Feasibility Analysis of Sustainable Concrete Paving Blocks Incorporating Waste Foundry Sand

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Abstract -This Annually a huge amount of WFS is generated from ferrous and non-ferrous metal casting industries around 6-10 million tons and this waste is dumped on near-by landfill sites which is really harmful and can cause adverse effects on the environmental health and rapid increase in disposal cost. Waste foundry sand is uniformly sized, high quality silica sand, combined with binders and used to form moulds of ferrous and non-ferrous castings. Foundry successfully recycles and reuses the sand many times, when it can no longer be reused in the foundry it is removed and dumped on landfill sites. Utilization of this WFS as a replacement of fine aggregate in concrete paver blocks will be helpful for both environmental and economic aspects in the construction industry in the present context of sustainability. Lots of research conducted on replacement of natural aggregate with (NA) with waste foundry sand (WFS) considering its strength parameters but prediction of durability is main aspect.

This study investigated the mechanical (compressive strength, flexural strength, water absorption strength) and durability (abrasion resistance test, RCPT test) properties of paver blocks incorporating WFS as fine aggregate replacement in various replacement percentages like 0%, 10%, 20%, 30% and 40% along with 40% GGBS and 10% fly ash as cement replacement. The compressive strength was observed to be in the range of 45.6MPA to 47.8MPA, flexural strength in the range of 3.26MPa to 4.87MPA and water absorption in 3.67 to 5.88 %. Greatest increase in strength characteristics and economic feasibility compared to conventional paver blocks is achieved at 30% incorporation of WFS along with 40% GGBS and 10% Fly ash. The inclusion of WFS and fly ash, ggbs does not affect strength properties negatively as strength remains within limit upto 40% replacement.

Key Words*:Concrete paver blocks, Waste foundry sand, Mechanical properties, Durability properties, Economic feasibility.*

1.INTRODUCTION

Foundry industries like iron, steel, non-ferrous metal casting industries produces a large amount of by-product material during casting process. Foundry industry utilize excellent explicit size silica sand for their trim and throwing process. Foundry effectively reuses and reuses the sand commonly, when it can never again be reused in the foundry it is expelled and dumped on landfill destinations causing natural contamination effect and corruption, this dumped sand is squander foundry sand (WFS). In India 6-10 million tons sand is discarded annually. WE are facing this major problem today i.e. disposal of solid waste, so to produce sustainable development we have to reuse and recycle these waste materials in the construction sector in structural, non-structural construction components. To reduce this solid waste impact on environment we are trying to reuse this waste sand in non-structural member like concrete paving blocks as an alternative to fine aggregates in concrete production.

Over the past several decades, the demand for concrete has been increasing rapidly due to infrastructure development. Quick urbanization and worldwide populace development have fueled the interest for sand and rock, with somewhere in the range of 32 and 50 billion tons extricated all around every year. This causes increase in consumption of natural resources like river sand i.e. fine aggregates. Due to this enormous and huge demand fine aggregates are depleting day by day causing its scarcity. India is importing river sand (3million tons in 2018 from various countries) to satiate the growing demand of its construction industry and to keep soaring sand prices in check. However, imports alone won't get the job done without viable execution of guidelines and advancement of elective development materials.

Thus, we are attempting to utilize this WFS as fine totals substitution in non-auxiliary segment for example Concrete Paver Blocks. Today concrete paver squares are the most favored decision for clearing of trails, parking garages, transport stops, enterprises, and so forth. Solid Paving Blocks were first produced in the Netherlands in 1924. The overall pattern towards beautification of city asphalts, the increasing expense of bitumen as a clearing material and the quick increment in development and upkeep cost have urged originators to substitute clearing material, for example, solid squares.[2]

SIGNIFICANCE OF STUDY

This research work is carried out to obtain feasibility data i.e. its strength, durability and economic data on concrete paver blocks which are green paver blocks with waste foundry sand as fine aggregate replacement and combine use of fly ash and ggbs as cement replacement. The results of this research will be helpful to produce sustainable concrete paver blocks with low cement content including reuse and recycle of waste material which is abundantly found. This study would lead to cost saving, material saving and environmental pollution saving.

2. SYSTEM DEVELOPMENT

2.1. Material Specifications

1. Cement

Ordinary Portland cement of 43 grade conforming to IS:12269-1987 is used in manufacturing the concrete paver blocks of research work.

2. GGBS

GGBS is the material left after extraction of iron from iron ore. It is one of the source materials to produce a cementless binder. Ground granulated blast furnace slag is obtained from Guru Corporation, Ahmedabad.

3. Fly Ash

Fly ash used in this research work is class-F fly ash obtained from Sai Vision Creators, Pimpari, Pune.

4. Waste Foundry Sand (WFS)

Waste foundry sand used in this research work is obtained from Aum Enterprises, Bhosari, Pune. Specific gravity and water absorption of used WFS is 2.29 & 1.97% respectively. The chemical composition of WFS is mentioned in following table.

Table– 1: Chemical composition of WFS as per IS:4032

Sr. No.	Chemical constituent	Unit	Test results
1	SiO_2	%	93.82
2	Al_2O_3	%	2.11
3	Fe_2O_3	%	0.56
4	MgO	%	0.76
5	CaO	%	1.36
6	SO_3	%	0.12

5. Fine Aggregates

Fine aggregate used in manufacturing of paver blocks is passing through 4.75mm sieve conforming to zone II of IS:383-1970 and obtained from S.R. Industries, Bhavdi Road, Wagholi, Pune. Specific gravity and water absorption of used F.A. is 2.74 & 2% respectively.

6. Coarse Aggregate

Coarse aggregate used in the manufacturing of paver blocks is 12mm crushed sand obtained from S.R. Industries, Bhavdi Road, Wagholi, Pune. Specific gravity and water absorption of C.A. is 2.76 & 0.25% respectively.

2.2. Mix Proportions

Table-2: Mix Proportion for Conventional (M40 Grade)

Ingredients	**SSD weight (kg/m^3)**
Cement	400 kg/m^3
Water	155.82 kg/m^3
Fine Aggregate	595.56 kg/m^3
Coarse Aggregate	1174.104 kg/m^3
W/C Ratio	0.36
Chemical	4 kg/m^3

(Notations used in table)Conventional paver blocks= S1

0%WFS& 40%GGBS+10%Fly ash= S2 M1

10%WFS& 40%GGBS+10%Fly ash= S2 M2

20%WFS& 40%GGBS+10%Fly ash= S2 M3

30%WFS& 40%GGBS+10%Fly ash= S2 M4

40%WFS& 40%GGBS+10%Fly ash= S2 M5

Table-3: Mix Proportion for casting 1 batch of paver block

Details of replacement	S1	S2M1	S2M2	S2M3	S2M4	S2 M5
W/C Ratio	0.36	0.36	0.36	0.36	0.36	0.36
Cement(kg)	15	7.5	7.5	7.5	7.5	7.5
GGBS (kg)	-	6	6	6	6	6
Fly ash(kg)	-	1.5	1.5	1.5	1.5	1.5
Coarse Agg(kg)	60	60	60	60	60	60
Fine Agg(kg)	40	40	36	32	28	24
WFS (kg)	-	-	4	8	12	16
Water(kg)	15	15	15	15	15	15
Chemical(kg)	2.5	2.5	2.5	2.5	2.5	2.5

2.3. Specimen casting & curing

The paver blocks casted are of M-40 Grade concrete having thickness of 80mm as per IS:15658-2006. The material was mixed in concrete mixture and filled in molds next vibrated on table kept for 48hrs and then demolded. Then cured in water for 1,7&28 days to perform mechanical and durability tests. The size of zig zag pavers is 250mmX120mmX80mm. Size of RCPT specimen is 100mmX50mm.

2.4. Results and Discussions

A. Workability

Table- 4: Workability test results

Details of Replacement		**Slump(mm)**
Conventional paver blocks (0% Replacement)	S1	0mm
0% WFS & 40% GGBS+10% Fly ash	S2 M1	0mm
10% WFS & 40% GGBS+10% Fly ash	S2 M2	60mm
20% WFS & 40% GGBS+10% Fly ash	S2 M3	40mm
30% WFS & 40% GGBS+10% Fly ash	S2 M4	20mm
40% WFS & 40% GGBS+10% Fly ash	S2 M5	20mm

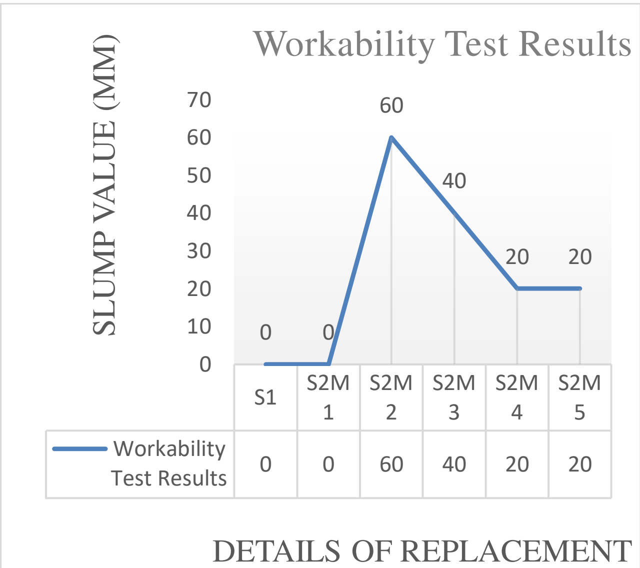

Chart 1: Workability

B. Water absorption test

Table- 5: Water absorption test results

Details of replacement	Notation	Water absorption test results (%) 1 Day	28 Days
Conventional paver blocks (0% Replacement)	S1	4.96	5.91
0% WFS & 40% GGBS+10% Fly ash	S2 M1	2.57	3.67
10% WFS & 40% GGBS+10% Fly ash	S2 M2	3.35	4.57
20% WFS & 40% GGBS+10% Fly ash	S2 M3	3.58	5.39
30% WFS & 40% GGBS+10% Fly ash	S2 M4	4.49	5.47
40% WFS & 40% GGBS+10% Fly ash	S2 M5	4.82	5.88

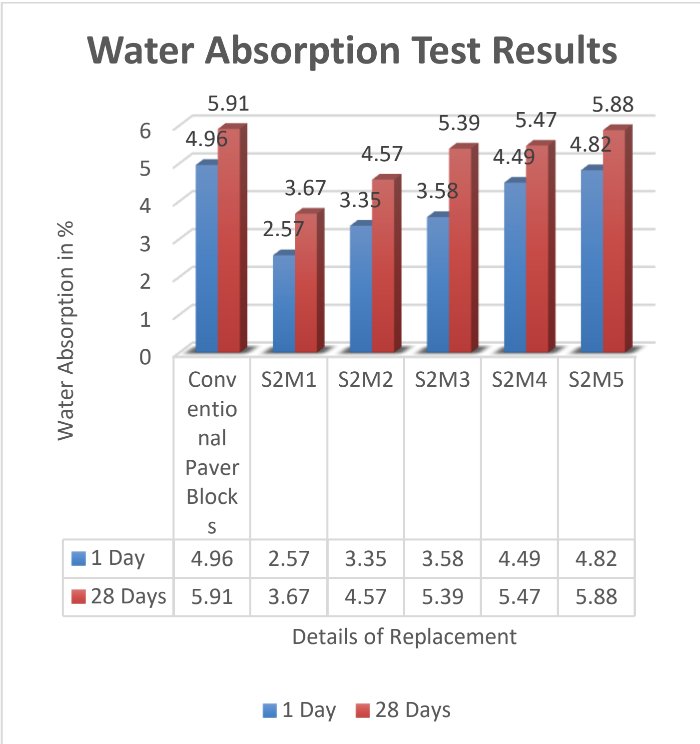

Chart 2: Water absorption results

C. Compressive strength test

Table- 6: Compressive strength test results

Details of replacement	Notation	7 Days (N/mm^2)	28 Days (N/mm^2)
Conventional Paver Blocks (0%Replacement)	S1	35.74	51.43
0% WFS & 40% GGBS+10% Fly ash	S2M1	31.76	45.6
10%WFS& 40% GGBS+10% Fly ash	S2M2	26.32	45.8
20%WFS& 40% GGBS+10% Fly ash	S2M3	28.64	46.7
30%WFS& 40% GGBS+10% Fly ash	S2M4	30.12	47.8
40%WFS& 40% GGBS+10% Fly ash	S2M5	26.45	47.0

D. Flexural strength test

Table- 7: Flexural strength test results

Details of replacement	Notation	7 Days (N/mm^2)	28 Days (N/mm^2)
Conventional Paver Blocks (0%Replacement)	S1	4.91	5.32
0% WFS & 40% GGBS+10% Fly ash	S2M1	3.54	4.65
10%WFS& 40% GGBS+10% Fly ash	S2M2	2.68	3.26
20%WFS& 40% GGBS+10% Fly ash	S2M3	2.91	3.89
30%WFS& 40% GGBS+10% Fly ash	S2M4	3.38	4.87
40%WFS& 40% GGBS+10% Fly ash	S2M5	3.05	4.71

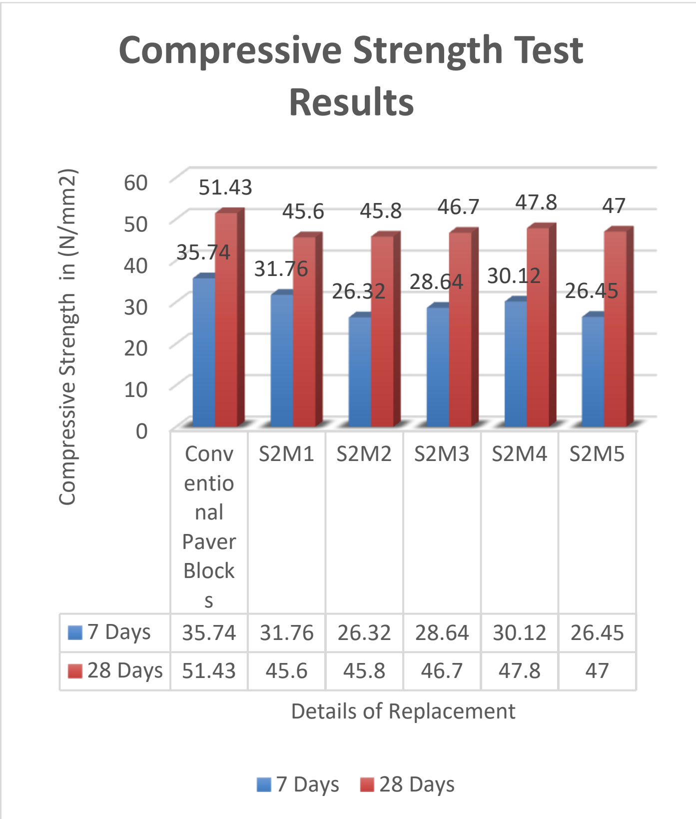

Chart 3: Compressive strength test results

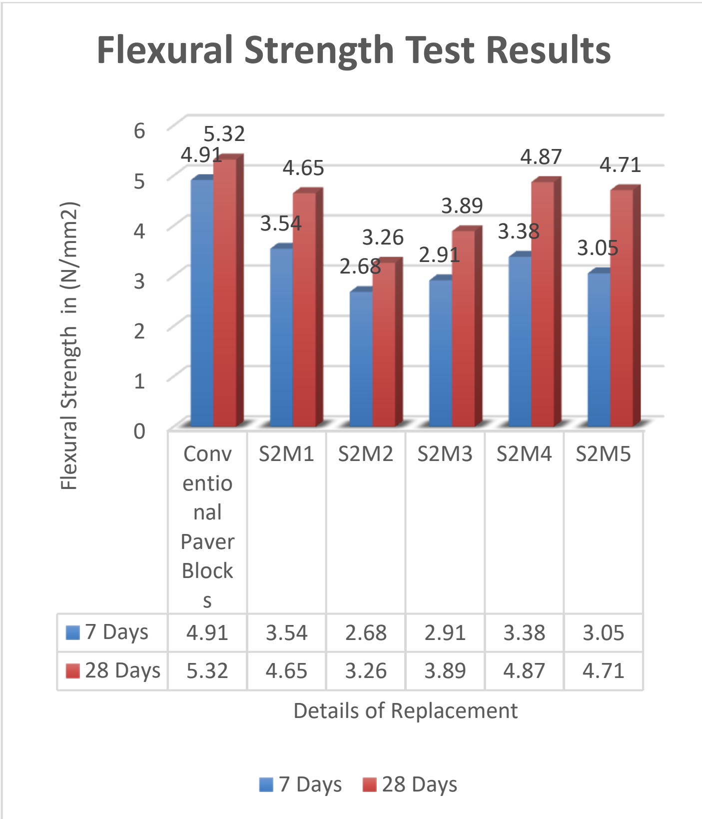

Chart 4: Flexural strength test results

E. Abrasion resistance test

Table- 8: Abrasion resistance test results

Details of Replacement		Abrasion wearing thickness (mm) 28 Days
Conventional Paver Blocks (0%Replacement)	S1	3.21
0% WFS & 40% GGBS+10% Fly ash	S2 M1	3.08
10% WFS & 40% GGBS+10% Fly ash	S2 M2	2.83
20% WFS & 40% GGBS+10% Fly ash	S2 M3	2.42
30% WFS & 40% GGBS+10% Fly ash	S2 M4	2.085
40% WFS & 40% GGBS+10% Fly ash	S2 M5	2.21

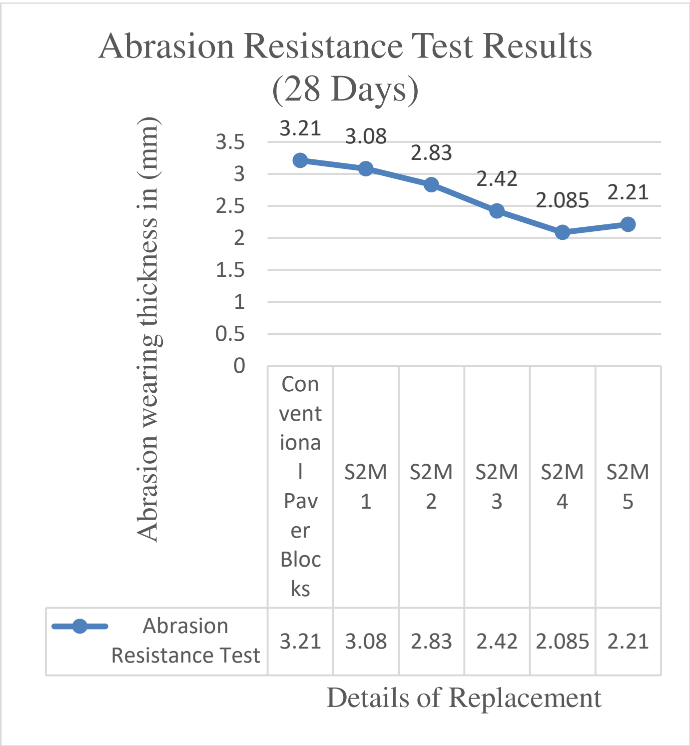

Chart 5: Abrasion resistance test results

F. RCPT test

Table- 9: RCPT test results

Details of Replacement		RCPT Test Result (Coulomb) 28 Days
Conventional Paver Blocks (0%Replacement)	S1	1648.8
0% WFS & 40% GGBS+10% Fly ash	S2 M1	1723
10% WFS & 40% GGBS+10% Fly ash	S2 M2	1561
20% WFS & 40% GGBS+10% Fly ash	S2 M3	1342
30% WFS & 40% GGBS+10% Fly ash	S2 M4	1257
40% WFS & 40% GGBS+10% Fly ash	S2 M5	1288

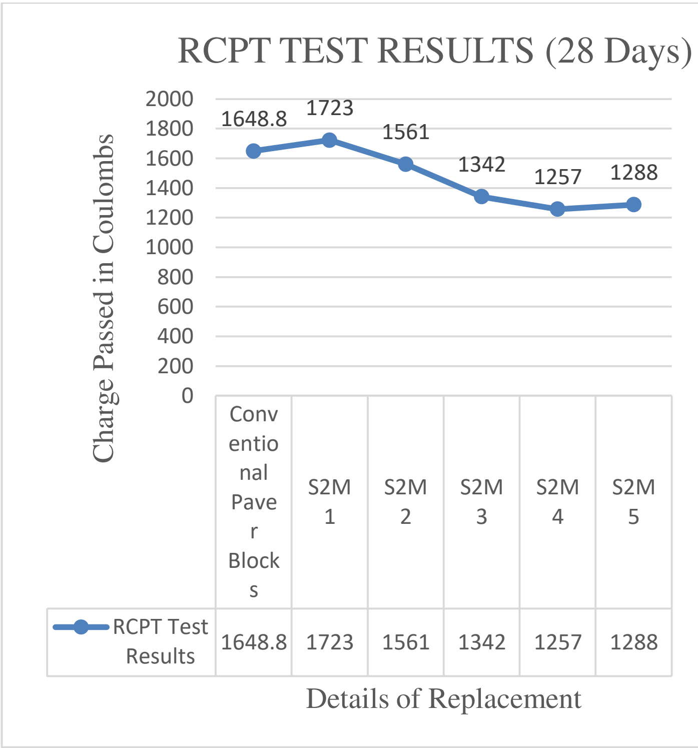

Chart 6: RCPT test results

Fig. 1- Material Testing

Fig. 2- Manufactured paver blocks

Fig. 3- Concrete mixing

Fig. 4- Performing slump cone test

Fig. 5- Compressive strength test

2.5. Cost Evaluation

Table- 10: Cost for conventional concrete paver block manufactured for research work

Elements	Quantity(kg)	Price/kg	Total price (Rs)
Cement	90	6.3	567
Coarse Aggregate	360	0.5	180
Fine Aggregate	240	3.1	744
Water	90	1	90
Chemical	15	45	675
Total Cost			Rs. 2256

Table- 11: Cost for new combination S2 M4(with max strength value 30%WFS+40%GGBS+10%Fly ash) concrete paver block manufactured for research work

Elements	Quantity(kg)	Price/kg	Total price (Rs)
Cement	45	6.3	283.5
Fly ash	9	1.8	16.2
GGBS	36	2.1	75.6
Coarse Aggregate	360	0.5	180
Fine Aggregate	168	3.1	520.8
WFS	72	-	-
Water	90	1	90
Chemical	15	45	675
Total Cost			Rs. 1841

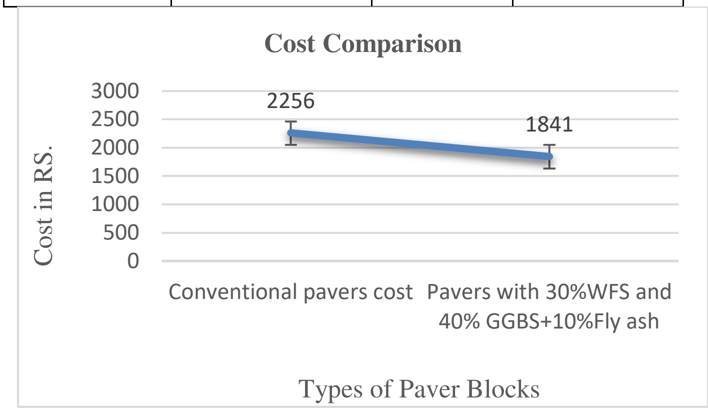

Chart 7: Cost Analysis

- Total no. of blocks casted = 132
- Cost of 132 blocks as per conventional materials = RS. 2256
- Cost of 132 blocks as per waste materials utilization = RS. 1841
- Cost reduction in % = $\frac{2256-1841}{2256}$ = 18.39%

3. CONCLUSIONS

From the literature collected and studied regarding various sustainable materials used in the concrete paver blocks in context of achieving sustainability development and beneficial reuse of waste materials, the following conclusions are drawn.

1) All these waste materials can beneficially use in construction of concrete paver blocks so; it will result into economic feasibility. It will also reduce natural resources consumption and illegal dumping of hazardous waste material which are causing serious health and environment issues.
2) Production of 1 ton of cement produces almost 1 ton of CO_2 which is contributing in 7-8% CO_2 emission globally cause increasing global warming day by day, by using GGBS and fly ash up to 50% we can definitely reduce cement consumption to the greater extent.
3) Workability of concrete decreases as percentage of waste foundry sand increases from 10% to 40%. Minimum value of slump i.e. 20mm is observed at 30% and 40% WFS content.
4) Water absorption values of concrete paver blocks increases as percentage of WFS increases but it is less than water absorption of conventional paver blocks at both 7 and 28 days. Water absorption at 30% WFS and 40%GGBS, 10% fly ash content reduced by 9.47% and 7.44% at 7 and 28 days than conventional pavers respectively.
5) Maximum compressive strength was obtained at 30% WFS and 40%GGBS, 10% fly ash along 0% to 40% replacement of WFS i.e. 30.12 N/mm^2 and 47.8 N/mm^2 at 7 and 28 days respectively.
6) Maximum flexural strength was obtained at 30% WFS and 40%GGBS, 10% fly ash along 0% to 40% replacement of WFS i.e. 3.38 N/mm^2 and 4.87 N/mm^2 at 7 and 28 days respectively.
7) Resistance to chloride ion penetration increases as WFS content increases from 0% to 40% maximum resistance occurred at 30% WFS content which is greater by 23.76% than conventional paver block and the charge passed is 1257 coulomb.
8) Utilization of waste materials like WFS, fly ash and GGBS provided great extent of economic feasibility as the results clearly shows there is reduction in cost of 18.39% in paver blocks manufactured with 30% WFS and 40%GGBS, 10%fly ash than the conventional paver blocks.

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