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Energy Generating Solar Paver Blocks Incorporating Waste Materials for Smart Walkways in Coimbatore, India

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Abstract: The rapid expansion of urban infrastructure and the increasing demand for decentralized renewable energy systems necessitate the development of multifunctional pavement solutions with integrated energy-harvesting capabilities. This study investigates the design, fabrication, and performance evaluation of photovoltaic-integrated sustainable concrete paver blocks for smart walkway applications in Coimbatore (CBE), India. M20 grade concrete paver blocks were prepared using 53-grade Ordinary Portland Cement, natural river sand, and 12 mm nominal size coarse aggregate, following IS mix design guidelines. To enhance sustainability, eggshell powder (ESP), primarily composed of calcium carbonate ($CaCO_3$), was used as a 10 % partial replacement for cement, while recycled coarse aggregate (RCA) was incorporated at a 30 % replacement level. Specimens were cast, cured under standard conditions, and tested at 7, 14, 21, and 28 days. Mechanical properties were evaluated through compressive and flexural strength tests, while durability characteristics were assessed using water absorption, acid resistance, and skid resistance tests. The ESP–RCA modified paver blocks exhibited compressive strength comparable to conventional concrete with marginal variation within permissible limits, along with adequate flexural strength for pedestrian loading. Water absorption remained within acceptable limits, indicating a dense microstructure, while satisfactory acid resistance and enhanced skid resistance confirmed improved durability and surface performance. A polycrystalline photovoltaic module (6 V, 99 × 69 mm) was embedded within the paver block and protected by a 2 mm thick polycarbonate layer to ensure mechanical integrity and effective light transmission. The system demonstrated efficient conversion of solar energy for low-power applications such as pathway lighting. The results confirm that the proposed system offers a structurally sound, energy-efficient, and environmentally sustainable solution for smart walkway infrastructure.

Keywords: Photovoltaic-integrated paver blocks, Sustainable concrete, Eggshell powder (ESP), Recycled coarse aggregate (RCA), Energy-harvesting pavement, Smart walkways, Solar energy integration

I. INTRODUCTION

Eggshell powder used as a partial cement replacement in M25 concrete shows optimal performance at around 10 %, improving compressive and flexural strength while promoting sustainable waste management.[1] Geopolymer masonry blocks incorporating eggshell ash, rice husk ash, and quarry waste reduce energy consumption and CO_2 emissions while meeting non-load-bearing strength requirements.[2] Eggshell powder can be used as a partial sand replacement in concrete paver blocks, with around 30 % substitution enhancing both strength and sustainability.[3] Similarly, using eggshell powder as a fine aggregate replacement in paver blocks achieves optimum strength at approximately 30% substitution, along with improved environmental performance.[4] Construction and demolition waste can effectively replace natural aggregates in paver blocks. This contributes to sustainable construction practices without compromising performance.[5] High-strength concrete paver blocks have been successfully produced using 100% recycled aggregates through compression casting, resulting in improved durability.[6] Models for pavement solar collectors have been developed to assess their ability to harvest and optimize low-temperature thermal energy from solar radiation.[7] Transparent resin-concrete solar pavement modules are designed to balance mechanical strength, energy generation, and economic feasibility.[8] Recycled concrete aggregates can replace up to 45 % of coarse aggregates and 40 % of fine aggregates in paver blocks without significant performance loss.[9] Their use in mortars and concrete further demonstrates reliable performance at optimal partial replacement levels.[10] Elevated solar walkway systems integrate energy generation, pedestrian shelter, and rainwater harvesting, enabling efficient urban space utilization.

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[11] Sustainable paver blocks can be produced by partially replacing cement with eggshell powder and M-sand with sawdust, reducing carbon emissions and promoting waste utilization.[12] Eggshell powder shows strong potential as a partial cement replacement by improving concrete strength and offering environmental benefits.[13] However, excessive replacement of eggshell powder beyond approximately 10 % may lead to a reduction in mechanical properties.[14] Interlocking paver blocks made using processed concrete waste and coir fiber exhibit improved strength and eco-friendly performance.[15] Energy harvesting in pavements can be achieved through solar heat, mechanical displacement, and embedded photovoltaic systems, along with suitable energy storage methods.[16] Bio-treated and carbonated recycled aggregates enhance durability due to microbial $CaCO_3$ formation, with only minor reductions in strength compared to conventional blocks.[17] Solar roadways represent smart infrastructure by replacing conventional pavements with energy-generating panels, reducing fossil fuel use and emissions.[18] Solar paver technology is influenced by key factors such as cost, feasibility, and practical implementation, which determine its adoption.[19] Recycled concrete aggregates can replace up to 60% of natural aggregates in paver blocks while maintaining performance, with lab-produced blocks often showing better quality than factory-made ones.[20] The use of recycled concrete aggregates in precast paver blocks serves as a sustainable alternative to natural aggregates, reducing construction waste while maintaining cost-effective pavement performance.[21]

II. MATERIALS USED

The ordinary Portland cement (OPC) 53 grades used in this research, conforming to IS: 12269-1987.The cement was purchased from Ramco Cements Limited dealer located at Keeranatham, Coimbatore. The colour of cement was uniform Gray with light greenish shade and chemical composition of cement were listed in Table 1. The selection of 53 grade cement ensures higher early strength and improved durability properties in concrete. The cement conforms to the requirements specified in relevant Indian Standards for cement used in structural concrete.

Fine aggregate used in this study was manufactured sand (M-sand), conforming to IS 383:2016, obtained from the Structural Technology centre (STC) Laboratory at Kumaraguru College of Technology, Coimbatore.

The physical property is listed in Table 2 The fine aggregate was clean, well graded, and free from impurities such as clay, silt, and organic matter. It was used to provide proper workability and improve the strength characteristics of the concrete mix Crushed stone coarse aggregates of size 12 mm were used in the concrete mix. The aggregates were sourced from Karattumedu, Coimbatore. The physical property is listed in Table 2. The aggregates were angular in shape and free from dust and organic impurities. Coarse aggregates play a major role in providing strength and stability to the concrete paver blocks.

Eggshells used for this research were collected from the hostel kitchen at Kumaraguru College of Technology, Coimbatore. Approximately 650 eggshells were collected from KCT hostel and used for the preparation of eggshell powder. The collected eggshells were first washed thoroughly to remove impurities and organic residues. They were then dried in an oven at 105° C and later ground into fine powder using a grinding machine. The prepared eggshell powder was sieved to obtain a uniform particle size before being used as a partial replacement for cement in the concrete mix. Eggshell powder primarily consists of calcium carbonate ($CaCO_3$), which contributes to improved strength and sustainability in concrete. Recycled aggregates used in this study were obtained from construction and demolition (C&D) waste available at Kumaraguru College of Technology campus. The physical property is listed in Table 2 The collected waste concrete materials were crushed manually to obtain recycled aggregates suitable for use in the concrete mix.

These recycled aggregates were used as a partial replacement for natural coarse aggregates to reduce construction waste and promote sustainable material usage. Potable water conforming to IS 456:2000 was used for mixing and curing. The water was free from harmful impurities, with a pH value of 6.2 and specific gravity of 1.0. Proper water quality ensured effective hydration and strength development The energy generation component of the paver block consists of a polycrystalline mini epoxy solar panel of size 99 mm × 69 mm with an output capacity of 6 volts. The solar panel is provided with alligator clip connectors for electrical output with current range 180 mAh, Weight: 200 grams A 2 mm thick polycarbonate sheet was used as a protective cover for the embedded solar panel, ensuring resistance to external loads and environmental effects while allowing proper sunlight exposure. The panel was fixed at the surface level of the paver block to maintain structural integrity and efficiency. A 5V (1–3 W) solar panel was employed to generate energy during daylight, which is stored in a 3.7V lithium-ion battery (18650, 2200 mAh). The lighting system consists of a 1W/3W high-power LED with a heat sink for thermal management. The control circuit includes an IRFZ44N N-channel MOSFET, a 1N4007 diode for reverse protection, and a 10kΩ resistor, with an optional 100Ω resistor for LED safety. A TP4056 lithium battery charging module with protection was incorporated for efficient and safe charging. The system enables the paver block to generate and store solar energy for walkway lighting and other low-power applications.

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TABLE I
CHEMICAL COMPOSITION OF OPC 53 CEMENT AND EGGSHELL POWDER

Compound	CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	SO_3	LOI
OPC 53 cement (%)	64.50	21.30	5.20	3.10	2.10	2.30	1.50
Eggshell powder (%)	96.20	0.80	0.35	0.25	0.50	0.10	1.80

TABLE II
PHYSICAL PROPERTIES OF M-SAND, NATURAL COARSE AGGREGATE AND RECYCLED AGGREGATE

III. TEST PROCEDURE

A. Testing of Paver Blocks

1) Compressive Strength Test:

Compressive strength tests were conducted using a compression testing machine in accordance with IS 15658:2006 and IS 516 (Part 1):2021. Specimens from both conventional and sustainable mixes were tested after curing periods of 7, 14, 21, and 28 days. The maximum load at failure was recorded, and the compressive strength was calculated. The results were compared to assess the influence of sustainable material replacement on load-bearing capacity.

Fig. 1

2) Acid resistance test:

The resistance to acidic environment was examined by immersing both types of paver blocks in a 5 % acid solution after 28 days of curing. The specimens were kept immersed for 7 days, after which changes in weight and surface condition were observed. The comparative analysis helped in understanding the durability performance of sustainable paver blocks under aggressive conditions.

3) Water absorption test:

Water absorption tests were carried out after 28 days of curing. The oven-dried weights of both conventional and sustainable paver blocks were recorded, followed by immersion in water for 24 hours. The percentage increase in weight was calculated, and the results were compared to evaluate the porosity characteristics of the modified blocks.

Property	Specific Gravity	Bulk Density (kg/m^3)	Water Absorption (%)	Fineness Modulus	Crushing Value (%)	Impact Value (%)	Shape	Surface Texture
M-Sand (Fine Aggregate)	2.65	1650	1.20	2.75	-	-	Angular	Rough
Natural Coarse Aggregate	2.70	1550	0.50	6.80	18.00	15.00	Angular	Rough
Recycled Aggregate	2.45	1350	5.00	6.50	28.00	25.00	Angular	Rough and Porous

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4) Flexural Strength Test:

Flexural strength tests were performed to determine the resistance of the paver blocks to bending stresses, as per IS 15658:2006. Both conventional and modified paver blocks were tested at 7, 14, 21, and 28 days. The specimens were subjected to two-point loading, and the ultimate load was noted. The comparative results indicate the effect of recycled and waste materials on flexural performance.

5) Skid Resistance Test:

Skid resistance tests were conducted on both conventional and sustainable paver blocks after 28 days of curing to evaluate surface friction properties. The results were compared to determine the suitability of the developed paver blocks for safe usage in pedestrian and traffic areas.

IV. PREPARATION OF MATERIALS

Eggshells were collected from Hostel of KCT, Coimbatore, washed thoroughly to remove impurities and they were then dried in an oven at 105° C and later ground into fine powder using a grinding machine. The prepared eggshell powder was sieved to obtain a uniform particle size before being used as a partial replacement for cement in the concrete mix Recycled aggregates used in this study were obtained from construction and demolition (C&D) waste available at Kumaraguru College of Technology campus. All aggregates were tested as per IS 2386 standards.

A. Mix proportion

Concrete mix was prepared based on standard design procedures (IS 10262:2019). Cement was partially replaced with 10 % of eggshell powder, and natural coarse aggregate was partially replaced with 30 % of recycled aggregate. All dry materials such as cement, M-sand, coarse aggregate, recycled aggregate, eggshell powder, and sawdust were mixed thoroughly to achieve a uniform blend. Water was then added gradually and mixed until a consistent and workable concrete mix was obtained. The prepared concrete was placed into paver block moulds in three equal layers. Each layer was compacted by giving 25 tamping strokes using a standard tamping rod to ensure proper compaction and to eliminate air voids. After tamping, the moulds were subjected to vibration for uniform compaction and to achieve a smooth surface finish. The top surface was levelled and finished properly. The specimens were demoulded after 24 hours and cured in water for 7, 14, and 28 days. Proper curing ensured adequate strength and durability of the paver blocks.

B. Embedding of Solar Components

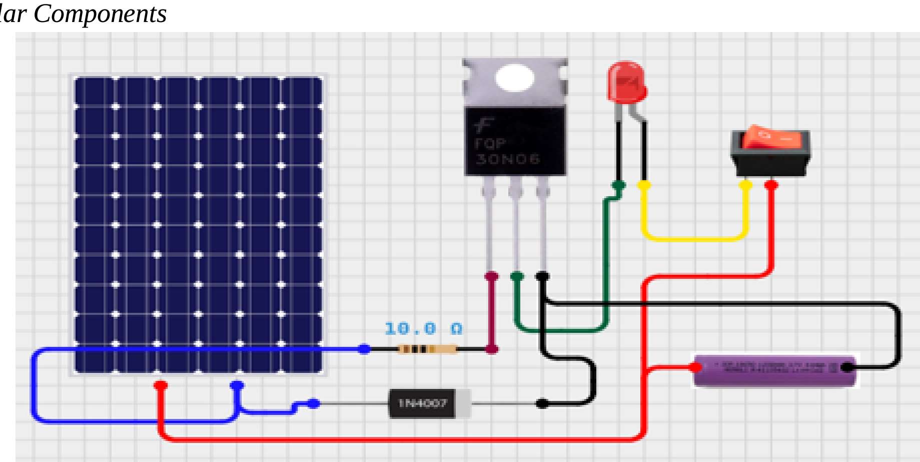

Fig. 2 Circuit Diagram

1) Working Principal Explanation:

The circuit operates automatically based on the availability of sunlight. During daytime, the solar panel generates voltage, which is used to charge the battery. At this time, the MOSFET remains in the OFF state, preventing current flow to the LED, so the LED stays OFF. During nighttime, the solar panel does not produce any voltage, causing the MOSFET to turn ON. This allows the battery to supply power to the LED, making it glow.

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The circuit includes a diode connected between the solar panel and battery to prevent reverse current flow during night. Overall, the system ensures automatic switching, where the LED turns OFF in the presence of sunlight and turns ON in the absence of sunlight. A solar-powered automatic LED lighting system that operates based on the presence or absence of sunlight. During daytime, the solar panel generates electrical energy and charges the 3.7V Li-ion battery through a diode, which prevents reverse current flow. At the same time, the MOSFET (IRFZ44N/IRLZ44N) remains in the OFF state, keeping the LED turned OFF. During nighttime, when there is no solar voltage, the MOSFET turns ON due to the absence of gate voltage, allowing current to flow from the battery to the LED. As a result, the LED automatically lights up. The circuit uses a 10kΩ resistor to control the MOSFET gate, ensuring proper switching operation, and overall provides an efficient and automatic day/night lighting solution.

V. TEST RESULTS

A. Compressive strength test

TABLE III
COMPRESSIVE STRENGTH FOR CONVENTIONAL BLOCK

Conventional paver block	Days	Compressive strength (MPa)
M20	7	14
M20	14	17
M20	21	19
M20	28	20

TABLE IV
COMPRESSIVE STRENGTH FOR SUSTAINABLE BLOCK

Conventional paver block	Days	Compressive strength (MPa)
M20	7	7
M20	14	12.1
M20	21	15.5
M20	28	20.2

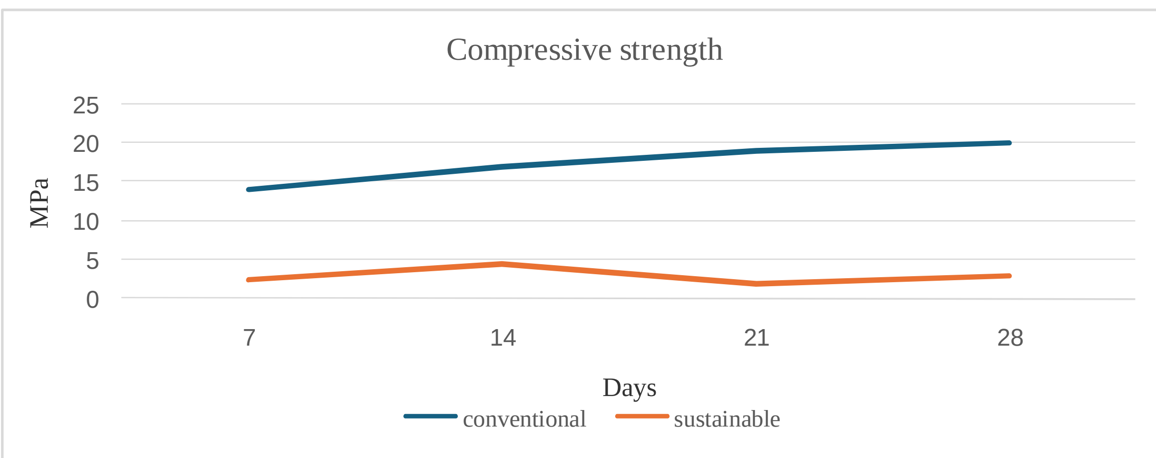

Fig.3 Graph for compressive strength

B. Acid resistance test

TABLE V
ACID RESISTANCE FOR CONVENTIONAL BLOCK

Days	7	14	21	28
Percentage loss (%)	0.6	0.5	0.45	0.4

TABLE VI
ACID RESISTANCE FOR SUSTAINABLE BLOCK

Days	7	14	21	28
Percentage loss (%)	0.6	0.5	0.45	0.4

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C. Water absorption test

TABLE VII
WATER ABSORPTION FOR CONVENTIONAL BLOCK

Days	7	14	21	28
Water absorption (%)	6.3	5.2	4.6	4.2

TABLE VIII
WATER ABSORPTION FOR SUSTAINABLE BLOCK

Days	7	14	21	28
Water absorption (%)	7	6	5.2	5

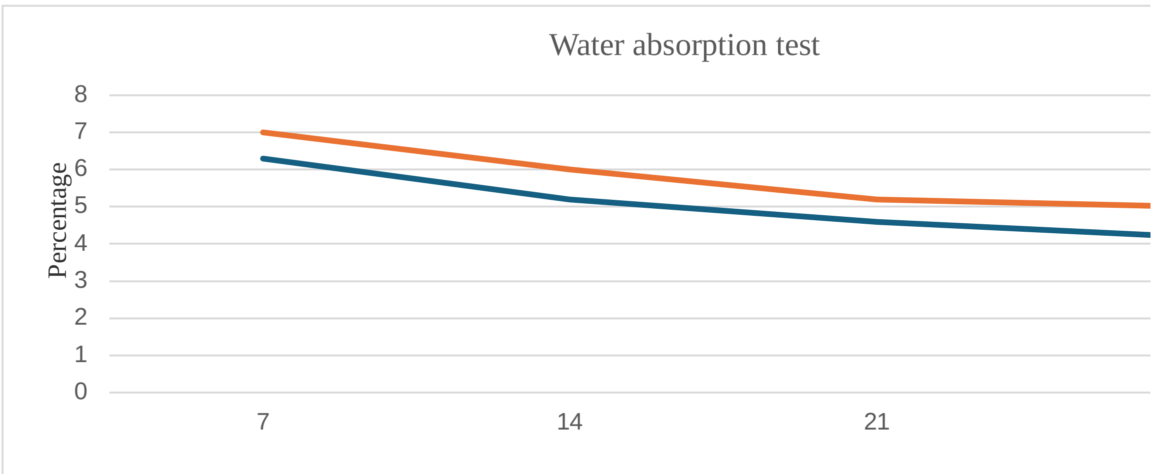

Fig.4 Graph for water absorption

D. Flexural strength test

TABLE IX
FLEXURAL STRENGTH FOR CONVENTIONAL BLOCK

Days	7	14	21	28
Flexural strength (MPa)	2.5	2.9	3.1	3.4

TABLE X
FLEXURAL STRENGTH FOR SUSTAINABLE BLOCK

Days	7	14	21	28
Flexural strength (MPa)	1.39	1.91	2.19	2.39

E. Skid resistance test

TABLE XI
SKID RESISTANCE FOR CONVENTIONAL BLOCK

Days	7	14	21	28
BPN	66.7	71	73	74

TABLE XII
SKID RESISTANCE FOR SUSTAINABLE BLOCK

Days	7	14	21	28
BPN	65.3	69.6	72	73

VI. CONCLUSION

The experimental results demonstrate that both conventional and sustainable paver blocks exhibited an increase in strength with curing age (7, 14, 21, and 28 days), with the sustainable blocks—prepared by replacing 30% cement with eggshell powder and 10% coarse aggregate with recycled aggregate—showing slightly lower early strength but achieving acceptable compressive and flexural strength by 28 days; although water absorption was marginally higher due to the porous nature of the replacement materials, it remained within permissible limits, while acid resistance and skid resistance were found to be comparable to conventional blocks, indicating no significant compromise in durability or surface performance; moreover, the successful embedding of solar panels within the sustainable paver blocks demonstrated effective electricity generation without affecting structural integrity, leading to the conclusion that such sustainable solar paver blocks provide a viable, eco-friendly alternative for construction by reducing material consumption, utilizing waste resources, and supporting renewable energy integration in infrastructure.

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REFERENCES

[1] Saleh Ali Said Al Abri , Chiranjeevi Rahul Rollakanti , Kiran Kumar Poloju, Adams Joe , "Experimental Study on Mechanical Properties of Concrete by partial replacement of Cement with Eggshell Powder for Sustainable Construction" , Volume 65, Part 2, 2022, Pages 1660-1665.

[2] Navaratnarajah Sathiparan "Optimum mix design for quarry waste-based masonry blocks with alkali-activated rice husk ash and eggshell ash as a binder", Published: 22 March 2024, Volume 7, pages 3267–3284, (2024).

[3] D. Chandan Kumar, P. Vasanthi "Characterization of paver blocks using Eggshell powder", Volume 68, Part 5, 2022, Pages 1658-1662.

[4] D. Chandan Kumar, D. Manoj Kumar and R. Deepak Kumar "Effective utilization of waste eggshell powder in sustainable paver block production", International Journal of Construction Engineering (IJCE) Volume 5, Issue 1, January-June 2023, pp. 1-10, Article ID: IJCE_05_01_001.

[5] E.Gifty , N.Harini Devi , P.Meena , S.Gunasekar "Strength Property Study on Paver Block Made with Recycled Concrete Aggregates" (IRJMT) ISSN 2582-1040 Published online 02 November 2019, Received 10 August 2019 ISSN 2582-1040 Accepted 16 October 2019 2019; 1(6); 480-485 Published online 02 November 2019.

[6] Muhammad Umer Farooq , Rashid Hameed , Muhammad Tahir , Muazzam Ghous Sohail , Shaban Shahzad " Mechanical and durability performance of 100% recycled aggregate concrete pavers made by compression casting", Journal of Building Engineering Volume 73, 15 August 2023, 106729.

[7] Gert Guldentops , Alireza Mahdavi Nejad , Cedric Vuye , Wim Van den bergh , Nima Rahbar " Performance of a pavement solar energy collector: Model development and validation", Applied EnergyVolume 163, 1 February 2016, Pages 180-189.

[8] Hengwu Hu, Xudong Zha, Zihao Li, Ruidong Lv "Preparation and performance study of solar pavement panel based on transparent Resin-Concrete, Sustainable Energy Technologies and Assessments" ,Volume 52, Part B, August 2022, 102169.

[9] GyanendraKumar Attri, R.C. Gupta, Sandeep Shrivastava "Impact of recycled concrete aggregate on mechanical and durability properties of concrete paver blocks", Volume 42, Part 2, 2021, Pages 975-981.

[10] Jan Pizoń , Kateřina Matýsková , Marie Horňáková , Małgorzata Gołaszewska , Gabriela Kratošová " Recycled concrete paving block waste as a selected sustainable substitute for natural aggregate in cement composites, Construction and Building Materials" ,Volume 478, 6 June 2025, 141356.

[11] Saikat Mondal , Avik Sanyal , Souvik Brahmachari , Biplab Bhattacharjee , Poorna D. Mujumdar , Raviteja J , Arkopal K. Goswami , Dipanjan Nag "Utilization of Constrained Urban Spaces for Distributed Energy Generation – Development of Solar Paved Pedestrian Walkway, Energy Procedia",Volume 130, September 2017, Pages 114-121.

[12] Arathy Madhu, Jishnu V.R, Poornima Balan, Pramitha K.P, Prasoon P.P "Sustainable Paver Block by Partial Replacement of Cement with Eggshell Powder and M-Sand with Sawdust International Journal of Engineering Research and Applications" ,ISSN: 2248-9622, Vol. 15, Issue 5, May 2025, pp 109-119.

[13] M.S. Sugirtha, K. Sargunan "A Review on Impact of Chicken Egg Shell Powder on Strength Characteristics of Cement Concrete",Received 21 September 2019 Accepted 29 October 2019 ISSN 2582-1040 2019; 1(6); 405-410 Published online 02 November 2019.

[14] ,Shivaraj S J, S Kalappa, Sangmesh V Biradar and Abhay M "Development and Strength Assessment of Paving Block using Demolished Building Waste and Coir Fiber,Journal of Physics: Conference Series", Volume 2779, International Conference on Materials Innovation and Sustainable Infrastructure 02/02/2024 - 03/02/2024 Bhimavaram, India.

[15] Hussein Hamada, Bassam A. Tayeh , Alyaa Al-Attar, Fadzil M. Yahaya , Khairunisa Muthusamy , Ali M. Humada " The present state of the use of eggshell powder in concrete: A review,Journal of Building Engineerin",Volume 32, November 2020, 101583.

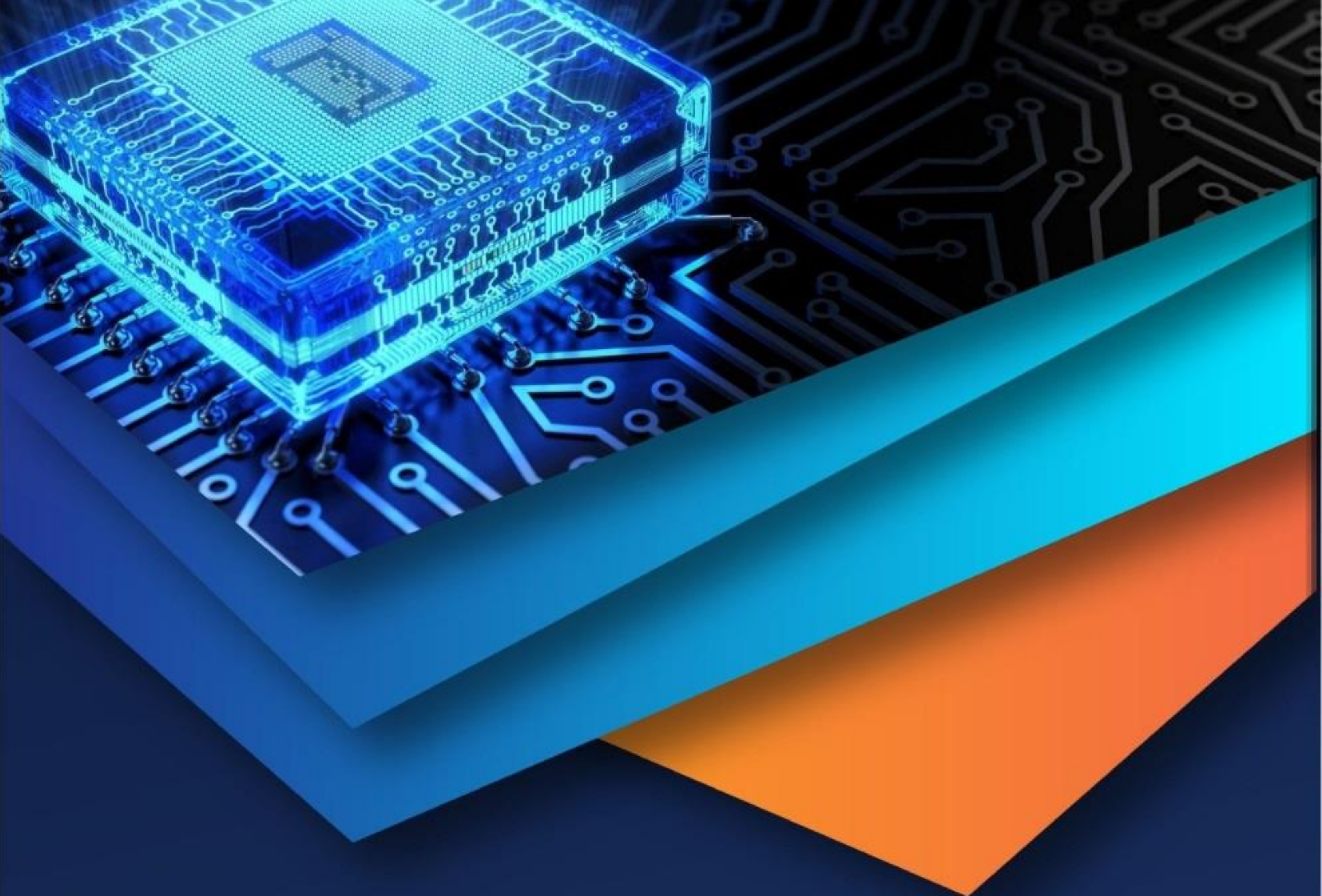
[16] Andrew Dawson, Rajib Mallick, Alvaro García Hernandez & Pejman Keikhaei Dehdezi "Energy Harvesting from Pavements, Chapter",First Online: 01 January2014,pp481517.

[17] Jagan Sivamani "Performance studies on energy efficient paver block with treated recycled aggregate" Online Publication Date: 10 August 2023 , Vol. 9 Iss. 4 (2023) 1239-1253 .

[18] Ankit Singh, Kaustubh Sachin Kulkarni, Vikas Namdev Chavan "Solar Roadways: A Significant Infrastructural Reform Prof,International Research Journal of Engineering and Technology (IRJET)" ,Volume: 06 Issue: 09 | Sep 2019.

[19] PeiLee Teh teh.pei.lee@monash.edu , Dotun Adebanjo "Key enablers and barriers of solar paver technologies for the advancement of environmental sustainability".

[20] Wastel Gyanendra Kumar, Sandeep Shrivastava, R.C. Gupta "Paver blocks manufactured from construction & demolition", Volume 27, Part 1, 2020, Pages 311-317.
[21] Hariom Chourasiya, Devansh Jain, Rajesh Joshi "Use of Recycled Aggregate in Cement Concrete Paver Blocks for Medium Traffic Roads", IJSRD - International Journal for Scientific Research & Development, Vol. 3, Issue 07, 2015 | ISSN (online): 2321-0613.



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