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Experimental Study on Partial Replacement of Cement by Prosopis Juliflora Ash and Fine Aggregate by Steel Slag

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Abstract: ***The main aim of this paper is to evaluate the performance of concrete by partial replacement of cement with prosopis Juliflora Ash and Fine aggregate with Steel Slag. Steel Slag is an industrial waste which is generated during the production of steel. In India, annual outcome of Steel Slag is about 10 Million Tonne.it is very important to utilize these waste in order to avoid the land pollution. Therefore, replacing some of the natural aggregate by Steel Slag would lead to considerable environmental benefits. Prosopis Juliflora Ash is the residue powder left after the combustion of wood, such as burning wood in home, hotels or an industrial power plant. It is also difficult to decompose and also absorbs more groundwater. Therefore, using PJA as a partial replacement of cement providing the green and clean environment. In this proposed work Prosopis Juliflora Ash with specified ratio of about 2.5%, 5%, 7.5% & 10% is replaced for cement and 10%, 20%, 30% & 40% of steel slag for partial replacement of fine aggregate is used. The mechanical properties of concrete such as compressive strength, tensile strength and workability has been evaluated. The optimum percentage of combined percentage was found to be 7.5% of PJA and 30% of SS. The project result reveals that 7.5% of PJA and 30% of SS enhance the strength of concrete compared to other replacements.***
Keywords: Prosopis Juliflora Ash (PJA), Steel Slag (SS), compressive strength, tensile strength, workability, environmental benefits.

I. INTRODUCTION

Concrete is the chief engineering material in the construction field. Concrete is a composite construction material composed mainly of cement, coarse aggregate, fine aggregate and water. The cement is a binding material which binds all the materials together. The aggregates are of two kinds, coarse aggregate and fine aggregate. Coarse aggregate is obtained by crushing the rock. Fine aggregate which is known as sand, obtained from river bed. Various chemical admixtures can also be used to achieve the special need or properties of the concrete. Water is mixed in concrete so that the concrete gets its shape and then gets hardened through a process called hydration. Almost three quarters of the volume of concrete is filled with aggregate. Therefore, aggregates are the important constituent in the production of concrete. But due to the demand of these basic building materials the cost of concrete is increasing rapidly which is one of the major drawback in this whole world. Aggregates and cement are the major important ingredient in the production of concrete. In India there is a great demand for fine aggregates. Recently Tamil Nadu Government has imposed restrictions for taking sand from the river beds due to its environmental impacts. While manufacturing the cement it causes the emission of carbon dioxide to the environment which leads to the ozone depletion. This affects the sustainability of concrete. In order to make concrete a sustainable material, an alternative material is needed. On the other hand of the world there are huge amount of wastes that have been generated. It's being a big problem of disposing this waste safety. The recent research made by the Waste management said that in India nearly 950 million tonnes of solid wastes were disposed annually which include both biodegradable and non- biodegradable. Steel Slag is a waste product generated during the production of steel and iron industry. These materials are otherwise considered to be a potential waste material which is been dumped near the industrial area. Steel slag are being used as aggregates in asphalt paving road mixes due to their mechanical strength, stiffness, porosity, wear resistance and water absorption capacity. Hence the usage of steel slag as fine aggregate increases the strength and durability of the concrete.

Prosopis Juliflora is one of the species which spreads over 100 hectares of our country. The prosopis juliflora absorbs more amount of groundwater which tends to reduction in the water table level. The juliflora is mainly used as fuel in home, hotels and industries. The residue obtained after burning of juliflora is difficult to decompose. Therefore, the partial replacement of cement by PJA would leads to environmental benefits. This project mainly emphasis towards combined utilization of prosopis juliflora ash and steel slag as a replacement of cement and fine aggregate in the concrete.

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A. Scope And Objectives

1) General

a) To evaluate the compressive strength of conventional cube and partially replaced cubes by 2.5%, 5%, 7.5%, 10% of Prosopis Juliflora Ash (PJA) and 10%, 20%, 30%, 40% of steel slag (SS).

b) To determine the finest percentage mixture of PJA and SS in the concrete mix.

2) Objectives: The main objective to choose this project is categorized into four categories .it is mainly based on 4R'S, they are mentioned here

a)	Reuse	Reuse the waste product.
b)	Reduce	Reduce the waste generated.
c)	Replacement & fine aggregate	Replacement of cement
d)	Reconstruct	Reconstruct the global environment.

3) Scope: The original scope of this project was to investigate the properties of concrete with steel slag as fine aggregate and prosopis juliflora ash as cement. The fresh and hardened properties of concrete were tested with steel slag aggregate and prosopis juliflora ash. In addition to this research tests were also included such as compressive strength and split tensile strength of the concrete. For this research the percentage of volume of natural aggregate were replaced by steel slag by 10%, 20%, 30% & 40% and percentage of volume of cement were replaced by PJA 2.5%, 5%, 7.5% and 10%.

II. MATERIALS

A. Cement

Cement is the binder material which holds the aggregate together. The commonly available ordinary Portland Cement (OPC 53 grade) confirming to IS12269-1987 is preferred for this study. The properties of the cement were tested in laboratory and mentioned below.

Table 3.1 Preliminary test on cement

SI. NO	TEST	RESULTS
1	Fineness of cement	3%
2	Normal consistency of cement	33%
3	Specific gravity of cement	3.16
4	Initial setting time of cement	33 mins
5	Final setting time of cement	535 mins

B. Fine Aggregate

Natural river sand passing through 1.18mm sieve and retained on 150μm sieve was used and tested as per IS: 2386-1983. The specific and confirmed Zone II grade of sand as per IS: 383 – 1987 was used.

Table 3.2 Preliminary test on fine aggregate

SI.NO	TEST	RESULTS
1	Fineness modulus	3.44
2	Specific gravity of fine aggregate	2.6
3	Water absorption of fine aggregate	1.23

C. Coarse Aggregate

Crushed granite aggregate confirming to IS: 383 – 1987 was used as coarse aggregate passing through 40mm sieve and retained on 20mm sieve.

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Table 3.3 Preliminary test on Coarse aggregate

SI.NO	TEST	RESULTS
1	Fineness modulus	3.54
2	Specific gravity of coarse aggregate	2.73
3	Water absorption of coarse aggregate	0.7

D. Steel Slag

Steel slag is a by-product 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). We collected steel slag from PULKIT steel Re-Rolling mill, Pondicherry.

TABLE 3.4 Physical properties of Steel Slag

SI.NO	DESIGNATION	PROPERTIES
1	Color	Light to dark brown
2	Shape	Highly angular
3	Bulk density	1911.11 kg/m3
4	pH (in water)	8
5	Combustibility	Non-combustible
6	Surface texture	Rough
7	Specific gravity	2.73

TABLE 3.5 Chemical properties of Steel Slag

SI. NO	CONSTITUENT	COMPOSITION
1	Calcium Oxide (CaO)	40 – 52
2	Silica (SiO2)	10 – 19
3	Iron Oxide (FeO)	10 – 40
4	Manganese Oxide (MnO)	5 – 8
5	Magnesium Oxide (MgO)	5 – 10
6	Alluminium Oxide (Al2O3)	1 – 3
7	Phosphorous Oxide (P2O5)	0.5 - 1

E. Prosopis Juliflora Ash

The Prosopis juliflora used for this study were acquired from the nearby areas in Cuddalore and converted as ash

TABLE 3.6 Physical properties of Prosopis Juliflora Ash

1	Specific gravity	2.2
2	Mean size	23µm

TABLE 3.7 Chemical properties of Prosopis Juliflora Ash

S.NO	PARTICULAR	VALUE
1	SiO2 (%)	20.25
2	Al2O3 (%)	5.04
3	Fe2O3 (%)	3.16
4	CaO (%)	63.61
5	MgO (%)	4.56
6	Na2O (%)	0.08
7	K2O (%)	0.5
8	Loss on ignition	3.12

Fig 3.1 prosopis juliflora ash and steel slag

III. EXPERIMENTAL OBSERVATION

A. Design Mix

a) Water cement ratio – 0.4

b) Mix ratio – 1:1.37:2.41

Based on the preliminary test value, the design mix is prepared as per IS: 10262-2009 with the w/c ratio of 0.40. we got the mix proportion of 1:1.37:2.41 for M30 grade of concrete.

Material	kg/cum	Ratio
Water	191.58	0.40
Cement	479	1
Fine aggregate	655.27	1.37
Coarse aggregate	1152.24	2.41

Table 4.1 Mix proportions

B. Workability Test

Workability is a vital property of concrete and related with compaction as well as strength. Desired workability is not same for all type of concrete. It is a property determining the effort required to manipulate a freshly mixed quantity of concrete with minimum loss of homogeneity.

1) Slump Cone Test: The slump value to determine the workability of conventional concrete along with various partially replaced concrete mixtures is measured and discussed for water cement ratio of 0.40. (in mm)

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Fig 4.1 Slump Cone Test

C. Casting Of Cubes And Cylinder

The total 45 numbers of cube (9 Nos. of Conventional concrete & 9 Nos. of cube for each 2.5% of PJA & 10% of SS, 5% of PJA & 20% of SS,
7.5% of PJA & 30% of SS, and 10% of CCA & 40% of SS replacements) are tested in a Compression testing machine.
Similarly, for each test that was conducted, the total number of **30** cylinders were prepared of size 150x300mm.The specimens were casted by using mixture as that used for cube casting and cured for 28 days at normal temperature to determine the split tensile strength of concrete.


Fig 4.2 Conventional Cubes

IV. RESULTS AND DISCUSSION

A. Slump Test

CONCRETE TYPE	SLUMP VALUE
Conventional concrete (CC)	75
2.5% of PJA & 10% of SS	75
5% of PJA & 20% of SS	74.5
7.5% of PJA & 30% of SS	72.5
10% of PJA & 40% of SS	72

Table 5.1 Results of various slump values obtained

The slump obtained are within the permissible limit as per IS code 456 and appropriate for construction purpose and also has a good workability

B. Compressive Strength

Compressive strength is the capacity of a material or structure to withstand loads tending to reduce size, as opposed to tensile strength, which withstand load tending to elongate. In other words, compressive strength resist compression (being pushed together). In the study of strength of materials, tensile, compressive strength and shear strength of the concrete, 150mm x 150mm x 150mm cubes were cast and cured. After 7 days, 14 days, and 28 days of curing the cubes were tested under compression test machine of capacity 2000kN.

P/A

Where, P ultimate load (KN) A area (m^2) $\longrightarrow$
The test results obtained by conducting compression test are tabulated below, $\longrightarrow$

SI.NO	% of PJA & SS Replacement	COMPRESSIVE STRENGTH (N/mm^2)		
		7D	14D	28D
1.	Conventional concrete (CC)	22.2	27.33	37.55
2.	2.5% of PJA & 10% of SS	22.67	27.11	37.66
3.	5% of PJA & 20% of SS	24.77	27.55	39.94
4.	7.5% of PJA & 30% of SS	26.22	28.9	42.55
5.	10% of PJA & 40% of SS	25.11	27.55	39.11

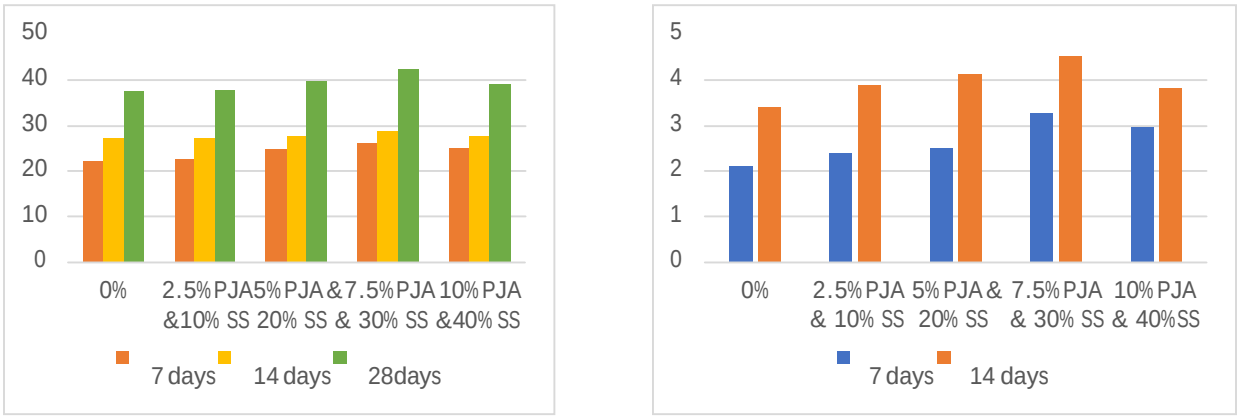

Chart 1: Overall Comparison Of Conventional and all Replaced concrete

C. Split Tensile Strength

Tensile strength is one of the basic and important properties of the concrete. The concrete is not usually expected to resist the direct tension because of its low tensile strength and brittle nature. However, the determination of tensile strength of the concrete is necessary to determine the load at which the concrete members may crack. The cracking is the form of tension failure. The split tensile strength was computed by using formula,

$$T = 2P/ \pi LD$$

Where,

P ⟶ ultimate load (KN)

L depth of the cylinder (m)

D diameter of the cylinder (m).

The test results obtained by conducting split tensile strength test are tabulated below.

S.no	Percentage of PJA & SS Replacement	Tensile strength (N/mm2)	
		7D	28D
1.	Conventional concrete (CC)	2.12	3.40
2.	2.5% of PJA & 10% of SS	2.4	3.89
3.	5% of PJA & 20% of SS	2.51	4.13
4.	7.5% of PJA & 30% of SS	3.29	4.52
5.	10% of PJA & 40% of SS	2.97	3.81

Table 5.2 Results for Compressive Strength

Chart 2: Overall Comparison Of Conventional and all Replaced concrete

V. CONCLUSION

The present work investigates the utility of prosopis juliflora ash as cement and steel slag as fine aggregate in the production of high compressive strength concrete.

A. In this project we tried to replace the cement and fine aggregate partially by prosopis juliflora ash (2.5%, 5%, 7.5% and 10%) and steel slag (10%, 20%, 30% and 40%) respectively to increase the strength of the concrete.

B. The mechanical behavior of concrete with partial replacement of cement by prosopis juliflora ash and steel slag as fine aggregate were investigated and presented.

C. Prosopis juliflora ash can be used to partially replace cement in the production of concrete to a maximum of 10% because replacement beyond it this reduces the strength of the concrete.

D. Steel slag can be used to partially replace fine aggregate in the production of concrete to a maximum of 40% because replacement beyond this reduces the strength of the concrete.

E. Higher percentage of prosopis juliflora ash in the production of concrete reduces the bonding capacity between the aggregate and also higher percentage of steel slag leads to reduction in the strength and workability of the concrete.

F. So, we concluded that the cement and fine aggregate replaced with prosopis juliflora ash at 7.5% and steel slag at 30% in concrete is suitable for construction. Moreover, it reduces the construction cost of cement and demand of fine aggregate and it also reduces the environmental pollution due to prosopis juliflora and steel slag.

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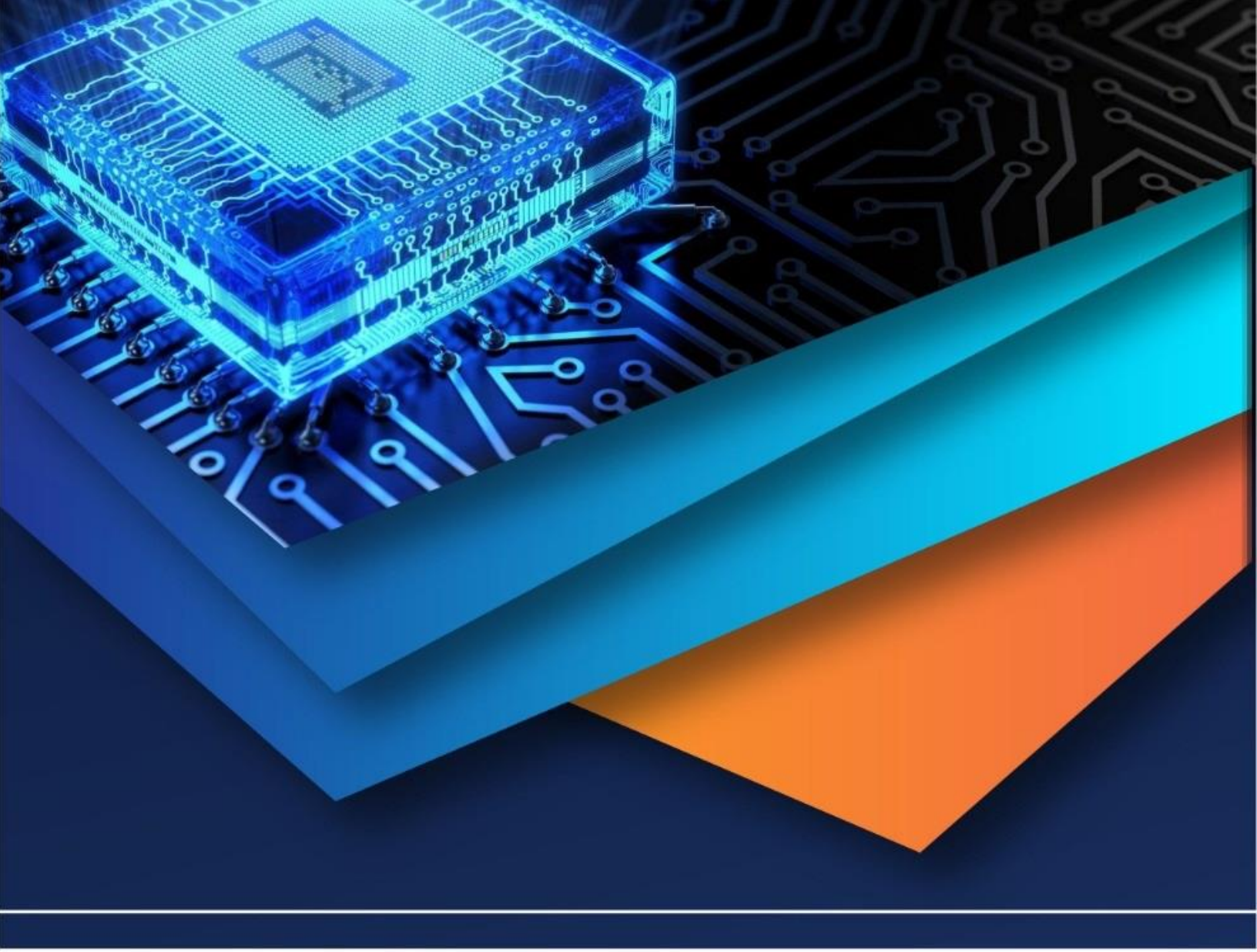

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