength and durability of steel slag aggregate concrete can be improved. **Takashi and Ayano, 2007**, they have been studied about the freezing and thawing of steel slag aggregate concrete with compares to the different natural aggregate concrete and the concluded that:

The resistance to freezing and thawing of steel slag aggregate concrete was better than the natural/recycled aggregate concrete. The compressive strength and the resistance to freezing and thawing increase with increasing the content of cement. **NSA, 2008**, the study has been done on the deposition of steel slag from different manufactured mild industries. They found that the manufacturing of slag process consisting the different chemical reaction which can produce the insignificance risk to human health. And the results also showed that the iron and steel manufacturer were not probably affect the environment when the slag used in different activities of residential location such as agricultural and construction applications.

NSA, 2008, the study has been done on the deposition of steel slag from different manufactured mild industries. They found that the manufacturing of slag process consisting the different chemical reaction which can produce the insignificance risk to human health. And the results also showed that the iron and steel manufacturer were not probably affect the environment when the slag used in different activities of residential location such as agricultural and construction applications.

Wagam and Stanley, 2005, they studies about the effect of slag on environment as a by-product from mild industries. This study showed that the slag has been used in treatment of acid mine drainage discharge in which rendering waste water more ecologically beneficial. In short notes about steel slag effect on environment, the utilization of the steel waste products from the manufacturing industries can help to save environment as well as the health of human being.

II.4 Concrete mix design

The first requirement in ensuring a good concrete road is to scientifically design the concrete mix so that it gives a strength in the field which is equal to or better than that assumed in the design. Till the few years ago, the practice was to adopt volumetric prescribed mix based on the experience. A mix of 1:2:4 and 1:1.5:3 was common used, it has now been realized that such prescribed mixes are either uneconomical or not meeting the demands of high strength concrete needed for road works. Thus, it is common to use designed mixes based upon the proportion the ingredients by weight and conducting laboratory trials. In India, the BIS and IRC have brought out codes of practices for concrete mix design.

Raj K. Agarwal, Rajeeb Kumar et al, 2006, they have been described the concrete mixing design as the process of selecting a suitable ingredient of concrete and determining their relative amounts with the object of producing the concrete of the required, strength, durability and workability as economically as possible is termed the concrete mix design. The proportioning of concrete ingredients is governed by the required performance of concrete in 2 states namely, plastic and hardened state if the plastic concrete is not workable, it cannot be properly placed and compacted. The property of workability therefore becomes of vital importance. The compressive strength of hardened concrete which is generally considered to be an index of its other properties depends upon many factors such as:

- ✓ Quality and quantity of cement
- ✓ Water and aggregates
- ✓ Batching and mixing
- ✓ Placing and compaction
- ✓ Curing and finishing

The cost of concrete is made up of the cost of materials, plant and labours. The variation in the cost materials arise from the fact that the cement is several times costly than the aggregate, thus the aim is to produce as lean a mix as possible. From technical point of view, the rich mix may lead to high shrinkage and cracking in structure concrete, and to evolution of high heat of hydration in mass concrete which may cause cracking.

The actual cost of concrete is related to the cost of materials required for producing a minimum mean strength which is known as characteristic strength and that is specified by designer of structure. This depends on the quality control measure, but there is no doubt that the quality control adds to the cost of concrete. The extent of quality control is often an economical compromise and depends on the size and type of job. The costs of labour depend the workability of mix, (eg: a concrete mix of inadequate workability may result in a high cost of labour to obtain the degree of compaction with available equipment.

From the same authors, described also the different requirements which form the basic selection and proportioning of mix ingredients in road construction as mentioned below:

- Flexural strength adopted in the design
- The minimum compressive strength required from structure consideration.
- The adequate degree of workability desired for full compaction with the compacting equipment available.
- Maximum water-cement ratio and/or maximum cement content to give adequate durability for the particular site condition.
- Maximum cement content to avoid shrinkage and cracking due to temperature cycle in mass concrete.
- Type and maximum nominal size of aggregate, grading of combined aggregate.
- Level of quality control that can be exercised given the equipment and expertise available.
- Standard deviation of concrete strength that can be expected

Dr.M.C.Nataraja et al, 2011 in their researches described the different types of concrete mixes as mentioned below:

1. Nominal mixes:

In the past specification for prescribed the proportion of cement, fine, coarse aggregate. These mixes of fixed cement-aggregate ratio which ensure adequate strength are termed nominal mixes. This offer simplicity and under normal circumstance, has a margin of strength above that specified. However due to variability of mix ingredients, the nominal concrete for a given workability varies widely in strength.

2. Standard mixes:

The nominal mix of fixed cement-aggregates ratio (by volume) vary widely in strength and may result in under/or over rich mixes. For this reason, the minimum compressive strength has been included in many specifications. These mixes are termed as standard mixes.

Indian standard (IS 456-2000) has designated the concrete mixes into a number of grades as:

M10, M15, M25, M30, M35, M40. In this designation the letter M refer to the Mix and number refer to the specified of 28 days cube (15cm) strength of mix in N/mm^2 . The mixes of the bellow grades and their corresponding proportion are shown in table:

Grade of mixes	Proportion of mixes	Max water/cement ratio
M10	1:3:6	0.5
M15	1:2:4	0.5
M20	1:1.5:3	0.5
M25	1:1:2	0.45
M30	1:1:2	0.45
M35	1:1.6:2.91	0.45
M40	1:1.65:2.92	0.4

3. Designed mixes:

In these mixes the performance of concrete is specified by the designer but the mix proportion is determined by producer of concrete except that the minimum cement content can be laid down. This is rational approach to the selection of mixing proportions with specific materials in mind processing more or less unique characteristics. Approach results in production of concrete with the appropriate properties most economically. However the designer mix does not serves as guide since this does not guarantee the mix proportions for the prescribed performance. For the concrete undemanding performance of nominal or standard mixes [prescribed in the codes by quantities of dry ingredients per cubic meter (m^3) and by slump] may be used only for small jobs, when the 28 days strength of concrete does not exceed $30N/mm^2$. No control testing is necessary reliance being placed on the mass of concrete ingredients

Dr. M. C. Nataraja et al 2011 described the different factors affecting the choice of mix proportion as mentioned below:

1. Compressive strength:

It is one the most important properties of concrete and influence many other describable properties of hardened concrete. The mean compressive strength required at specific age, usually 28 days, determines the nominal cement-content of the mix. The other factors affecting compressive strength at a given age and cured at prescribed temperature is the degree of compaction. According to Abraham's law, the strength of full compacted concrete is inversely proportion to the cement-water ratio.

2. Workability:

The degree of workability required depends on the three factors; these are the size of section to be concreted, the amount of reinforcements and the method of compaction to be used. For the narrow and complicated section with numerous corner or inaccessible parts, the concrete may have high workability so that full compaction may be achieved with a reasonable amount of effort. This also applied to the embedded steel section. The desired workability depends on the compaction equipment available at the road construction site.

3. Durability:

The durability of concrete is its resistance to the aggressive environmental condition. High strength concrete is generally more durable than low strength of concrete. In the situations when the high strength is not necessary but conditions of exposure are such that high durability is vital. The durability requirement will be determined by cement-water ratio to be used.

4. Maximum nominal size of aggregate:

In general, larger the maximum size of aggregate, smaller is the cement requirement for a particular cement-water ratio, because the workability of concrete increase with increase in maximum size of the aggregates. However, the compressive strength tends to increase with the decrease in size of aggregates. IS 456:2000 and IS 1343:1980 recommends that the nominal size of aggregate should be as large as possible.

5. Grading and types of aggregates:

The grading of aggregates influence the mixing proportions of specified workability and water cement ratio. Coarser the grading leaner will be mix which can be used. Very lean mix is not desirable since it does not contain enough finer materials to make concrete cohesive.

The types of aggregates influence strongly the aggregate-cement ratio for the desired workability and stipulated water-cement ratio. An important feature of a satisfactory is the uniformity of the grading which can be achieved by mixing different sizes of fractions.

6. Quality control:

The degree of control can be estimated statistically by variations in test results. Variation in strength results from the variation in properties of the mix ingredients and lack of control of accuracy in batching, mixing, placing, curing and testing. The lower the difference between the mean and minimum strength of the mix lower will be the cement content required. The factor controlling this difference is termed as quality control.

7. Mix proportion designations:

The mix proportioning is the process of determining the quantities of concrete ingredients that meet the mix design criteria. The common method of expressing proportion of concrete ingredients mix is in the terms of parts or ratios of cement, fine and coarse aggregate. For example, a concrete mix of proportion 1:2:4 means that one part of cement bag, 2 parts of fine aggregate and 4 parts of coarse aggregate. The proportion may be either by volume or by mass. The water-cement ratio is usually expressed in mass.

IS-10262, 2009, the guidelines of Indian standard concrete mix proportion was revised by Bureau of Indian standard in order to update the information from the IS-10262, 1982. From the revised guidelines, they provided the factors and procedures to be followed in mixing design as mentioned below:

- **The factors to be considered in mixing design can be described as shown below:**

- ✓ The grade designation giving the characteristic strength requirement of concrete.
- ✓ The types of cement influence the rate of development of compressive strength of concrete.
- ✓ Maximum nominal size of aggregate to be used in concrete may be as large as possible within the limit prescribed by **IS 456:2000**.
- ✓ The cement content is to be limited from shrinkage, cracking and creep.
- ✓ The workability of concrete for satisfactory placing and compaction is related to the size and shape of section, quantity and spacing of reinforcement, technique used for transportation, placing and compaction.

- **Procedures for mixing concrete design:** The procedures to be followed in road concrete mixing design are enlisted below:

1. All the basic data needed for project is collected
2. The target average flexural/compressive strength is determined on the basis of the minimum strength specified and quality control standard that can be expected.
3. Obtain water-cement ratio for the desired mean target using the empirical relationship between flexural/compressive strength and water-cement ratio so chosen is checked against the limiting water-cement ratio for the requirement of durability and adopts the lower of the two values. W/C ratio is determined to give estimated flexural/compressive strength.
4. Estimate the amount of entrapped air for maximum nominal size of the aggregate.
5. Select the water content, the required workability for the project is chosen for the project, and the aggregate/cement ratio is determined for giving the required workability.
6. Determine the % of fine aggregates in total aggregate by absolute volume for the concrete used crashed aggregate.
7. Adjust the value of water content and % of sand for any difference in workability, water-cement ratio, grading of fine aggregate and for rounded aggregate value.
8. Calculate cement content from the water-cement ratio and the final water content as arrived after adjustment. Check the cement against the minimum cement content from the requirement of the durability and greater of two values is adopted.
9. From the quantity of water and cement content per unit volume of concrete and % of the fine aggregate as already determined in step 6 and 7 above, calculate the content of the coarse and fine aggregate per unit volume of concrete for the following relation:

$$V = \left[W + \frac{C}{S_c} + \frac{1}{p} \frac{f_a}{S_{fa}} \right] \times \frac{1}{1000}$$

$$V = \left[W + \frac{C}{S_c} + \frac{1}{1-p} \frac{C_a}{S_{ca}} \right] \times \frac{1}{1000}$$

The meanings of above parameters are described below:

- **V:** Absolute volume of concrete [gross volume (1m³) – volume of entrapped air]
 - **S_c:** Specific gravity of cement
 - **W:** Mass of water content per m³ of concrete, kg
 - **C:** Mass of cement content per m³ of concrete, kg
 - **p:** Ratio of fine aggregate to total volume by absolute volume
 - **f_a:** Total masse of fine aggregates per m³ of concrete
 - **c_a:** Total masse of coarse aggregate per m³ of concrete
 - **S_{fa}:** Specific gravity of saturated surface dry fine aggregate
 - **S_{ca}:** Specific gravity of saturated surface dry coarse aggregate.
10. Determine the concrete mix proportion of all ingredients for the first trial mix.
 11. Prepare the concrete using the calculated proportion and cast three cubes of 150 mm size and test them wet after 28 days moist curing and check for the strength.

12. A trial mix using the proportions arrived at is prepared in the laboratory to test whether the mix meets the desired properties. Tests are carried out and any adjustments needed are made.
13. The selected mix is produced in the plant, and final adjustments are made in the production, depending up on actual site conditions.

M.S.Shetty et al', 1992 and **Durocrete mix design manual**, they described the different method used in concrete mix design as enlisted below:

1. Arbitrary proportion mixing design method
2. Maximum density mixing design method
3. Fineness modulus mixing design and Surface area mixing design method
4. American concrete institute mixing design method (A CI)
5. Grading curve mixing design method (Road Note No.4)
6. Indian road congress mix design method (IRC-44)
7. High strength concrete mix design method and Design based of flexural strength method
8. Indian standard mixing design method (IS)

III. CONCLUSIONS

The study of different papers in this literature review was focused on the rigid pavement by describing the significance and impact of using steel slag in concrete pavement. The overall research papers have been shown that the utilization of steel slag in concrete mixes could improve the properties of fresh concrete as well as the hardened concrete. The formation and properties of steel slag were studied careful in this literature. The different researchers showed that the physical and mechanical properties of steel slag could improve the strength of concrete with compare to natural aggregates. There is no effect for using the steel slag in road pavement as well as for human being. The utilization of these waste steel products was saving the natural ingredient as well as environment friendly. The mix design was also taken into account in this research for producing the required strength as well as workability for rigid pavement.

AKNOWLEDGEMENT

This research paper was focused on the review of using the steel slag in concrete mixes. Although the different researchers were studied impact for using the steel mills industry wastes in concrete mixes for rigid pavement. The first acknowledge was addressed to the referred researchers in this review paper. Acknowledge was also addressed to my guide of this part of my thesis for his advice, helping as well as encouragement to achieve this good work. Finally as always firstly, I thankful, almighty God for giving me strength for achieving this review work.

REFERENCES

- [1] P. E. Tsakiridis, G. D. Papadimitriou, S. Tsivilis, and C. Koroneos(2008).“Utilization of steel slag for Portland cement clinker production,”
- [2] Irem Zeynep Yildirim and MonicaPrezzi, (2011).”Chemical, mineralogical and morphological properties of steel slag” Advances in civil engineering volume, ArticleID463638
- [3] IS-10262:2009, “Indian standard for concrete mix proportioning guidelines” First revision, Bureau of Indian Standard, New Delhi.
- [4] IS 9103:1999, “Specification for admixtures for concrete”, Bureau of Indian Standards, New Delhi, India.
- [5] IS 383-1970, “Specification for coarse and fine aggregates from natural sources for concrete” Bureau of Indian Standards, New Delhi.
- [6] IS: 383-1970, “Specification for coarse and fine aggregates from natural sources for concrete”, Bureau of Indian Standards, New Delhi.
- [7] IS: 516-1959, “Method of test for strength of concrete”, B I S, New Delhi.
- [8] IS: 5816-1959, “Splitting tensile strength of concrete - Method of test”, Bureau of Indian Standards, New Delhi
- [9] Prof. M.H.Lunagaria and Gatesi Jean De Dieu (2015) “A Study on the Compressive and Split Tensile Strength of Steel Slag Concrete Mixes for Rigid Pavement”IJSRD,vol.2, issue11, 2015.
- [10] ASTM C496-96, Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens, Annual Book of ASTM Standard, Vol.04.02, 2001

AUTHOR'S BIBLIOGRAPHY



Mr. GATESI JEAN DE DIEU, Was born 1983 in Rwanda, his completed Bsc in Civil Engineering & Environmental Technology (College of Science & Technology-University of Rwanda), at present is final year student pursuing master's degree in Civil (Transportation Engineering), L.D College of Engineering -Gujarat Technological University, India. He has published two papers in international journals. Interested area of research: Pavement materials, Public transport and Traffic engineering.



Prof. M.H. Lunagaria is currently professor in the department of civil engineering at Government Engineering College, Godhra., he obtained his BE in Civil Engineering and M.E in Civil (CASAD) degree from LDCE, Gujarat university. He has an experience of more than 25 years of consultancy and teaching. He has published numerous research papers in various international and national journals/ conferences. Interested area of research: concrete technology and building structures.