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Experimental Study Of Paver Block Using Partial Replacement Of Fly Ash And Quarry Dust.

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Abstract

The growing need for green building material has spurred the use of industrial by-product as a partial replacement in cement-based construction. This research investigates the mechanical properties and durability characteristics of paver blocks manufactured by partial replacement of cement with fly ash and partial replacement of fine aggregate with quarry dust. Fly ash, a coal combustion by-product, and quarry dust, a waste material produced from the stone crushing process, were chosen because they have pozzolanic and filling characteristics, respectively. In the current experimental work, cement was replaced with fly ash to the extent of 30 percentages (30%), whereas fine aggregates were replaced with quarry dust by 0%, 10%, 20%, 30%, 40%, and 50%. Normal paver block specimens were cast and subjected to compressive strength test and water absorption after 7, 14, and 28 days of curing. It shows that there are replacement levels optimum at which strength and durability of the paver blocks are equal to or even superior than those of regular mix designs. The incorporation of fly ash and quarry dust not only improves performance at certain levels of substitution but also aids the encouragement of green and economically sound construction by reducing industrial waste. This study justifies the sustainability of environmentally friendly alternatives in pavement material production.

Keyword: *Paver Blocks, Cement OPC 53, Fly Ash, Quarry Dust, X-ray Diffraction (XRD), Scanning Electron Microscopy (SEM), X-ray fluorescence (XRF).*

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INTRODUCTION

With the age of urbanization and infrastructure growth, the building industry plays a significant part in shaping green cities. But there is an entire spectrum of environmental problems that accompany this growth hand in hand, such as natural resource degradation and industrial waste concentration. Hence, sustainable building strategies are at the forefront of the world, with their objective to reduce environmental impact along with maximizing resource performance.

Among different waste materials, fly ash, the waste product of burning coal in thermal power plants, and quarry dust, which is a by-product while crushing stones, are now extremely promising alternatives as building materials. They are usually wasted as landfill wastes or remain idle, but if utilized as a part of building material, they have excellent potential. Their recycling not only mitigates the environmental dangers of dumping waste but also saves natural resources that were once spent on construction.

One of the uses is in the manufacture of paver blocks, which are used extensively in pavement, drives, and landscapes. Fly ash and quarry dust as partial substitutes for cement and fine aggregate can help make paver blocks more sustainable. The substitutes can also enhance some physical and mechanical properties.

The aim of this research is to experimentally examine the effect of partial cement replacement with fly ash and fine aggregates by quarry dust in the manufacture of paver blocks. The study is meant to establish the performance of the alterative paver blocks with respect to compressive strength, durability, and other related properties, and thus assess the applicability of utilizing such alternative materials in green construction technology.

LITERATURE REVIEW

S. Yamini Roja, N.Arun Balaji & N. Ashwin Kumar APRIL(2017) Experimental Investigation of Behaviour Of Paver Blocks With Partial Replacement of Sand Using Quarry Dust. 40% of fine aggregate replaced with quarry dust provides highest strength than normal concrete and reduces slightly in strength from 50%.

Poonam Sharma & Manoj Sharma JUNE(2017) Examined the Use of Quarry Dust in Cement Concrete Paver Blocks for Rural Roads. Experimental Study on Use of Quarry Rock Dust as Partial Replacement of Sand in Concrete" Compressive strength of cubes with 28 days curing of controlled specimen Q0 is found to be 23.25 N/mm2.

Radhikesh P. Nanda , Amiya K. Das & Moharana.N.CMARCH(2010) Investigation of use of Stone crusher dust as fine aggregate in Concrete for paving block Replacement of fine aggregate with crusher dust is up to 50% by weight has no effect on reduction of any physical and mechanical properties such as compressive strength, flexural strength, split tensile strength etc.There is saving of 56% of money in replacement of sand with crusher dust.

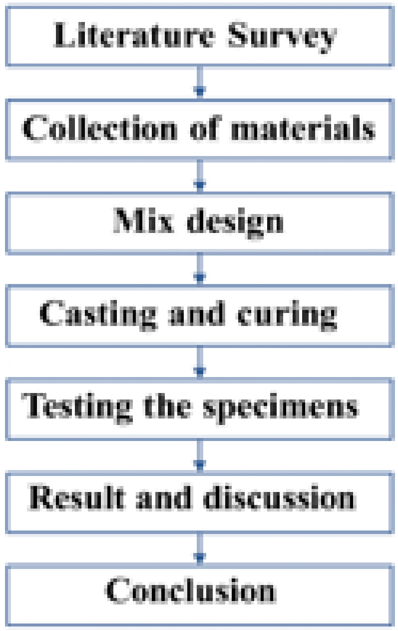
Deepak Kumar Singh & Shri Ram Chaurasia MAY(2016) Tested 28-day solid state compressive quality of all mixes, except M-50 which has all proportion of fly slag is found greater than the targeted mean strength of mixes, After addition of fly fiery, ratio of water to cementitious material reduces for all mixes for the same level of workability. The provided mixture descriptions and their conclusions establish that the fly fiery remains in high extent can be utilized conveniently as part of a cost-saving material further, biological means in paver hinders manufacturing for use in road construction and other related fields of application.

Nitin Sharmal, Sanjay Tiwari JUNE(2020) Checked the Compressive strength of fly ash paver blocks, results indicate compressive strength fly ash paver blocks is enhanced with the replacement of fly ash with cement in paver blocks mix and on rectification according to IS 15658 recommendation provides maximum value of 20%. Cement mix provides compressive strength of 51.52 N/mm2 for 7 days curing, 54.83 N/mm2 for 21 days curing, 51.20 N/mm2 for 28 days curing when 20% fly ash is added in weight of cement, it achieves a maximum compressive i.e. 47.24 N/mm2.

Reagan J. Case, Kai Duan, Thuraichamy G. Suntharavadivel OCTOBER(2012) An investigation of the systematic experimental study of the influence of fly ash as a partial cement replacement has been undertaken.

The test results indicate that the quality of fly ash containing concrete increases at a faster rate with age compared to their free fly ash counterparts, and there is an optimal fly ash replacement ratio at which the maximum compressive strength of fly ash containing concrete can be obtained. Specifically, the final strength of 28-day and older specimens is greater than that of fly ash free concrete, and this can be attributed to an understanding of the combined effect of the fly ash-aggregate and cement-aggregate interfaces and the variable strength of cement and fly ash

METHODOLOGY



MATERIAL USED

A. CEMENT

Selection of cement grade will depends upon the overall requirements of the concrete such as strength, durability etc., in this experimental study OPC (Ordinary Portland Cement) 53 grade is used conforming to IS 12269 (1987). For 53grade cement the strength is not less than 53N/mm2. Some physical properties of OPC are given below:

Table 1: Test on Cement

S. No	Properties	Values
1	Specific gravity	3.15
2	Standard consistency	32%
3	Fineness of cement	2.5%
4	Initial setting time	35min
5	Final setting time	310 min

B. FINE AGGREGATE

Fine aggregate are the materials passing through IS sieve that is less than 4.75 mm sieve. Usually natural sand is used as a fine aggregate due to scarcity crushed stone is used in this project.

Table 2: Test on Fine aggregate

S. No	Properties	Values
1	Specific gravity	2.65
2	Fineness Modulus	2.78
3	Water absorption	0.68%

C. COARSE AGGREGATE

Coarse aggregate are the materials retained on 4.75 mm sieve and the broken stone is generally used. According to IS 383:1970 maximum 20 mm coarse aggregate is suitable for concrete. The nature of work decides the maximum size of coarse aggregate.

Table 3: Test on Coarse Aggregate

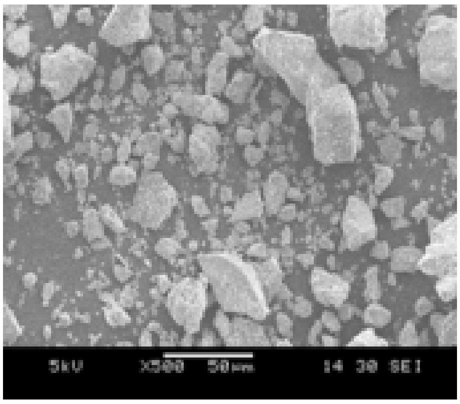
S. No	Properties	Values
1	Specific gravity	2.73
2	Water absorption	2.60

D. QUARRY DUST

Quarry dust are the material used as partial replacement of fine aggregate. The Quarry dust is a waste material which retain on earth as waste, by partially replacing it with fine aggregate at percentage of 0%, 10%, 20%, 30%, 40%, 50%.

Table 4: Test on Quarry Dust

S. No	Properties	Values
1	Specific gravity	2.54
2	Fineness Modulus	4.13%



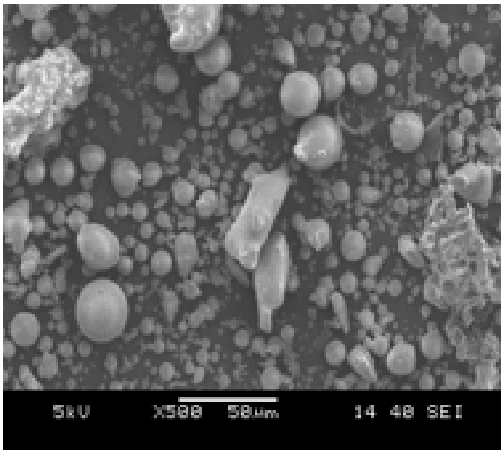
Sample ID	Formula	Element name	Oxide content	Mass %
	SiO2	Silicon	50.000	23.371
	Al2O3	Aluminium	16.400	8.680
	Fe2O3	Iron	14.000	9.792
	CaO	Calcium	10.100	7.218
	MgO	Magnesium	5.430	3.274
	TiO2	Titanium	2.570	1.540
	K2O	Potassium	0.445	0.369
	P2O5	Phosphorus	0.298	0.130
	SO3	Sulfur	0.234	0.094
Quarry dust	MnO	Manganese	0.205	0.159
	V2O5	Vanadium	0.128	0.072
	CuO	Copper	0.029	0.023
	SrO	Strontium	0.026	0.022
	ZrO2	Zirconium	0.020	0.015
	NiO	Nickel	0.014	0.011
	Cr2O3	Chromium	0.011	0.008
	ZnO	Zinc	0.010	0.008
	Bao	Barium	0.008	0.007
		Oxygen	---	45.207

E. FLY ASH

Fly ash is a fine, powdery material that is a byproduct of burning pulverized coal in thermal power plants. Fly ash primarily consists of silica, alumina, and iron, and possesses pozzolanic properties, meaning it can react with calcium hydroxide in the presence of water to form compounds with cementitious properties, that cement was partially replaced with fly ash at 30%.

Table 5: Test on Fly Ash

S. No	Properties	Values
1	Specific gravity	2.40
2	Fineness modulus	30%



Sample ID	Formula	Element name	Oxide content	Mass %
	SiO2	Silicon	58.400	27.297
	Al2O3	Aluminium	31.000	16.406
	Fe2O3	Iron	4.460	3.119
	TiO2	Titanium	1.610	0.965
	K2O	Potassium	1.530	1.270
	CaO	Calcium	1.490	1.065
	MgO	Magnesium	0.532	0.321
	P2O5	Phosphorus	0.531	0.232
	SO3	Sulfur	0.251	0.101
Fly Ash	V2O5	Vanadium	0.066	0.037
	MnO	Manganese	0.053	0.041
	ZrO2	Zirconium	0.033	0.024
	Cr2O3	Chromium	0.030	0.020
	SrO	Strontium	0.016	0.014
	NiO	Nickel	0.013	0.011
	ZnO	Zinc	0.012	0.009
	BaO	Barium	0.011	0.010
	CuO	Copper	0.010	0.008
	PbO	Lead	0.005	0.005
	CeO2	Cerium	0.003	0.003
	La2O3	Lanthanum	0.002	0.001
		Oxygen	---	49.041

F. WATER

Water is an important ingredient of concrete, as it actively participates in chemical reaction with cement. The quantity and quality of water is required to be looked very carefully. In the present study tap water is used.

EXPERIMENTAL INVESTIGATION

In this research work, the concrete strength and replaced concrete strength grade M40 grade of concrete was found. The properties of concrete materials and strength are determined as per IS 10262-2009. Mix design was designed to 40N/mm^2 compressive strength at 28 days using water cement ratio 0.38.

A. MIX DESIGN OF CONCRETE GRADE

Table 6: Mix proportion

Cement	Fine aggregate	Coarse aggregate	Fly Ash	Water
1	2.39	3.79	0.43	0.38

Table 7: Replacement of Fine aggregate with Quarry dust

Mix	Water	Cement	Fly Ash	Sand	Quarry dust	Coarse agg.
%	(Kg)	(Kg)	(Kg)	(Kg)	(Kg)	(Kg)
0	0.76	2	0.86	4.78	0	7.58
10	0.76	2	0.86	4.3	0.47	7.58
20	0.76	2	0.86	3.82	0.95	7.58
30	0.76	2	0.86	3.34	1.43	7.58
40	0.76	2	0.86	2.86	1.19	7.58
50	0.76	2	0.86	2.38	2.38	7.58

B. PREPARATION OF MOULD SIZE

- Block size – 225mm x 112.5mm x 80mm

C. CURING OF CONCRETE

Curing of concrete is a method by which the concrete is protected against loss of moisture required for hydration and kept at recommended temperature. It will increase the strength and decrease the permeability of hardened concrete. It helps to improve the durability of concrete by reducing the cracks. Cubes are cured for and tested at 7, 14 and 28 days. The results from the compressive strength are used to determine the strength of concrete.

TEST RESULTS

A. TEST ON FRESH CONCRETE

The concrete slump test measures the consistency of fresh concrete before it sets. Workability of fresh concrete is known by slump cone test as per 1199-1959 is followed.

Table 8: Workability of concrete mixture

Mix Identity (%)	Slump value (mm)
0% QD	86
10% QD	79
20% QD	68
30% QD	56
40% QD	44
50% QD	31

*Where, QD – Quarry dust

B. TEST ON HARDENED CONCRETE

Hardened concrete helps to investigate the fundamental physical behaviour of concrete such as elastic properties and strength characteristics.

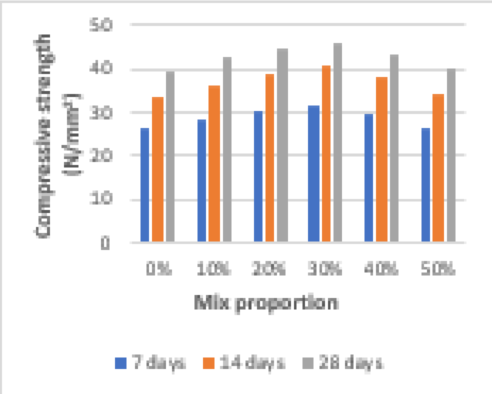
1. **Compressive strength**: Compression strength is the capacity of a material or structure to withstand loads tending to reduce size. Test is done according to code specification IS 516:2959. To determine the compressive strength, paver blocks mould of size 225mm x 112.5mm x 80mm were casted. , paver blocks were prepared and tested at 7, 14 and 28 days of curing in water under laboratory temperature. The compressive strength is calculated using the formula,

Compressive strength (N/mm^2) = P/A
Where,
P – Ultimate load (N)
A – Loaded area (mm^2)

Table 9: Compressive strength test results (N/mm^2)

Mix proportion	Compressive strength in 7 days (N/mm^2)	Compressive strength in 14 days (N/mm^2)	Compressive strength in 28 days (N/mm^2)
0%	26.4	33.7	39.2
10%	28.1	36.5	42.6
20%	30.2	38.8	44.9
30%	31.5	40.7	46.3
40%	29.8	38.1	43.5
50%	26.7	34.5	40.1

From the test result, it can be seen that optimum percentage attained at 30% of replacement using quarry dust. Finally, the compressive strength increases with increase in its duration. The maximum percentage of increase in strength is found to be 46.3 N/mm^2 at 30% replacement of fine aggregate by Quarry dust, while comparing to 39.2 N/mm^2 for a normal mix.



2. Water absorption test:

It is observed from the test results that Water absorption reduces with the substitution of sand with quarry dust up to 30% because of improved packing and fewer voids. With higher quarry dust content (40-50%), water absorption again slightly increases because of excess fines leading to increased surface area and space for micro-voids.

Water Absorption (%) = (W_W – W_D) / W_D x 100

Where,

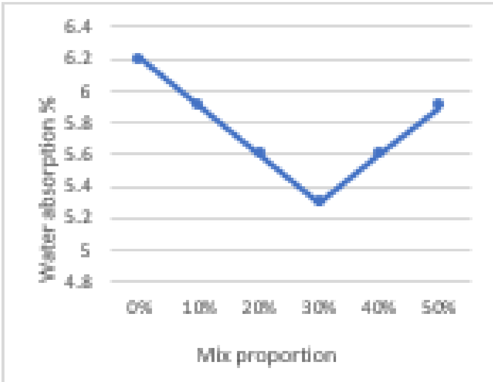
W_W – Wet weight

W_D – Dry weight

Table 10: Water absorption test results

Mix proportion	% of water Absorption
0%	6.2
10%	5.9
20%	5.6
30%	5.3
40%	5.6
50%	5.9

From the test results, it can be seen that Water absorption decreases as quarry dust replaces sand up to 30%, due to better packing and reduced voids. At higher quarry dust levels (40-50%), water absorption slightly increases again due to excess fines leading to more surface area and potential for micro-voids.



CONCLUSION

The experimental study clearly demonstrates that fly ash and quarry dust can be effectively utilized as partial replacements in the manufacturing of paver blocks. The inclusion of fly ash improved the workability and environmental sustainability, while quarry dust enhanced the mechanical strength due to its fine particle nature and good binding properties. The optimum replacement levels were observed to be 30%, beyond which the compressive strength began to decline slightly. The developed paver blocks not only meet the required strength criteria as per relevant standards but also promote the sustainable use of industrial and construction waste materials. Thus, this study supports the feasibility of incorporating fly ash and quarry dust in paver block production, offering both economic and ecological advantages for the construction industry.

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