EFFECT OF PARTIAL REPLACEMENT [10%] OF SAND BY STEEL SLAG ON STRENGTH CHARACTERISTICS OF PAVEMENT

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ABSTRACT *Due to growing environmental awareness, as well as stricter regulations on managing industrial waste, the world is increasingly turning to researching properties of industrial waste and finding solutions on using its valuable component parts so that those might be used as secondary raw material in other industrial branches.Although iron and steel slag is still today considered waste and is categorized in industrial waste catalogues in most countries in the world, it is most definitely not waste, neither by its physical and chemical properties nor according to data on its use as valuable material for different purposes. Moreover, since the earliest times of the discovery and development of processes of steel and other metals production, slag as by-product is used for satisfying diverse human needs, from the production of medicines and agro-technical agents to production of cement and construction elements.*

Keywords: *Industrial waste ,Steel slag ,Environmental awareness,Metal production*

1.Introduction: -

Concrete is the most widely used material on earth after water. Many aspects of our daily life depend directly or indirectly on concrete. Concrete is prepared by mixing various constituents like cement, aggregates, water, etc. which are economically available. Concrete is unique among major construction materials because it is designed specifically for particular civil engineering projects. Concrete is a composite material composed of granular materials like coarse aggregates embedded in a matrix and bound together with cement or binder which fills the space between the particles and glues them together.Concrete plays a critical role in the design and construction of the nation infrastructure. Almost three quarters of the volume of concrete is composed of aggregates. 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.According to some estimates after the year 2010, the global concrete industry will require annually 8 to 12 billion metric tons of natural aggregates (U.S.G.S and nationalatlas.gov, accessed Nov 2008).When a desired metal has been separated by smelting from its raw ore, a glass like product is left over it is called as slag. Usually slag is the mixture of oxides of metal oxides and silicon dioxide, it also contains metal sulphides.

Slag can be ferrous example iron steel and non ferrous example lead, zinc, Copper .Slag is a totally waste by product which can be produced by manufacturing of pig steel and pig iron which is mainly used to remove waste in metal smelting. Slag is a by-product generated during manufacturing of pig iron and steel. It is produced by action of various fluxes upon gangue materials within the iron ore during the process of pig iron making in blast furnace and steel manufacturing in steel melting shop. Primarily, the slag consists of calcium, magnesium, manganese and aluminum silicates in various combinations. The cooling process of slag is responsible mainly for generating different types of slags required for various end-use consumers. Although, the chemical composition of slag may remain unchanged, physical properties vary widely with the changing process of cooling.

INTRODUCTION TO PAVEMENT DESIGN

A highway pavement is a structure consisting of superimposed layers of processed 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 pollution. 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. Two types of pavements are generally recognized as serving this purpose, namely flexible pavements and rigid pavements.

Rigid Pavements

(a) Rigid pavements have sufficient flexural strength to transmit the wheel load stresses to a wider area below. A typical cross section of the rigid pavements. Compared to flexible pavement, rigid pavements are placed either directly on the prepared sub-grade or on a single layer of granular or stabilized material. Since there is only one layer of material between the concrete and the sub-grade, this layer can be called as base or sub-base course.

(b) **Design Life & maintenance Period:** One of the most well known advantages of concrete is its superior durability and longer structural life. A 1998 life cycle cost report by ERES Consultants Inc. indicates that the expected life of an asphalt road is 17 years compared to 34 years for concrete. The report also indicates that asphalt highways require maintenance activities every three to five years and major rehabilitation becomes more and more frequent after the initial 17th year overlay. Maintenance cost is large sealing cracks; potholes, resurfacing and resealing are done frequently. Major maintenance / rehabilitation required after few years of service. Traffic adversely affected due maintenance creating extra difficulties in urban areas. Use of CRCP reduces number of joints and hence their maintenance.

2. Methods, Materialsand Design Methodolgy

The present research paper deals with the presentation of results obtained from various tests conducted on material used for the concrete. In order to achieve the objectives of present study, an experimental program was planned to investigate the effect of steel slag on compressive strength of concrete.

2.1 Materials

The properties of material used for making concrete mix are determined in laboratory as per relevant codes of practice. Different materials used in present study were cement, coarse aggregates, and fine aggregates, in addition to steel slag. The aim of studying of various properties of material is used to check the appearance with codal requirement sand to enable an engineer to design a concrete mix for a particular strength. The description of various materials which were used in this study is given below:

2.1.1. Portland Cement

Although all materials that go in to concrete mix are essential, cement is very often the most important because it is usually the delicate link in the chain. The function of cement is first of all to bind the sand and stone together and second to fill up the voids in between sand and stone particles to form a compact mass. It constitutes only about 20 percent of the total volume of concrete mix; it is the active portion of binding medium and is the only scientifically controlled in gradient of concrete.

2.1.2 Aggregates

Aggregates constitute the bulk of a concrete mixture and give dimensional stability to concrete. The most important function of the fine aggregate is to assist in producing workability and uniformity in mixture.

a)Coarse Aggregates: The aggregate which is retained over IS Sieve 4.75 mm is termed as coarse aggregate.

Locally available coarse aggregate having the maximum size of 20mm was used in this work. The aggregates were washed to remove dust and dirt and were dried to surface dry condition. The aggregates were tested as per IS:383-1970.

b)Fine Aggregates: The aggregates most of which pass through 4.75mm IS sieve are termed as fine aggregates. In this experimental program, fine aggregate was locallyprocured and conformed to Indian Standard Specifications IS: 10262:2009. The sand was sieved through 4.75mm sieve to remove any particles greater than 4.75mm and conforming to grading zone II. It was coarse sand light brown in colour.

2.1.3 Water

Generally, water that is suitable for drinking is satisfactory for use in concrete. Water from lake sand streams that contain marine life also usually is suitable. When water is obtained from sources mentioned above, no sampling is necessary. Accordinglypotable water was used for making concrete available in Material Testing laboratory. This was free from any detrimental contaminant sand was good potable quality.

2.1.4 Steel Slag

In this work, the Steel Slag is taken from the Iron and Steel Industry located atBalgarh Haryana. It is black in color as shown in figure 1.

Figure 1 Concrete Mixwith Steel slag

The Sieve Analysis of steel slag is shown in Table-1

Weightof sample taken=1000gm.					
Sr.No.	**IS-Sieve(m**	**Wt.Retained(gm)**	**%ageretained**	**%agepassing**	**Cumulative%retained**
1	4.75	14	1.4	98.6	1.4
2	2.36	28	2.8	95.8	4.2
3	1.18	94.5	9.45	86.35	13.65
4	600µ	189.5	18.45	67.8	32.1
5	300µ	329.5	32.95	34.95	65.05
6	150µ	291.5	29.15	5.8	94.2
7	Pan	58	5.8		
	Total	**1000.00**		**SUM**	**210.6**
				FM =	*2.10*

2.2 TEST METHODS

2.2.1 Specific Gravity

Specific gravity is ratio of the weight of a given volume of a substance to the weight of an equal volume of some reference substance, or equivalently the ratio of the masses of equal volumes of two substances.

2.2.2 Sieve Analysis for Coarse and Fine Aggregates as per IS: 10262-2009

The sieve analysis is used for the determination of particle size distribution of fine and coarse aggregates by sieving or screening.The split tensile strength of concrete is determined by casting cylinders of size 150 mm X 300 mm. The cylinders were tested by placing them uniformly. Specimens were taken out from curing tank at age of 7 days of moist curing and tested after surface water dipped down from specimens. This test was performed on Universal Testing Machine (UTM). The magnitude of tensile stress (T) acting uniformly to the line of action of applied loading is given by formulaWhere,

T = Split Tensile Strength in MPa P = Applied load,

T= 0.637P/dl

D = Diameter of Concrete cylinder sample in mm. L =Length of Concrete cylinder sample in mm.

2.3 MIX DESIGN (M25)

a) Test data for materials

(i)	Specific gravity of cement	3.15
(ii)	Specific gravity of coarse aggregates	2.8
(iii)	Specific gravity of fine aggregates	2.64
(iv)	Zone of fine aggregates	III
(v)	Water absorption of coarse aggregates	0.43%
(vi)	Water absorption of fine aggregates	0.89%

2.2.1 CALCULATIONS FOR MIX DESIGN OF M25 GRADE

M-25 Mix Designs as per IS-10262-2009

M-25CONCRETEMIXDESIGN		
AsperIS10262-2009&MORT&H		
A-1	**StipulationsforProportioning**	
1	**GradeDesignation**	**M25**
2	TypeofCement	OPC43gradeconfirmingtoIS-12269-
3	MaximumNominalAggregateSize	20mm
4	MinimumCementContent(MORT&H1700-3A)	310kg/m^3
5	MaximumWaterCementRatio(MORT&H1700-3A)	0.50
6	Workability(MORT&H1700-4)	50-75mm(Slump)
7	ExposureCondition	Normal
8	DegreeofSupervision	Good
9	TypeofAggregate	CrushedAngularAggregate
10	MaximumCementContent(MORT&HCl.1703.2)	425kg/m^3
11	ChemicalAdmixtureType	Steel SlagConfirmingtoIS-9103
A-2	**TestDataforMaterials**	
1	CementUsed	Ambuja CementOPC43grade
2	Sp.GravityofCement	3.15
3	Sp.GravityofWater	1.00
4	ChemicalAdmixture	Steel Slag Factory Balgarh Haryana
5	Sp.Gravityof20mmAggregate	2.8
6	Sp.Gravityof10mmAggregate	2.64
7	Sp.GravityofSand	2.69
8	WaterAbsorptionof20mmAggregate	0.43%
9	WaterAbsorptionof10mmAggregate	0.89%
10	WaterAbsorptionofSand	1.23%

11	Free(Surface)Moistureof20mmAggregate	Nil
12	Free(Surface)Moistureof10mmAggregate	Nil
13	Free(Surface)MoistureofSand	Nil
14	SieveAnalysisofIndividualCoarseAggregates	SeparateAnalysisDone
15	Sp.GravityofCombinedCoarseAggregates	2.882
16	SieveAnalysisofFineAggregates	SeparateAnalysisDone
A-3	**TargetStrengthforMixProportioning**	
1	TargetMeanStrength(MORT&H1700-5)	46N/mm^2
A-4	**SelectionofWaterCementRatio**	
1	MaximumWaterCementRatio(MORT&H1700-3A)	0.50
2	AdoptedWaterCementRatio	0.50
A-5	**SelectionofWaterContent**	
1	MaximumWatercontent(10262-table-2)	186Lit.
2	EstimatedWatercontentfor50-75mmSlump	197Lit.
3	Steel Slagused	0.5%bywt.ofcement
A-6	**CalculationofCementContent**	
1	WaterCementRatio	0.50
2	CementContent(191/0.50)	383kg/m^3
		Whichisgreaterthen320kg/m^3
A-7	**ProportionofVolumeofCoarseAggregate&FineAggregateContent**	
1	Vol.ofC.A.aspertable3ofIS10262	62.00%
2	AdoptedVol.ofCoarseAggregate	62.00%
	AdoptedVol.ofFineAggregate(1-0.62)	38.00%
A-8	**MixCalculations**	
1	VolumeofConcreteinm^3	1.00
2	VolumeofCementinm^3	0.122
	(MassofCement)/(Sp.GravityofCement)x1000	
3	VolumeofWaterinm^3	0.150
	(MassofWater)/(Sp.GravityofWater) x1000	
4	VolumeofAdmixture@0.5%inm^3	0.02025

	(MassofAdmixture)/(Sp.GravityofAdmixture)x1000	
5	VolumeofAllinAggregateinm^3	0.776
	Sr.no.1−(Sr.no.2+3+4)	
6	VolumeofCoarseAggregateinm^3	0.566
	Sr.no.5x0.62	
7	VolumeofFineAggregateinm^3	0.29
	Sr.no.5x0.38	
A-9	**MixProportionsforOneCumofConcrete(SSDCondition)**	
1	MassofCementinkg/m^3	**383**
2	MassofWaterinkg/m^3	**175**
3	MassofFineAggregateinkg/m^3	**401.304**
4	MassofCoarseAggregateinkg/m^3	895.44
5	WaterCementRatio	0.50

2.2 CONCRETE MIX DESIGN AND COMPRESSION STRENGTH TEST

Design concrete mix of 1:1.05:1.171 is adopted. The water cement ratio of 0.5 is used. After several trails this mix design was finalized .Thirty cube specimens were casted and tested after curing of 7 and 28 days. For every percentage of replacement 3 cubes have been casted. Totally 60 cubes were casted and tested. These cubes were tested in Compression Testing Machine (CTM) AND Split tensile strength machine (STM).

2.3 Proportions of Concrete Mixtures For M25 Grade

Material	Mix designation				
	SS 0%	**SS 10%**	**SS 20%**	**SS 30%**	**SS 40%**
Coarse Aggregate (kg/m3)	895.44	895.44	895.44	895.44	895.44
Fine Aggregate (kg/m3)	401.304	360.872	320.44	280.008	239.576
Steel slag (kg/m3)	0	40.432	80.864	121.296	161.728
Cement (kg/m3)	383.04	383.04	383.04	383.04	383.04
Water (kg/m3)	114.912	114.912	114.912	114.912	114.912
Water- Cement Ratio	0.5	0.5	0.5	0.5	0.5

3. RESULTS AND DISCUSSION

This research paperdeals with the presentation of results obtained from various tests conducted on concrete specimens cast with and without steel slag. The main objective of the research program was to understand the strength and durability aspects of concrete obtained using steel slag as partial replacement for sand. In order to achieve the objectives of present study, an experimental program was planned to investigate the effect of steel slag on compressive strength and split tensile strength of concrete. The experimental program consists of casting, curing and testing of controlled and steel slag concrete specimen at different ages.

The experimental program included the following:

- Testing of properties of materials used for making concrete.
- Design mix (M25).
- Casting and curing of specimens.
- Tests to determine the compressive strength and split tensile strength of concrete.

3.1. Compressive Strength

3.1.1 Test Procedure and Results

Test specimens of size 150*150*150 mm were prepared for testing the compressive strength concrete. The concrete mixes with varying percentages (0%, 10%) of steel slag as partial replacement of fine aggregate (sand) were cast into cubes and cylinders for subsequent testing.

In this study, to make concrete, cement and fine aggregate were first mixed dry to uniform color and then coarse aggregate was added and mixed with the mixture of cement and fine aggregates. Water was then added and the whole mass mixed. The interior surface of the moulds and the base plate were oiled before concrete was placed. After 24 hours the specimens were removed from the moulds and placed in clean fresh water at a temperature of 27±20º C. The specimens so cast were tested after 7 days of curing measured from the time water is added to the dry mix. For testing in compression, no cushioning material was placed between the specimen and the plates of the machine. The load was applied axially without shock till the specimen was crushed. Results of the compressive strength test on concrete with varying proportions of steel slag replacement at the age of7 and 28 days are given in the Table 2.

Table 2 Compressivestrengthofconcrete mixes of specimensize150 ×150× 150withSteelslag

Mix	Compressive Strength (N/mm2)		Average Compressive Strength(N/mm2)	
	7 days	28 days	7 days	28 days
CM	19.89	31.03		
	20.38	32.06	20.36	32.07
	20.57	33.15		
10%	22.35	33.75		
	22.67	34.33	22.8	34.66
	22.96	35.78		

The cube strength results of concrete mix are also shown graphically. The compressive strength increases as compared to control mix as the percentage of steel slag is increased. After adding 10%steel slag in the mix, there is an increase of 12% after 7 day and 7% increasing after 28 days as compared to control mix.

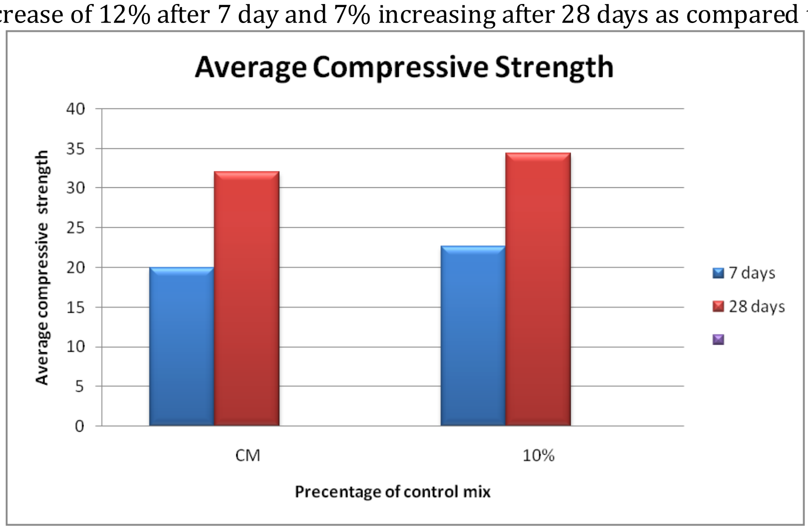

Figure 2 Compressive strength of steel slag concrete

Figure2 shows the variation of percentage increase in compressive strength with replacement percentage of Steelslag. The results also indicate that early age strength gaint 7 and 28 days, is higher when compared to the control mix.

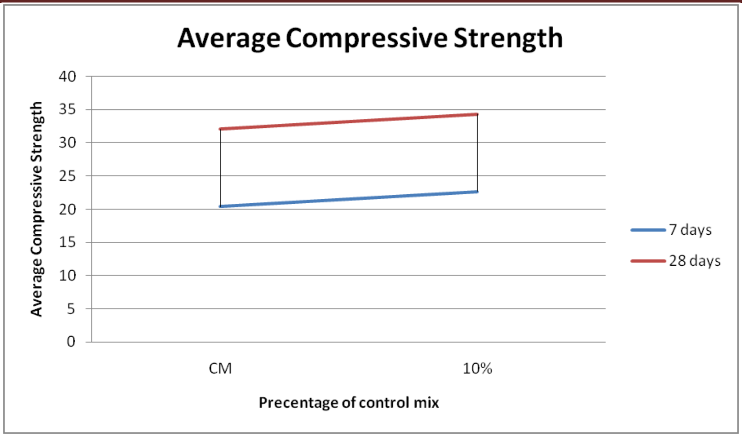

Figure 3 Percentage (%) increase in compressive strength of steel slag concrete

3.2 Split Tensile Strength Test

Split tensile strength studies were carried out at the age of 7 and 28days. The test results were given below on Table 3.

Table 1 Splitting tensile strength of concrete mixes with steel slag

Mix	Splitting Tensile Strength (N/mm2)		Average Splitting Tensile Strength(N/mm2)	
	7 days	28 days	7 days	28 days
CM	1.3	3		
	1.87	2.59	1.50	2.41
	1.59	2.99		
10%	1.58	2.85		
	1.47	2.55	1.72	2.69
	1.52	2.49		

The split tensile strength results of concrete mix are also shown graphically in Figure4. The split tensile results follow a pattern similar to compressive strength i.e. increase in the value with increase in percentage of slag replacement. However, the percentage increase in split tensile strength is smaller as compared to compressive strength. The split tensile strength increases with the percentage increase of steel slag as compared to control mix. After adding 10% steel slag in the mix, there is an increase of 15% after 7 days, 12% increase after 28 days.

Figure 4 shows the variation of percentage increase in split tensile strength with replacement percentage of steel slag. The strength gain at early age of 7 and 28 days is highest for 30% slag replacement.

From the strength point of view, it can be concluded that at early age presence of more amount of steel slag as sand replacement in concrete is beneficial for improving the strength characteristics.

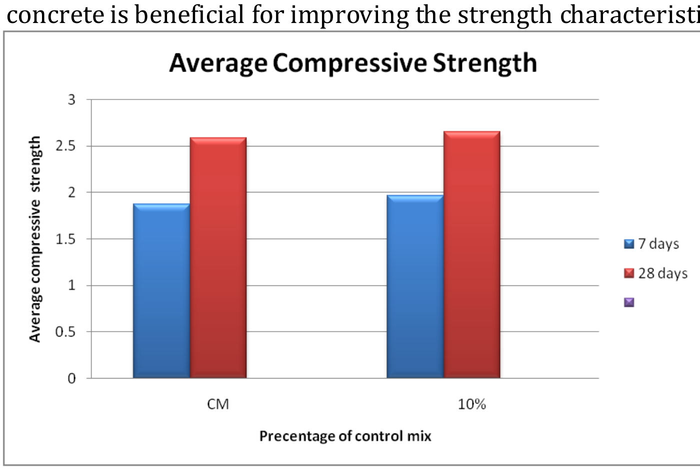

Figure 2 Split tensile strength of steel slag concrete

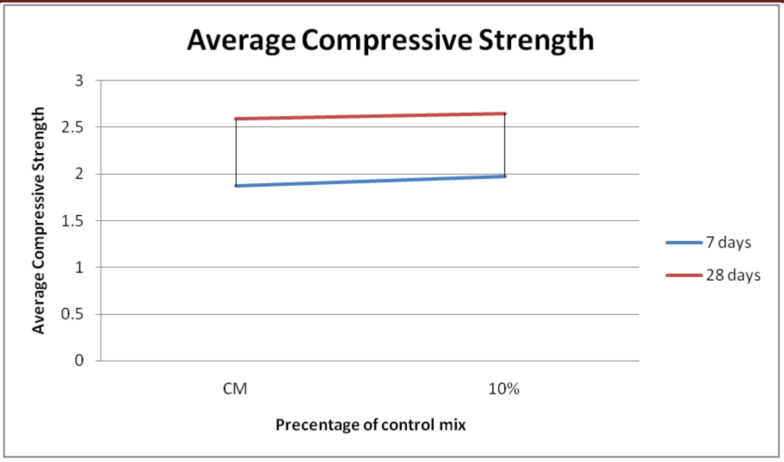

Figure 5 Percentage (%) increase in split tensile strength of steel slag concrete

4. CONCLUSION

The strength and durability characteristics of concrete mixtures have been computed in the present work by replacing 10% steel slag with the sand. On the basis of present study, following conclusions are drawn.

COMPRESSIVE STRENGTH

- The Compressive strength tends to increase with increase percentages of steel slag in the mix.
- After adding 10% steel slag in the mix, there is an increase of 12% after 7 days, 7% increase after 28 days as compared to the control mix.

SPLIT TENSILE STRENGTH

- The Split tensile strength also tends to increase with increase percentages of steel slag in the mix.
- After adding 10% steel slag in the mix, there is increase of 15% and 12% after 7 and 28 days.
- At early age presence of more amount of steel slag as sand replacement in concrete is beneficial for improving the strength characteristics.

SPLIT TENSILE STRENGTH

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