

Comparative Analyzing of Replacement of Natural Fine and Coarse Aggregate by Foundry Waste and Treated Waste Water

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Abstract: *Generation of foundry waste of metal casting industries causes environmental problems because of its improper disposal. Thus, its usages in building material construction and in other field is essential for reduction of environmental problems. Due to industrialization, infrastructure development and soft housing policy of government of India, the construction industry is in full boom due to which within short span of time there is a tremendous increase in the utilization of cement and concrete for various construction activities. It is expected that the same rate will continued in the next decade and this many invite the threat to the environment. Availability of raw material required for manufacturing of cement and production of concrete are limited in nature. This increased demand will lead to fast depletion of natural resources and will cause bog thread environment. This project is carried out to produce a low- cost and eco-friendly Plain Cement Concrete Blocks This project demonstrates the use of waste foundry product (foundry sand slag aggregates and recycled waste water C.E.T.P. Kagal). The main goal of this study is to demonstrate the possibility of using foundry wastes as a substitute rather than natural aggregates in concrete production in %. The experimental work consists of casting of cubes, beams and paving blocks of grade M20. cross-sectional dimensions of cube 150mm x 150mm and 150mm length. And cross-sectional dimensions of beam 500mm x 100mm x 100mm, and cross-sectional dimensions. Paving block 90mm x 90mm x 60mm*

Keywords: Compressive strength, Concrete, Industrial waste, foundry sand slag aggregates and recycled waste water C.E.T.P. Kagal)

1. Introduction

Economy of the world depends upon the magnitude of available natural resources. Hence sustainable development can be achieved by optimum utilization of these resources, solid waste generation and its management. The waste generated from the industries cause environmental problems hence the reuse of this waste material can be emphasized. Foundry sand is high quality silica sand that is a byproduct from the production of both ferrous and non-ferrous metal casting industries. Foundry sand is available in huge amount. Metal industries use foundry sand which is of uniform size than the normal sand which is used in metal casting process. Sustainable development can only be achieved by conserving the natural resources and reducing the impact on environment. The production of fresh natural aggregates involves a lot of quarrying and consumption of energy. Developing an awareness regarding optimum use of available natural resources and recycling of the available natural resources in the form of recycled aggregates and recycled water can be an effective alternative.

2. Relevance/Motivation

Now-a-days disposal of different waste produced from different Industries is a great problem. These materials pose environmental pollution in the nearby locality because many of them are non-biodegradable. The construction sector is exploring rapidly on a large scale and also involves new techniques for rapid and comfort works on the field. Concrete as a building material plays an important role in this sector. The consumption of natural resources as an ingredient of concrete, costs high it is on verge of extinct.

These problems force us to recover the natural resources or to find replacement.

Disposal of Wastewater is also posing various problems on environment and treatment of which comes costly and low cost treatment has very less efficiency. So, combining the foundry waste from foundry as well as wastewater will help to mitigate treatment of both the waste.

3. Objectives

- 1) To study the physical and chemical properties of foundry waste, blast furnace slag and treated waste water.
- 2) To study the compressive strength and of plain cement concrete blocks available in market and blocks casted using foundry waste and treated wastewater.
- 3) To study the durability aspect of plain cement concrete blocks available in market and blocks casted using foundry waste and treated wastewater, like acid effect, etc.
- 4) To compare cost analysis of plain cement concrete blocks available in market and blocks casted using foundry waste and treated wastewater.

4. Testing Programme

In the present study various tests on material such as cement, fine aggregate, coarse aggregate and the waste material industries foundry waste and treated wastewater were performed as per the Indian Standards.

Material Used

Cement

PortlandPozzolanic Cement of 43 grade was purchased from the local supplier and used throughout this project. The properties of cement used in the investigation are presented below.

Company: Ultratech(43 Grade)

Sr. No.	Type of Test	Results
1	Fineness of Cement (%)	1.55 %
2	Standard Consistency (%)	31.00 %
3	Initial Setting Time (min)	275 min
4	Final Setting Time (min)	342 min
5	Specific gravity	3.15
6	7 Day's Compressive Strength	35.425 N/mm ²
7	28 Day's Compressive Strength	46.150 N/mm ²

*As cement reacts with water its specific gravity is determined with reference to a non-reactive liquid like kerosene

Coarse and Fine Aggregate

Locally available river sand, basalt stone chips were used for preparation of concrete. Machines crushed locally available hard basalt, well graded 10.00 mm and down size were used. Some of their properties were tested as per IS Code and the values are given in table below

Properties of Coarse Aggregate

Sr. No.	Properties	Value
1	Specific Gravity	3.05
2	Fineness Modulus	3.44
3	Water Absorption (24 hours)	0.5%

Properties of Fine Aggregate

Sr. No.	Properties	Value
1	Specific Gravity	2.83
2	Fineness Modulus	2.79
3	Water Absorption (24 hours)	0.45%

5. Blast Furnace Slag Aggregate

Air-cooled blast furnace slag (ACBFS) has been used as a coarse aggregate in concrete pavements since at least the 1930s. By definition, blast furnace slag is the non-metallic product, consisting essentially of silicates and aluminosilicates of calcium and other bases, that is developed in a molten condition simultaneously with iron in a blast furnace. It is important to recognize that ACBFS aggregates are distinct, unique materials, possessing a number of characteristics and properties that must be considered during the design and construction process to ensure long-term performance (Wang and Thompson 2011). For example, ACBFS typically exhibits the following characteristics when compared to natural aggregates



Figure 4.1: Slag

6. Properties of Blast Furnace Slag Aggregate

Sr. No.	Properties	Value
1	Specific Gravity	2.48
2	Fineness Modulus	1.34
3	Water Absorption (24 hours)	0.15 %

Foundry Sand

Foundry sand used for the centuries as a molding casting material because of its high thermal conductivity, the physical and chemical characteristics of foundry sand will depend in great part on the type of casting process and the industry sector from which it originates. In the casting process, molding sands are recycled and reused multiple times. Eventually, however, the recycled sand degrades to the point that it can no longer be reused in the casting process. At that point, the old sand is displaced from the cycle as byproduct, new sand is introduced, and the cycle begins again.



Figure 4.2: Foundry Sand

Properties of Foundry sand

Table 3.8: Properties of Foundry Sand

Sr. No.	Properties	Value
1	Specific Gravity	2.73
2	Fineness Modulus	3.1
3	Water Absorption (24 hours)	0.10 %

Water

The potable water from supply mains was used for the preparation of concrete and its subsequent curing.

Treated Water

Characterization of KagalPanchTarankit C.E.T.P. Co-Op Association Society Kasaba-Sangav, Kagaltreatment plant water used in the laboratory experiments

Table 3.10: Properties of Treated Water

Parameters	Inlet-Effluent	Outlet-Effluent
PH	8.24	7.70
COD mg/lit	528	168
BOD mg/lit	152	26
TSS	628	96
DO	Nil	2.8
Sulphides	Nil	Nil
Chlorides	698.6	531

Concrete Design Mix Ratio

Final Design Mix Ratio

Cement	Sand	Course Aggregate (1/8)	Course Aggregate (3/8)	Water	Chemical
1.000	4.267	1.746	1.676	0.560	1%

7. Preparation of Specimens

Based on the above results the water quantity, cement, fine aggregate and coarse aggregate required for design mix of M20. The final mix ratio was 1:4.267:1.746:1.676 with water cement ratio of 0.56. The measurement of materials was done by weight using electronic weighing machine. Water was measured in volume. Concrete was placed in molds in layers. The cast specimens were removed from

moulds after 24 hours and the specimens were kept for water curing. The details of mix designation and specimens used in experimental program are given below.

Optimization of Foundry Sand

Natural sand is replaced by foundry sand (from 0% to 100% at an increment of 20%)

Table 5.3: Final Mix Proportion (Optimization of Foundry Sand)

Cement (Kg/m ³)	Sand (Kg/m ³)	Foundry Sand (Kg/m ³)	Course Aggregate (1/8) Kg/m ³	Course Aggregate (3/8) Kg/m ³	Water (Kg/m ³)	Chemical
0% Replacement of NS by FS (Conventional Concrete)						
270	1152.076	-	471.303	452.45	0.56	1%
20% Replacement of NS by FS (A20)						
270	230.4152	921.6608	471.303	452.45	0.56	1%
40% Replacement of NS by FS (A40)						
270	460.8304	691.2456	471.303	452.45	0.56	1%
60% Replacement of NS by FS (A60)						
270	691.2456	460.8304	471.303	452.45	0.56	1%
80% Replacement of NS by FS (A80)						
270	921.6608	230.4152	471.303	452.45	0.56	1%
100% Replacement of NS by FS (A100)						
270	-	1152.076	471.303	452.45	0.56	1%
50% Replacement of NS by FS (A50)						
270	576.038	576.038	471.303	452.45	0.56	1%

Table 5.4: Final Design Mix Ratio (Optimization of Foundry Sand)

Cement (Kg/m ³)	Sand (Kg/m ³)	Foundry Sand (Kg/m ³)	Course Aggregate (3/8) Kg/m ³	Course Aggregate (1/8) Kg/m ³	Water (Kg/m ³)	Chemical
0% Replacement of NS by FS (Conventional Concrete)						
1.000	4.267	-	1.746	1.676	0.560	1.000
20% Replacement of NS by FS (A20)						
1.000	0.8534	3.4136	1.746	1.676	0.560	1.000
40% Replacement of NS by FS (A40)						
1.000	1.7068	2.5602	1.746	1.676	0.560	1.000
60% Replacement of NS by FS (A60)						
1.000	2.5602	1.7068	1.746	1.676	0.560	1.000
80% Replacement of NS by FS (A80)						
1.000	3.4136	0.8534	1.746	1.676	0.560	1.000
100% Replacement of NS by FS (A100)						
1.000	-	4.267	1.746	1.676	0.560	1.000
50% Replacement of NS by FS (A50)						
1.000	2.1335	2.1335	1.746	1.676	0.560	1.000

Optimization of Blast Furnaces Slag

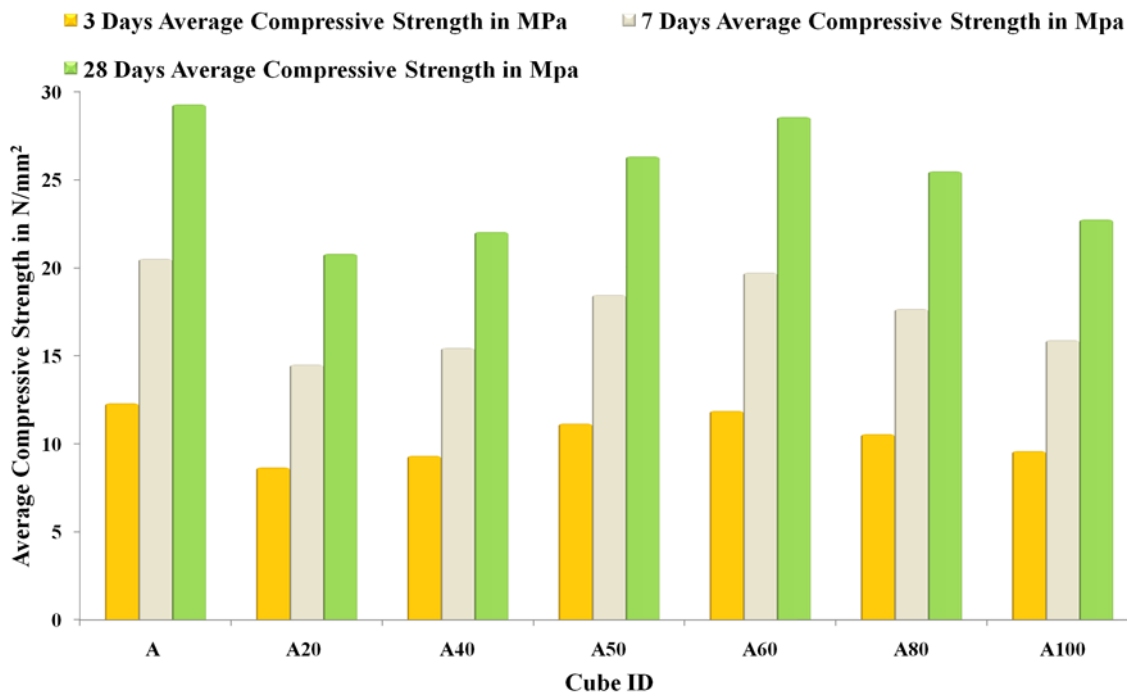
Coarse Aggregate ($\frac{1}{8}$) and Coarse Aggregate ($\frac{3}{8}$) both are replaced by Blast Furnaces Slag (from 0% to 60 % at an increment of 10%)

Table 5.5: Final Mix Proportion (Optimization of Blast Furnaces Slag)

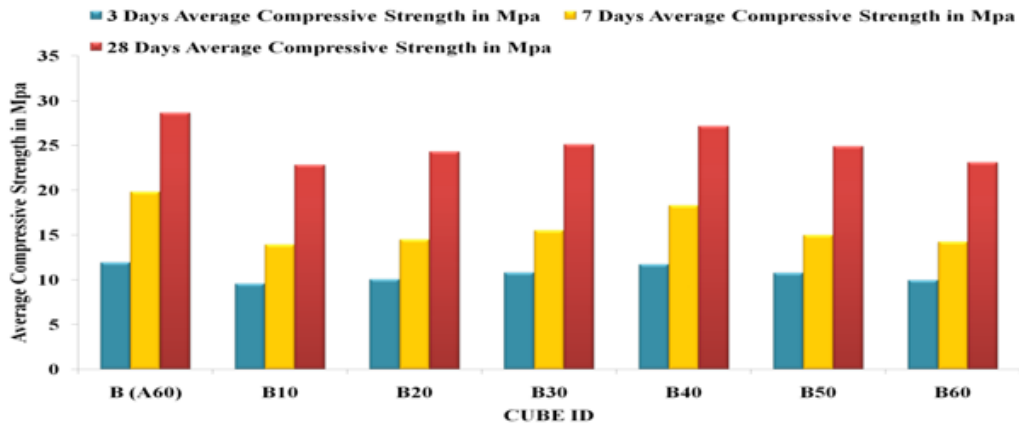
Cement (Kg/m ³)	Sand (Kg/m ³)	CA (1/8) (Kg/m ³)	BF Slag (1/8) (Kg/m ³)	CA (3/8) (Kg/m ³)	BF Slag (3/8) (Kg/m ³)	Water (Kg/m ³)	Chemical
0% Replacement of CA by BF Slag							
270	1152.076	471.303	0.000	452.450	0.000	0.560	1%
10% Replacement of CA by BF Slag							
270	1152.076	424.173	47.130	407.205	45.245	0.560	1%
20% Replacement of CA by BF Slag							
270	1152.076	377.042	94.261	361.960	90.490	0.560	1%
30% Replacement of CA by BF Slag							
270	1152.076	329.912	141.391	316.715	135.735	0.560	1%
40% Replacement of CA by BF Slag							
270	1152.076	282.782	188.521	271.470	180.980	0.560	1%
50% Replacement of CA by BF Slag							
270	1152.076	235.652	235.652	226.225	226.225	0.560	1%
60% Replacement of CA by BF Slag							
270	1152.076	188.521	282.782	180.980	271.470	0.560	1%

Table 5.6: Final Design Mix Ratio (Optimization of Blast Furnaces Slag)

Cement (Kg/m ³)	Sand (Kg/m ³)	CA (1/8) (Kg/m ³)	BF Slag (1/8) (Kg/m ³)	CA (3/8) (Kg/m ³)	BF Slag (3/8) (Kg/m ³)	Water (Kg/m ³)	Chemical
0% Replacement of CA by BF Slag							
1	4.267	1.746	0.000	1.676	0.000	0.56	1%
10% Replacement of CA by BF Slag							
1	4.267	1.571	0.175	1.508	0.168	0.56	1%
20% Replacement of CA by BF Slag							
1	4.267	1.396	0.349	1.341	0.335	0.56	1%
30% Replacement of CA by BF Slag							
1	4.267	1.222	0.524	1.173	0.503	0.56	1%
40% Replacement of CA by BF Slag							
1	4.267	1.047	0.698	1.005	0.670	0.56	1%
50% Replacement of CA by BF Slag							
1	4.267	0.873	0.873	0.838	0.838	0.56	1%
60% Replacement of CA by BF Slag							
1	4.267	0.698	1.047	0.670	1.005	0.56	1%



ID Mark	Description
A	= Conventional Concrete (0% Replacement of NS by FS)
A20	= 20% Replacement of Natural Sand by Foundry Sand
A40	= 40% Replacement of Natural Sand by Foundry Sand
A50	= 50% Replacement of Natural Sand by Foundry Sand
A60	= 60% Replacement of Natural Sand by Foundry Sand
A80	= 80% Replacement of Natural Sand by Foundry Sand
A100	= 100% Replacement of Natural Sand by Foundry Sand

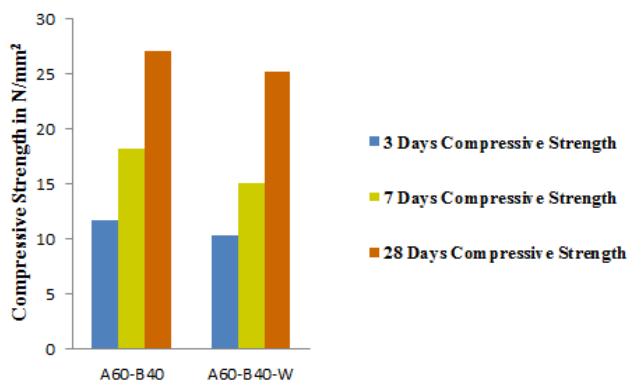


ID Mark	Description
B	= Optimum % replacement of Natural Sand by Foundry Sand and 0% Replacement of Course Aggregate by Blast Furnace Slag
B10	= Optimum % replacement of Natural Sand by Foundry Sand and 10% Replacement of Course Aggregate by Blast Furnace Slag
B20	= Optimum % replacement of Natural Sand by Foundry Sand and 20% Replacement of Course Aggregate by Blast Furnace Slag
B30	= Optimum % replacement of Natural Sand by Foundry Sand and 30% Replacement of Course Aggregate by Blast Furnace Slag
B40	= Optimum % replacement of Natural Sand by Foundry Sand and 40% Replacement of Course Aggregate by Blast Furnace Slag
B50	= Optimum % replacement of Natural Sand by Foundry Sand and 50% Replacement of Course Aggregate by Blast Furnace Slag
B60	= Optimum % replacement of Natural Sand by Foundry Sand and 60% Replacement of Course Aggregate by Blast Furnace Slag

8. Discussion on Results Analysis

Effect of Replacement of Natural Sand by Foundry Sand on Compressive Strength of Concrete

The effect of the % replacement of Natural Sand(NS) by Foundry Sand (FS) on the compressive strength was determined by testing of the cube samples. Test conducted on the various specimen with curing period of 3 days, 7 days, and 28 days. With 0% replacement of FS to NS the specimen gave strength of 12.287 N/mm². With 50%, 60% and 80% replacement results obtained are 11.86% N/mm², 11.859 N/mm² and 10.536 N/mm² respectively so the more relevant value providing to 11.859 N/mm². With it is interesting to note that there was a decrease in the compressive strength of the design mix for the initial % replacement of Natural Sand by Foundry Sand (i.e. for 20% replacement). After that there is an increase in the compressive strength with the increase in the % of Foundry Sand up to 60 % replacement. Further increase in the % of Foundry Sand reduces the compressive strength of the design mix concrete.



ID Mark	Description
A60-B40	= 60% replacement of Natural Sand by Foundry Sand and 40% Replacement of Course Aggregate by Blast Furnace Slag
A60-B40-W	= 60 % replacement of Natural Sand by Foundry Sand and 40% Replacement of Course Aggregate by Blast Furnace Slag and use recycled waste water C.E.T.P. Kagal

Effect Of Replacement Of Course Aggregate By Blast Furnace Slag On Compressive Strength Of Concrete

Again the effect of the % replacement of Course Aggregate (CA) by Blast Furnace Slag (BFS) on the compressive strength was determined by testing of the cube samples. Same as replacement of Course Aggregate (CA) by Blast Furnace Slag (BFS) was also determined by testing of cube samples curing period of 3 days, 7 days, and 28 days. With the 0% replacement of Course Aggregate (CA) by Blast Furnace Slag (BFS) and 60% replacement Natural Sand (NS) by Foundry Sand (FS) specimen strength is 11.859 N/mm². With 30, 40 and 50% replacement results obtained are 10.774 N/mm², 11.675 N/mm² and 10.720 N/mm² respectively from this more reliable and closer value I found is 40% giving 11.675 N/mm².

With it is interesting to note that there was a decrease in the compressive strength of the design mix for the initial % replacement of Course Aggregate (CA) by Blast Furnace Slag (BFS) (i.e. for 40% replacement). After that there is an increase in the compressive strength with the increase in the % Blast Furnace Slag (BFS) up to 40 % replacement. Further increase in the % of Blast Furnace Slag (BFS) reduces the compressive strength of the design mix concrete.

Effect of Replacement of Potable Water by Treated Waste Water on Compressive Strength of Concrete

With it is interesting to note that there was a decrease in the compressive strength of the design mix for the replacement of Potable Water by Treated Waste Water. Hence with 60% replacement of Natural Sand(NS) by Foundry Sand (FS) ,40% replacement of Course Aggregate (CA) by Blast Furnace Slag (BFS) and with usages of potable water more reliable compressive strength results are out.

9. Cost Analysis

Cost Analysis of M20 Grade Conventional concrete

Sr. No	Material	Quantity	Rate in Rs.	Unit	Amount
1	Cement	5.16	360.00	Bags	1857.60
2	Natural Sand	0.761	2135.65	Cum.	1625.23
3	Foundry Sand	-	-	-	-
4	Aggregate (1/8)	0.311	629.11	Cum.	195.65
5	Aggregate (3/8)	0.298	629.11	Cum.	187.47
6	Blast Furnace Slag (1/8)	-	-	-	-
7	Blast Furnace Slag (3/8)	-	-	-	-
8	Chemical	2.58	120	Liters	309.60
TOTAL					4175.56

Cost Analysis of Design Mix (With Replacement)

Sr. No.	Material	Quantity	Rate in Rs.	Unit	Amount
1	Cement	5.160	360.00	Bags	1857.60
2	Natural Sand	0.304	2135.65	Cum.	650.09
3	Foundry Sand	0.457	33.00	Cum.	15.07
4	Aggregate (1/8)	0.187	629.11	Cum.	117.39
5	Aggregate (3/8)	0.179	629.11	Cum.	112.48
6	Blast Furnace Slag (1/8)	0.124	47.00	Cum.	5.85
7	Blast Furnace Slag (3/8)	0.119	47.00	Cum.	5.60
8	Chemical	2.580	120.00	Liters	309.60
TOTAL					3073.69

A) Cost of 1 (ONE) Paver Block Casted in Laboratory

- Paver Blocks in Conventional Concrete =Rs 2.92/-
- Paver Blocks with replacement in ingredients= Rs. 2.15/-

B) Cost of 1 (ONE) Paver Block available in Market

- Paver Blocks (Rubber Mould)=Rs 3.76/-
- Paver Blocks (Normal Mould)=Rs 3.48/-

10. Conclusion

Chemical and physical properties of both Blast Furnace Slag (BFS) and foundry sand (FS) are similar to properties of natural course and fine aggregates. The primary characterization indicates the foundry sand have a enough suitability to utilize as a fine aggregate in production of concrete to enhance the strength and durability of the concrete by saving the natural resources like sand which is day by day become scared.

Evan 80% replacement by Blast Furnace Slag (BFS) and foundry sand gives appropriate compressive strength hence we can save valuable natural resource without much compromising in the strength.

The demand for aggregates is increasing rapidly and so as the demand of concrete. Thus, it is becoming more important to find suitable alternatives for aggregates in the future. Utilization of Blast furnace slag and foundry sand in concrete (as a replacement of Fine and Course Aggregate) might prove an economical and environmental friendly solution in local region. The results showed that it has properties similar to natural aggregates and it would not cause any harm if incorporated into concrete.

It can be conclude that the compressive strength of concrete with 60% replacement Natural Sand (NS) and 40% replacement Course Aggregate (CA) with potable water was increases by 7.137 N/mm² (35.69 %) than the design compressive strength of Convention concrete (20 N/mm²), where as the compressive strength was increased by 5.166 N/mm² (25.83 %) while treated water was used instead of potable water.

It can be concluded that the cost of M20 grade conventional concrete is Rs. 4175.56/- per m³ and the cost of concrete with 60% replacement of Natural Sand(NS) by Foundry Sand (FS) & 40% replacement of Course Aggregate (CA) by Blast Furnace Slag (BFS) is Rs. 3073.69/- per m³.

Similarly, if paver blocks are casted in laboratory with conventional concrete, then obtained cost was Rs 2.92/- per paver block and if paver blocks are casted in laboratory with concrete with 60% replacement Natural Sand (NS) and 40% replacement Course Aggregate (CA), then obtained cost was Rs 2.15/- per paver block. Whereas the cost of paver block available in market is Rs. 3.48/- per paver block. With reference to the observations of the present experimental work it can conclude that there was a saving of Rs. 1101.87 /- per m³ or saving of Rs 1.33 /- per paver block and also saving of natural resources like Fine Aggregate and Course Aggregate.

Therefore from the above observations finally it can be concluded that the replacement of fine and course aggregate by Blast furnace slag and Foundry sand was safe and economical.

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