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Design of Self-Cleaning Roads Using Nozzles

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***Abstract:** Self-cleaning roads represent a significant innovation in infrastructure design aimed at enhancing sustainability and reducing maintenance costs. This project focuses on the implementation of self-cleaning technology using water nozzles to effectively remove debris and pollutants from road surfaces. By integrating water nozzles into the road infrastructure, we aim to minimize manual cleaning efforts and improve the overall cleanliness and safety of roadways. Urban cleaning staff play a vital role in maintaining the cleanliness and functionality of city roadways. However, their work often exposes them to various hazards, including the risk of road accidents while performing cleaning tasks. This abstract examines the challenges faced by cleaning personnel in urban areas and proposes a comprehensive approach to mitigate road accidents, ensuring the safety and well-being of these essential workers. The project involves the design, implementation, and evaluation of self-cleaning roads equipped with strategically placed water nozzles. These nozzles are activated at regular intervals to spray water onto the road surface, loosening and washing away dirt, dust, and other contaminants. The system is designed to operate efficiently while minimizing water consumption and environmental impact. By designing the tanks on dividers at required intervals. Parameters such as cleaning efficiency, water usage, durability, and environmental impact will be assessed to determine the practicality and viability of this innovative approach. The findings of this project are expected to contribute to the development of sustainable infrastructure solutions for urban environments, with potential applications in cities worldwide. By reducing the need for manual cleaning and improving road cleanliness, self-cleaning roads using water nozzles have the potential to enhance public health, safety, and overall quality of life.*
***Keywords:** Self-cleaning roads, Infrastructure design, Maintenance cost, Water nozzles, Road safety, Urban cleaning staff, Cleaning Efficiency, Water usage, Durability*

I. INTRODUCTION

In India there are many Highways, Major state roads and other district roads which is the main appearance of India, but these roads are covered with filthy material and wastage, which is spoiling the beauty of the highway and streets and this wastage not only effect the human heath but also effecting the environment. Sometimes, these materials are the cause of accidents and also spread many types of diseases in environment. This type of problems is mainly existing in highly populated cities like Delhi, Mumbai, Hyderabad, Chennai, etc. Urban cleaning staff play a vital role in maintaining the cleanliness and functionality of city roadways. However, their work often exposes them to various hazards, including the risk of road accidents while performing cleaning tasks. This examines the challenges faced by cleaning personnel in urban areas and proposes a comprehensive approach to mitigate road accidents, ensuring the safety and well- being of these essential workers. Urban Cleaning Staff This project involves the design, implementation, and evaluation of self- cleaning roads equipped with strategically placed water nozzles. These nozzles are activated at regular intervals to spray water onto the road surface, loosening and washing away dirt, dust, and other contaminants. The system is designed to operate efficiently while minimizing water consumption and environmental impact. 2 Roads are the lifelines of modern civilization, facilitating the movement of people, goods, and services. However, as indispensable as they are, roads are also subject to various forms of degradation, including the accumulation of dirt, debris, and pollutants. These contaminants not only effect the aesthetic appeal of roads but also pose significant challenges to road maintenance and environmental sustainability. In recent years, there has been a growing interest in developing innovative solutions to address these challenges. One promising approach is the design and implementation of self- cleaning roads equipped with nozzle systems. These systems utilize strategically placed nozzles to distribute water or cleaning agents onto the road surface, effectively removing dirt, grime, and other pollutants. In India's major cities such as Surat, Ahmadabad and Delhi, streets are washed with clean water every day. So why should we clean the streets? There are many reasons to clean your driveway. This project briefly discusses why road cleaning is necessary and how to clean it properly. There are many specialized machines such as washing machines (approximately 100 tonnes) in India. Price Rs 1.30 Lakh/unit), road sweeping (estimated cost Rs 7 Lakh) etc. Therefore, choose the appropriate machine according to different situations. Just as the use of machinery increases fuel costs, labor costs also increase.

Even a large set of machines has a high initial cost. The concept of self-cleaning roads is not entirely new, but recent advancements in technology have opened exciting possibilities for their widespread implementation. By integrating smart sensors, real-time monitoring systems, and automated control mechanisms, modern self-cleaning road systems can adaptively respond to changing environmental conditions and traffic patterns. This project aims to explore the design considerations, benefits, and challenges associated with the implementation of self-cleaning roads equipped with nozzle systems. By examining the underlying principles, technological advancements, and potential applications of this innovative approach, we hope to shed light on its feasibility and potential impact on road infrastructure and sustainability. The various components of self-cleaning road systems, including nozzle design, water supply infrastructure, control mechanisms, and maintenance requirements. The environmental and economic benefits of adopting this technology, as well as the potential barriers to its widespread adoption.

II. OBJECTIVES OF THE STUDY

The main goals of this project are as follows:

1) Enhanced Road Maintenance:

Objective: The primary goal of implementing self-cleaning road systems is to enhance the efficiency of road maintenance operations.

Rationale: By automating the cleaning process through strategically placed nozzles, the frequency and intensity of manual cleaning efforts can be reduced, resulting in cost savings and improved resource utilization

2) Improved Environmental Sustainability:

Objective: Another key objective is to mitigate the environmental impact of road pollution and contaminants. Rationale: Self-cleaning road systems help prevent the accumulation of pollutants such as oil, grease, and particulate matter, thereby improving air and water quality in urban areas and reducing negative ecological footprints.

3) Optimized Water Usage:

Objective: To minimize water consumption while ensuring effective cleaning performance. Rationale: Through the integration of smart sensors and real-time monitoring systems, self- cleaning road designs aim to optimize water usage by activating cleaning mechanisms only when necessary and adjusting flow rates based on road conditions and traffic patterns.

4) Enhanced Road Safety and Functionality:

Objective: To promote safer driving conditions and improve overall road functionality. Rationale: Clean road surfaces contribute to better visibility, traction, and vehicle maneuverability, reducing the risk of accidents and enhancing the overall user experience for motorists, cyclists, and pedestrians alike.

5) Long-Term Durability and Sustainability of Road Infrastructure:

Objective: To extend the service life and reduce the life cycle costs of road infrastructure. Rationale: By preventing the accumulation of debris and pollutants that contribute to road deterioration, self-cleaning road systems help preserve the integrity of pavement surfaces, reducing the frequency of repairs and maintenance interventions over time.

6) Integration with Smart City Initiatives:

Objective: To align with broader smart city objectives and initiatives.

Rationale: Self-cleaning road technologies represent a forward-thinking approach to urban infrastructure management, contributing to the development of intelligent transportation systems and sustainable urban development strategies.

III. CRITICAL REVIEW ON THE LITERATURE

The integration of innovative technologies, such as nozzle-based self-cleaning systems, into road infrastructure holds significant promise for enhancing road cleanliness and maintenance efficiency. Kumar et al. (2022) emphasizes the importance of gutters in drainage systems for redirecting rainwater away from highways to prevent flooding, accidents, and erosion. Meanwhile, Zhang et al. (2022) propose a framework for integrating sensor-equipped nozzles into smart city infrastructure, enabling real-time monitoring and targeted cleaning of road surfaces.

Garcia and Lee (2021) focused on optimizing nozzle placement and configuration within road infrastructure using computational fluid dynamics simulations to maximize cleaning efficiency. Wang et al. (2020) conducted a comprehensive evaluation of nozzle-based self-cleaning systems for urban road networks, highlighting their technical feasibility, cost-effectiveness, and environmental benefits. Johnson and Patel (2019) analyzed different nozzle designs and cleaning mechanisms to identify the most suitable options for practical implementation in road infrastructure.

Smith et al. (2018) explored the feasibility of integrating nozzle technology directly into road surfaces to effectively remove debris and pollutants, thus improving road safety and environmental quality. Additionally, Taj et al. (2017) evaluated the performance of existing drainage systems using SWMM analysis, revealing the need for improved rainwater management infrastructure to prevent floods during heavy rainfall.

However, despite the potential benefits, challenges remain, including the need for further research to address practical implementation hurdles and scale up adoption. Moreover, the drawbacks of traditional road coatings, such as defects and maintenance issues, underscore the importance of continued innovation in road infrastructure design and management. Agarwal's study (2012) highlights the significance of managing runoff to prevent damage to flexible road coatings, emphasizing the need for sustainable water management practices in road infrastructure design.

In summary, while the integration of nozzle-based self-cleaning systems and advancements in road infrastructure offer promising solutions to enhance cleanliness and resilience, ongoing research and innovation are essential to overcome challenges and ensure widespread adoption.

IV. METHODOLOGY

The process of integrating nozzle-based cleaning systems into the current road infrastructure is usually the focus of multiple crucial processes in the self-cleaning road implementation technique. To choose the best location and arrangement for the cleaning nozzles, a detailed evaluation of the road's state and cleaning needs is first carried out. In order to identify high-traffic regions and areas susceptible to pollution, this assessment may involve examining traffic patterns, road layout, and environmental conditions. Computational fluid dynamics (CFD) simulations can be used to model fluid flow patterns and forecast the efficacy of various nozzle arrangements once the best sites for nozzle placement have been determined. The nozzle placement and orientation can be optimized with the aid of these simulations to guarantee optimal cleaning effectiveness. Next, nozzles with sensors attached are positioned at key spots all around the surface of the road. Based on real-time monitoring of the state of the road, including the presence of debris, pollution, or other contaminants, these nozzles are engineered to autonomously identify and target areas that require cleaning. The infrastructure of smart cities is then connected with the cleaning system to allow for real-time road cleanliness monitoring and management. As part of this integration, the cleaning nozzles might be linked to a central control system that can interface with sensors and other monitoring equipment positioned all throughout the road network. To guarantee optimum performance over time, the cleaning system must undergo routine maintenance and calibration. This could entail changing the nozzle's settings, doing routine checks, and replacing any worn-out or broken parts.

V. DESIGN AND ANALYSIS

The design and analysis of a self-cleaning road system involve several crucial steps. Route selection is paramount, considering factors like existing utilities, terrain, and environmental impact. Determination of pipeline diameter, depth, and material selection ensures efficient water distribution while minimizing disruption to road infrastructure. Discharge calculations optimize the number and size of nozzles needed for effective cleaning by considering pipe diameter, flow rate, and spacing.

Pressure calculations, utilizing Bernoulli's principle, ensure the cleaning system operates effectively to remove dust and debris from the road surface. Motor selection, based on flow rate and velocity calculations, determines the appropriate pump to supply water efficiently. Water tank design considers the volume of water required for cleaning and the duration of cleaning cycles to ensure continuous operation.

Model construction involves assembling the prototype using materials like bituminous, aggregates, drip pipes, and a pump system, with arrangements made for nozzle installation. Testing and optimization evaluate the system's performance under various conditions, adjusting design and functionality based on feedback. Data collection and analysis refine the design, aiming for a more advanced and reliable self-cleaning road system.

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VI. CALCULATIONS

1) Discharge calculations:

Diameter of nozzle = 0.12inches i.e.0.003048m Area of nozzle (A1)

$$A_1 = \frac{\pi}{4} D^2 = \frac{\pi}{4} (0.003048)^2$$

A_1 = 227.296 x $10^6 m^2$

Discharge through a single nozzle (Q_1)

Q_1 = 9.96 lit/min i.e.0.000166 m^3/sec

No of nozzles required for 250 m stretch by providing a spacing of 6.5 m = 78 No's

(Placing 2 nozzles in alternate directions at a single point)

Total number of nozzles required = 78 x 4 = 312 No's

Discharge through 78 nozzles is equal to the discharge through the 1.5 Inch diameter pipe

Q_2 = 78 x 9.96

Q_2 = 776.88 lit/min i.e. 0.012782 m^3/sec

Discharge required through 2.5Inch diameter pipe (Q3)

Q3 = 2*776.88

Q_3 = 1553.76lit/min i.e.0.0258m3/sec

Total discharge required for 1km stretch (Q_t) = (Q_4) = 4 x 776.88

Q_t = Q_4 = 3107.52 lit/min i.e. 0.051792 m^3/sec

2) Pressure Calculations:

Bernoulli's principle:

Bernoulli's principle states in the field of fluid mechanics that an increase in fluid velocity is always accompanied by a decrease in hydro-static pressure or a decrease in fluid potential energy.

To maintain a constant measured volume, the incompressible fluid must accelerate when it reaches the limit. Therefore, the narrow nozzle on the hose accelerates the water flow.

This equation is valid only for incompressible fluids and is given by,

$$\frac{P}{\delta g} + \frac{V^2}{2g} + Z = CONSTANT$$

Here,

V = Speed of the flow of fluid

g= Acceleration due to gravity,

z = Height of the point from the reference plane

P = Pressure of the fluid

ρ = Density of the fluid at all points According to this principle, the mass flow rate through the nozzle is

$V_1 = Q_1/A_1 = 0.000166/7.296 \times 10^{-6}$

Here,

A = Area of the cross-section of the nozzle (m^2)

V = Velocity of the flow, m/s

Q = discharge through the nozzle Consider a pipe of diameter 1.5 inches

Let's find the pressure in a pipe through the Bernoulli's equation i.e.,

Consider two sections one at the nozzle and the other on pipe of diameter 1.5 Inches Now apply the Bernoulli's equation at both the ends

Required pressure to remove dust on road is 30-100psi

Required Pressure in nozzle = 75psi (30 to 100psi), i.e.517107 N/m^2

Pressure required in 1.5-inch diameter pipe (P2)

$$\frac{P_1}{\delta g}+\frac{V_1^2}{2g}+Z_1 = \frac{P_2}{\delta g}+\frac{V_2^2}{2g}+Z_2$$

P_1 = Pressure required inside the nozzle

P_1 = 75psi i.e. 51707 N/m^2

P_2 = Pressure required inside 1.5Inch diameter pipe

V_1 = Velocity of water inside the nozzle

$$= \frac{0.000166}{7.296\times 10^{-6}} = 22.75\ /e$$

V_2= Velocity of water inside the pipe

$$— = \frac{0.012782}{0.00144} = 11.21\ /e$$

m/secδ = Density of water at all points

g = Acceleration due to gravity = 9.81m/sec

Z_1, Z_2 = Datum heads = 0 (considering the slope of pipeline as zero)

Substitute the valves in above equation

$$\frac{517107}{1000\times 9.81}+\frac{22.75^2}{2\times 9.81}+0 = \frac{P_2}{1000\times 9.81}+\frac{11.21^2}{2\times 9.81}+0$$

P_2 = 713056.2N/m2

P_2 = 103.42 psi

Pressure required in 2.5-inch diameter pipe (P_3)

$$\frac{P_2}{\delta g}+\frac{V_2^2}{2g}+Z_2 = \frac{P_3}{\delta g}+\frac{V_3^2}{2g}+Z_3$$

$$\frac{713056.2}{1000\times 9.81}+\frac{11.21^2}{2\times 9.81}+0 = \frac{P_3}{1000\times 9.81}+\frac{8.164^2}{2\times 9.81}+0$$

P_3 = 742562.8N/m2

P_3 = 107.69psi

Pressure required at the motor (P4)

V_4= Velocity of water required at the motor

$$\frac{P_3}{\delta g}+\frac{V_3^2}{2g}+Z_3 = \frac{P_4}{\delta g}+\frac{V_4^2}{2g}+Z_4$$

Substitute the valves in above equation
P4 = 641736.048 N/m^2

$$\frac{742562.8}{1000 \times 9.81} + \frac{8.164^2}{2 \times 9.81} + 0 = \frac{P_4}{1000 \times 9.81} + \frac{16.38^2}{2 \times 9.81} + 0$$

P4 = 93.075 psi

Motor required for water supply
Flow work equation: The flow work equation relates the power required to the flow rate and velocity of the fluid. It is commonly used in fluid mechanics and hydraulic engineering applications.

The formula for power is given by:

Where: oe () =

P = power (in watts)
= density of the fluid (in kg/m^3)

Q = flow rate (in cubic meters per second, m^3/s)

V = velocity of the fluid (in meters per second, m/s)

This equation represents the rate of energy transfer due to the movement of fluid particles. It does not account for other factors such as pressure, head losses, or efficiency.

Q = flow rate = 0.051792m3/sec
V = velocity of the fluid = 16.38m/sec

= density of the fluid = 1000kg/m3 Substitute the valves in above equation
= 1000 × 0.051792 × 16.38
P = 848.35 watts
P = 1.317 HP ~ 1.5 HP

Figure Centrifugal pump

The 1.5 Hp Centrifugal pump is used for the supply.

Designing of water tank
Number of liters of water required per second = 52.8453 liters
Number of liters of water required per 30 seconds = 1590 liters ~ 1600 liters Number of liters of water required per 15 seconds = 795 liters ~ 800 liters
The required capacity of the tank depends on the volume of water required for cleaning
The time required for cleaning of the road depends on the amount of dust accumulated on the road, and the pressure of water coming out from the nozzle.
Let us consider a time of 30 seconds and a tank of capacity 10,500 liters

Volume of water = 10.5 m^3
$V = L \times B \times H$
L = Length of tank = 3.5m
B = Breadth of a tank = 1.5 m
H = Height of a tank = 2 m

VII. RESULTS AND DISCUSSIONS

The design of self-cleaning roads primarily focuses on the safety of municipal workers in areas with regular traffic, as well as cleaning the road surface on a regular basis without interfering with traffic flow. Nozzles are installed in reflectors at regular intervals of 6.5 m. Each reflector consists of two nozzles pointing in the opposite direction. The series of nozzles are linked with the pipeline beneath the road, which is connected with the tank positioned on the divider, which is meant to supply water for the self-cleaning system. The water is delivered using a centrifugal pump of 1.5 HP to 2 HP for about 15 to 30 seconds. The water required for 30 seconds is 1600 L for each wash. The tank capacity is built for the 10500 L. It serves for 6 cycles of cleaning. The pavement is coated with hydrophobic coating to enhanced skid resistance and reduced water infiltration. Working of self-cleaning of road 48 Using nozzles to create self-cleaning roadways might save a lot of money on maintenance and increase cleanliness. To remove dirt, debris, and pollutants from roadways, a system of strategically positioned nozzles that spray water or cleaning chemicals may be used. This automated procedure could lessen the negative environmental effects of road pollution while improving road safety and aesthetics. Although the idea of self-cleaning roadways is not new, recent technological developments have created intriguing new opportunities for their broad application. Modern self-cleaning road systems may react to changing traffic patterns and environmental circumstances by combining automated control mechanisms, real-time monitoring systems, and smart sensors.

VIII. CONCLUSION

The design, construction, and assessment of self-cleaning highways using strategically positioned water nozzles are all part of this project. The purpose of these nozzles is to spray water onto the road surface at regular intervals, loosening and washing away dirt, dust, and other impurities. The system is made to function effectively with the least amount of water usage and environmental effect possible. This procedure also allows us to shield the surface from excessive heat.
Some of the benefits of this project include

1) Removing debris and dust from the undercarriage of cars reduces the need for vehicle maintenance.
2) It keeps the pavement temperature stable, which prevents the pavement from cracking.
3) Clears the pathway of debris and harmful materials.
4) Cracks on roads are avoided.
5) By reducing the amount of road debris, it lowers the average number of accidents. In addition, the automated nature of the system reduces the need for manual labor, resulting in more efficient and cost-effective road maintenance over time. Overall, adding fuel-based self-cleaning technologies to highways is an important step toward creating a cleaner, safer, and more sustainable urban environment.

IX. KEY FINDINGS

1) Self-cleaning road systems use water nozzles to reduce manual cleaning efforts, reduce labor costs, and improve road cleanliness and aesthetics.

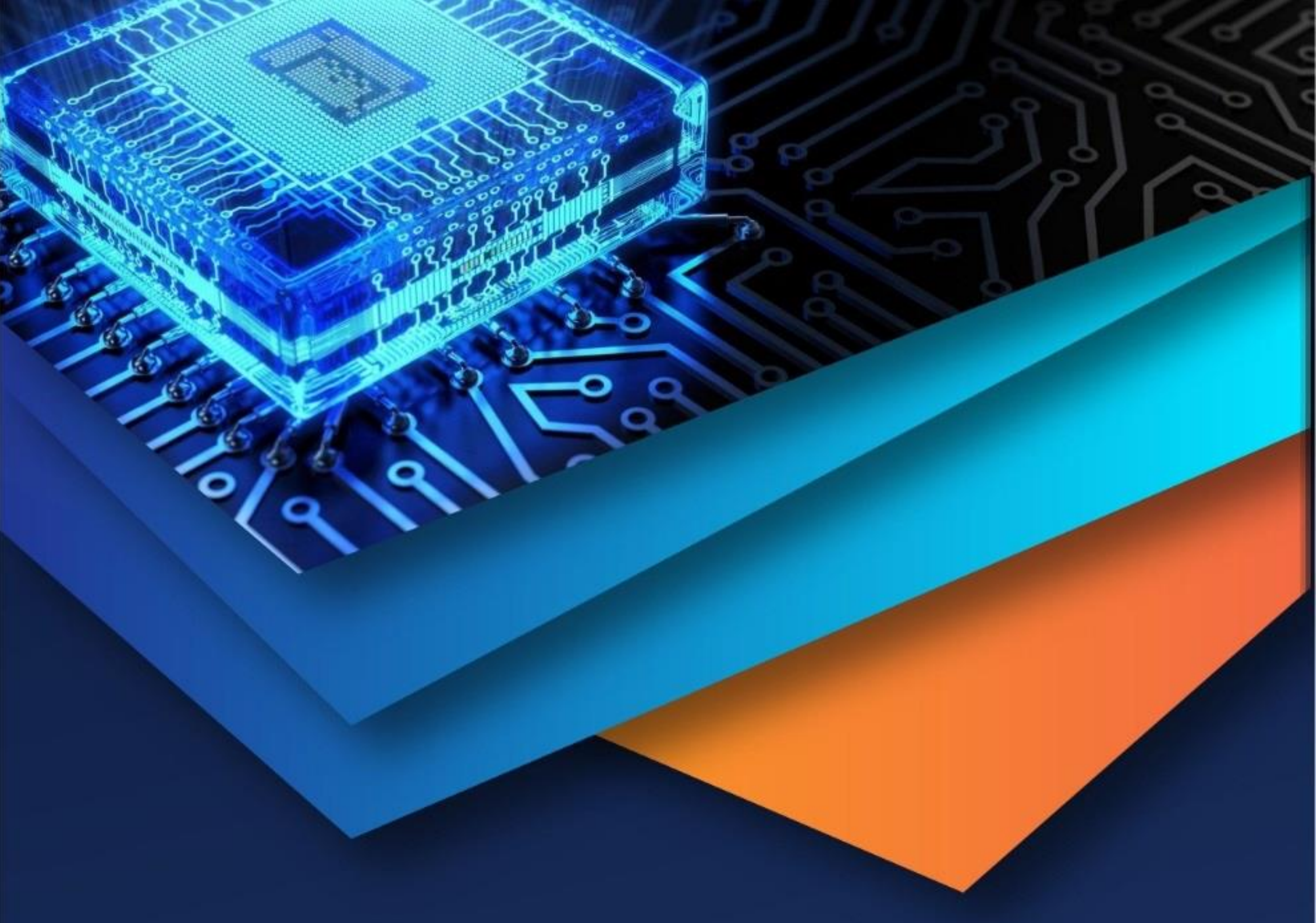
2) They also reduce the environmental impact of road maintenance activities by minimizing the use of chemical cleaning agents and water usage.
3) The project also improves safety for cleaning personnel by minimizing manual cleaning tasks and reducing the risk of road accidents.
4) The system is designed to work efficiently, use water efficiently, and reduce the environmental impact.
5) The results of the project contribute to the development of sustainable infrastructure solutions for urban environments, offering potential applications in cities around the world and promoting long term environmental and economic benefits.

X. CONCLUSION POINTS

1) Self-cleaning streets offer a transformative arrangement to urban foundation support, minimizing manual labor and diminishing related costs.
2) By coordination water spouts into street surfaces, flotsam and jetsam and poisons are proficiently expelled, upgrading street cleanliness and aesthetics.
3) The security of urban cleaning staff is essentially moved forward through the decrease of unsafe manual cleaning errands and potential street mischances.
4) The execution of self-cleaning innovation not as it were improving open security but moreover contributes to the by and large well-being of communities.
5) Through productive water utilization and minimized natural affect, self-cleaning streets advance supportability in urban advancement.
6) Thorough assessment of key parameters guarantees the common sense and practicality of self-cleaning street frameworks for broad selection.

REFERENCES

[1] Highway Engineering, S.K. Khanna & C.E.G. Justo, Edition-200 IRC-SP-20 (February 2002), Rural Roads Manual the Indian Road Congress, New Delhi-110011, 2002.
[2] "Evaluation of Nozzle-based Self-cleaning Systems for Urban Road Networks "Wang et al. (2020).
[3] Investigation of Self-cleaning Road Surfaces with Nozzle-based Cleaning Mechanisms "In this research by Johnson and Patel (2019).
[4] Review Paper on Defects in Flexible Pavement and its Maintenance' International Journal of Advanced Research in Education & Technology (IJARET), Vol. 4, Issue 2 (April - June 2017), ISSN: 2394-6814.
[5] Agarwal P.K Rocade.S Study on drainage related performance. of flexibility highway pavement 2012.
[6] "Optimization of Nozzle Placement and Configuration for Self-cleaning Roads "This research by Garcia and Lee (2021).
[7] The performance analysis of part of existing drainage network is carried out for combined system by using SWMM, Satish Taji et. al. (2017).



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