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Waterlogging And Flood Mitigation In New Khapri, Nagpur

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Abstract: Flooding and waterlogging have emerged as persistent challenges in New Khapri, Nagpur, due to an inefficient and outdated drainage infrastructure. This study aims to assess the existing drainage system, identify critical deficiencies, and propose sustainable flood mitigation measures. A comprehensive site investigation was conducted, highlighting major issues such as excessive vegetation growth in drains, inadequate drainage width, absence of retaining walls, improper road slopes, insufficient pipe sizes, and frequent blockages. Additionally, feedback from local residents provided valuable insights into the severity of waterlogging problems during heavy rainfall.

To understand the drainage characteristics, a morphometric analysis of the existing drain was performed using parameters such as slope, roughness, hillshade, aspect, Shuttle Radar Topography Mission (SRTM) data, and stream flow patterns. Based on these findings, a syphon system has been designed to regulate excess water flow and prevent waterlogging. The proposed intervention aims to enhance the efficiency of the drainage network, reduce flood risks, and improve the overall urban resilience of New Khapri. By integrating engineering solutions with hydrological analysis, this study provides a strategic framework for sustainable flood management, ultimately improving the quality of life for residents in the region.

Keywords: Flood mitigation, waterlogging, drainage infrastructure, morphometric analysis, syphon system, New Khapri, Nagpur.

I. INTRODUCTION

Urban flooding and waterlogging have emerged as critical challenges in several large cities, causing substantial economic losses and disruptions to daily life. Over the past decade, the frequency and intensity of urban floods have increased due to rapid urbanization and changing climate patterns. Unplanned urban expansion, insufficient drainage infrastructure, and increased impervious surfaces have further aggravated the situation by reducing natural infiltration and increasing surface runoff.

Nagpur, one of Maharashtra's rapidly growing cities, has been experiencing recurrent flooding and waterlogging, particularly in areas with inadequate drainage systems. Among these, New Khapri has been significantly affected due to factors such as improper slope of roads, inadequate pipe sizes, vegetation growth obstructing water flow, and blockage of drainage channels. The continuous increase in precipitation intensity and duration has further exacerbated the issue, highlighting the urgent need for a comprehensive study to identify the root causes and develop effective mitigation strategies.

This research aims to assess the existing drainage system of New Khapri and evaluate its deficiencies through site visits, data collection, and community feedback. The study focuses on identifying flood-prone areas, analyzing the drainage network using morphometric analysis with ArcGIS, and designing practical solutions such as improving drainage capacity, optimizing pipe sizes, constructing retaining walls, and proposing a siphon design to enhance water flow management. Additionally, rainfall data from the Regional Meteorological Centre (RMC) will be utilized to strengthen the analysis.

The findings of this study will contribute to the development of sustainable flood management strategies for New Khapri, ensuring better resilience against future waterlogging and urban floods. By integrating scientific analysis with community engagement, this research aims to provide actionable recommendations for policymakers, urban planners, and engineers to mitigate urban flooding and enhance drainage infrastructure in growing cities like Nagpur.

II. LITERATURE REVIEW

Tunji et al. (2011) studied Management of urban storm-water is characterized by the use of hydraulic structures like culvert, man-made channels, water ways, detention basins, infiltration trench, spillway, dams and other drainage structures to either convey or store the storm-water downstream. But in some cases these structures may not be effective to either convey or store the excess runoff because of some inherent factors like topography, soil type, and other factors could include high rain intensity over a long duration and poor drainage design.

In the case of BatuPahat, Johor, Malaysia, some of the contributing factors include; flatness of the catchment area and low infiltration rate of the top layer soil (clayey). The method of injecting some of the storm-water into the ground (aquifer) through a recharge well (perforated pipe), so as to reduce the peak flow rate reaching these structures was adopted to mitigate flood.

Ole Mark(2012) studied Flooding in urban areas is an inevitable problem for many cities in Asia, in the year 2000 Bombay, India and Phnom Penh, Cambodia had serious problems related to urban flooding. In Bangladesh, Dhaka has faced water logging for the last years. Even a smaller rain events may cause that parts of Dhaka have water standing in the streets. The situation was highlighted in September, 1996 when residences experienced ankle to knee-deep water on the streets. Daily activities in parts of the city were almost paralyzed. Heavy traffic jams occurred due to stagnant water on the streets. With the advances in computer technology, many cities manage local and small flood problems with the computer-based solutions. But at present, a few studies of urban flooding with the simulation of both a surcharged pipe network and extensive flooding on the surface are available. In this study, modelling of urban flooding with the interaction between the pipe system and the surface flooding, including a description of the interaction between street and pipe network are carried out.

W. E. Highfield and S. D. Brody (2012) studied Flood Losses FEMA introduced the Community Rating System (CRS) in 1990 to encourage local jurisdictions to enhance floodplain management beyond minimum standards. A study analyzing 450 CRS-participating communities from 1999 to 2009 evaluated the impact of CRS activities on insured flood loss claims. The results showed that freeboard requirements, open space protection, and flood protection significantly reduce flood damage.

D. P. Patel and P. K. Srivastava (2013) studied Flood Hazards Mitigation Analysis Using Remote Sensing and GIS: Correspondence with Town Planning Scheme. Water Resources Management, 27(7), 2353-2368. Flood is an overflow of water that submerges land and the inflow of tide onto land. Floods usually cause large-scale loss of human life and wide spread damage to properties. In this study, integration of the satellite and GIS datasets are carried out to prepare the flood zonation mapping of Surat district, Gujarat, India. High resolution remote sensing images from Google-earth, IRS-1D, 1:50000 topographical maps are combined with hydraulic analysis and digital elevation model (DEM) to identify the flood susceptible area of the various zones divided as North, South, East, West, Central, South-East and South-West validated with the field surveys. The work is extended up to the Town Planning Scheme (TPS), to detect the most vulnerable areas in terms of submergence. Overall analysis indicates that more than 90–95 % of the area would be submerged if the flood of the same frequency happened over this flood plain in the near future

F. N. Binti et al. (2014) studied Development of an Intelligent Decision Support System for Flood Mitigation in the Pahang River. International Journal of Sustainable Land Use and Urban Planning, 2(2), 1-8. This is an established truth that with the growing world, the flood hazards cannot be avoided but the technology is a solution to minimize this process. A sustainable development depends on plans, which are designed on the strong basis of comprehensive datasets. Managing river is an acute and more attentive area where it faces heavy water feeds due to rains. Malaysia is going on fast development including infrastructural developments and change of land uses from forest cover to other non- green land uses. Adopting innovative products for flood mitigation are required as an integral part of local design transformation. Keeping this fact in view, the vulnerability which may cause due to floods in Pahang River seems to be a threat for the sustainable development of the area. The general objective of this study was to propose a visual aided decision support platform providing an ease but acceptable level of strategy. Presented prototype includes modelling and GIS based visual aids. A study of Pahang River in Malaysia conducted, to explain the applications of the prototype. To achieve this goal a geodatabase, consisting of different hydro-informatics data layers, has been developed. Further work on modified models for better forecasting under real time data input and design of innovative self-protecting flood mitigation at industrial and house hold level is identified as future research area. Under this research studies, the required datasets were generated using remote sensing and GIS system integrated with field GPS surveys.

P. S. Chaudhari and S. R. Shinde (2014) studied Evaluation of Non-structural and Structural Flood Management Measures. International Journal of Innovative Research in Advanced Engineering (IJIRAE), 1(2), 83-87. The flooding can have ruinous impacts on the society and the environment. The cities are mostly located on the banks of rivers, coasts or in the valleys. Urbanization leads to developed catchments which are densły populated and are centers of economic activities with vital infrastructure. The loss of assets is directly related with flood exposure. The thorough knowledge of flood exposure helps in developing effective flood management measures. In the present study flood exposure analyses is performed by using GIS tool. The land use and flood map data is integrated in GIS framework to develop flood exposure map. Flood exposure map can be used to compute the flood losses at different locations in the watershed. The existing non-structural flood management measures are evaluated using the flood losses. To protect the lives and properties, structural flood management measure is proposed and evaluated. The proposed methodology is developed for Upper Godavari basin of Nashik city in Maharashtra of India.

J. K., Botzen et al. (2014) studied Factors of influence on flood damage mitigation behaviour by households. Environmental Science and Policy, 40(October 2016), 69-77. The cartography of floods by two different approaches enabled us to determine the limits and the advantages of each one of them. This cartography has been applied to the El Maleh basin situated in the South-East of Morocco. The HEC-RAS approach consists of a combination of the surface hydrologic model and the digital terrain model data. This combination allows thereafter the mapping of the flood zones by the use of the WMS software. Thus it can predict the probability occurrence of floods at various frequency times and determine the intensity of the flood (depth and velocity of flood water) inside the El Maleh river by using the existing hydrological data. Otherwise, FHI method approach introduces a multi-criteria index to assess flood risk areas in a regional scale. Six parameters (flow accumulation, distance from drainage network, drainage network density, slope, land use, and geology) were used in this last method. The relative importance of each parameter for the occurrence and severity of flood has been connected to weight values. These values are calculated following an Analytical Hierarchy Process: AHP, a method originally developed for the solution of Operational Research problems. According to their weight values, information of the different parameters is superimposed, resulting to flood risk mapping. The use of the WMS model allowed us to accurately map the flood risk areas with precisely flood heights in different levels. However, this method is only applicable for a small portion of the basin located downstream of the hydrological station. Otherwise, the FHI method allows it to map the entire basin but without giving an indication of the water levels reached by floods. One method does not exclude the other since both approaches provide important information for flood risk assessment.

Lung-Sheng Hsieh et al. (2016) studied Assessment of Various Flood Mitigation Measures for a Highly Developed Valley Zone in Taiwan. This study assesses flood mitigation measures in the densely populated Kee-Lung River Basin in northern Taiwan using 1-D unsteady flow and 2-D overland flow simulations. Urbanization has increased flooding risks, prompting the proposal of various engineering solutions, such as bank protection and retention reservoirs, based on field surveys and geomorphological data. The effectiveness of these measures was evaluated using flood stages, runoff peaks, and inundation depths. However, the results indicate that no single plan adequately addresses the flooding and inundation problems in the area.

S. N. Sahoo and S. Pekkat (2017) studied Detention Ponds for Managing Flood Risk due to Increased Imperviousness: Case Study in an Urbanizing Catchment of India. The study quantifies flood risk in Guwahati, India, due to increased imperviousness and other flood-causing factors. A 100-year flood hazard map was created using data from 2006 and 2011, with hazard ranks based on flood depth, inundated area, land use, population, and roads. Results showed increasing flood risk over time, driven mainly by flood depth and area. A detention pond was proposed to mitigate this risk, reducing maximum flood depth by 46.5% and inundated area by 43%. The study highlights detention ponds as an effective flood management solution.

M. S. Mukesh and Y. B. Katpatal (2021) studied Impact of the Change in Topography Caused by Road Construction on the Flood Vulnerability of Mobility on Road Networks in Urban Areas. The study assesses how road construction in Nagpur, India, impacts flooding by introducing the Flood Vulnerability Road Mobility Index (FVRMI). Using hydrologic modeling and factors like precipitation, land use, and elevation, it compares topography changes from 2010 to 2018. Results show a 20% increase in flood vulnerability in 2018, with 63% of road segments more affected, highlighting how reconstruction has altered Nagpur's flood flow regime.

III. METHODOLOGY

Our study follows a comprehensive methodology integrating field investigations, hydrological analysis, engineering solutions, and community engagement to develop effective flood mitigation measures for New Khapri, Nagpur.

1) Site Investigation and Identification of Flood-Prone Areas to understand the extent of waterlogging and flood issues in New Khapri, site visits were conducted to assess the drainage system, terrain, and water flow patterns.

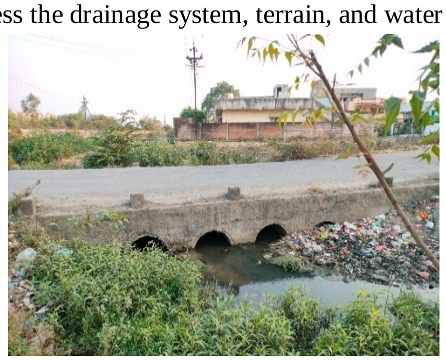


Figure3.1: Existing drain under bridge

Topographic surveys and satellite imagery were used to analyze elevation changes influencing water movement.
Major obstructions such as solid waste accumulation, sediment deposition, and vegetation growth in drainage channels were identified.
Existing drains under bridges were examined to understand structural limitations in water conveyance.

2) Assessment of Existing Drainage Infrastructure:
A detailed evaluation of the current drainage network was carried out, considering both primary and secondary drains.
Drain width and depth were measured to assess capacity limitations.
The absence of retaining walls was noted, which contributes to erosion and drainage inefficiencies.

3) Community Involvement and Public Reviews:
To understand the social impact of flooding, community participation was incorporated into the study.
Interviews and surveys were conducted with local residents to gather feedback on historical flood patterns and peak water levels.
Engagement with the Regional Meteorological Centre (RMC), Nagpur, facilitated the acquisition of rainfall data crucial for analyzing flood trends.

a) Rainfall Data Collection:
Accurate precipitation data was obtained from the Regional Meteorological Centre (RMC), Nagpur, through a systematic process:
- Visit to RMC Office – Understanding the procedure for data acquisition.
- .Submission of an Official Request – A formal email was sent detailing the purpose, required data (rainfall trends, duration, intensity, etc.), and the timeframe for analysis.
- Approval and Data Collection Upon approval, precipitation data was received.
- Data Utilization The acquired data was analyzed to assess rainfall patterns, peak rainfall periods, and their correlation with flooding incidents.

4) *Morphometric Analysis of the Catchment Area:* A morphometric analysis was conducted to understand the hydrological behavior of the catchment affecting New Khapri’s drainage system.

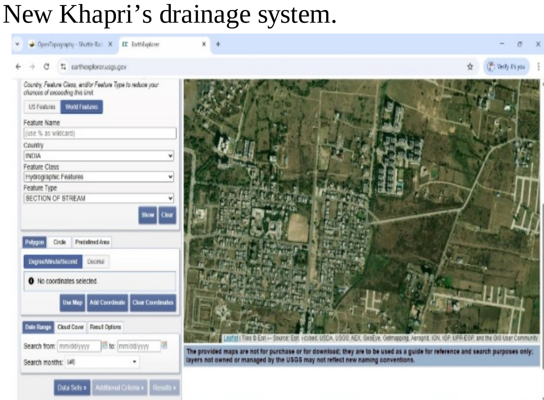


Figure3.2: View of catchment area in USGS earth explorer

a) Digital Elevation Model (DEM) Analysis
A Shuttle Radar Topography Mission (SRTM) DEM dataset was used for:
Watershed delineation
Flood modeling
Hydrological studies

b) Slope Analysis
Gentle slopes: Low runoff, high infiltration potential.
Moderate slopes – Influence flow velocity and drainage capacity.
Steep slopes – High runoff, erosion risk, potential landslides.

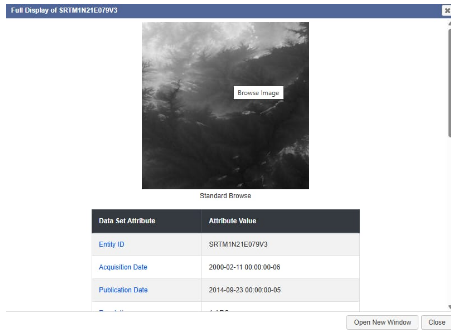


Figure3.3: DEM file

c) Roughness Analysis:
Low roughness zones – Suitable for infiltration and stable infrastructure.
High roughness zones – Prone to rapid runoff, erosion, and landslides.

d) Hillshade Analysis:
Used to visualize topography for effective drainage planning.
Higher elevation areas – Require afforestation and erosion control.
Low-lying areas – Suitable for water retention structures.

e) Aspect Analysis:
North-facing slopes – Retain moisture, suitable for vegetation growth.
South-facing slopes – Higher evaporation, prone to erosion.
East & West-facing slopes – Influence soil moisture and runoff patterns.

f) Stream flow Network Analysis:
Identified natural drainage paths and potential flood zones.
Stream order analysis helped determine flow accumulation points and flood risks.

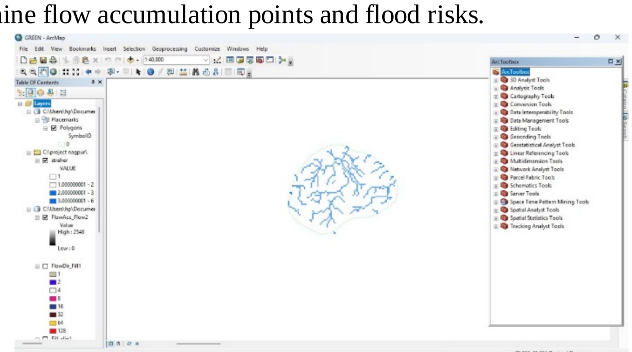
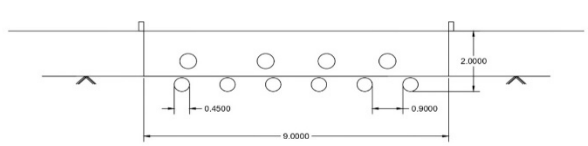


Figure 3.4: Stream flow network

5) Drainage Infrastructure Improvement and Engineering Solutions
a) Design of Syphon for Drainage Enhancement:
A syphon system was proposed to improve water conveyance efficiency at critical flood-prone sections.



CROSS SECTION

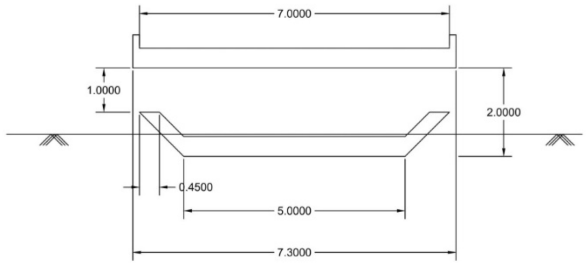


Figure 3.5: Cross section

Design Considerations:
Pipe Diameter Calculation:-
Based on flow velocity and hydraulic losses.
Calculated minimum diameter D = 450 mm to accommodate peak discharge.

Hydraulic Losses Assessment:-
Friction Loss (Hf) = 0.106 m
Minor Losses (Hinlet, Hout, and Bends) = 2.388 m
Total Hydraulic Loss = 2.494 m

Material Selection
Chosen for durability and resistance to clogging in flood-prone areas.

6) Flood Mitigation Strategies and Planning

Based on the analysis, several flood mitigation strategies were proposed:

- Vegetation Management in Drainage Channels – Regular removal of obstructions like solid waste and excess vegetation.
- Expansion of Drainage Capacity– Widening and deepening of primary drains.
- Construction of Retaining Walls – To prevent soil erosion and structural damage.
- 4.Implementation of Check Dams and Retention Basins – To control runoff and enhance groundwater recharge.
- Use of GIS and Remote Sensing for Future Planning – Continuous monitoring of flood-prone areas for adaptive management.

IV. RESULTS AND DISCUSSION

Hydrological and Structural Analysis for Flood Mitigation in New Khapri, Nagpur

1) Site Assessment and Drainage Challenges:

The study identified major drainage issues contributing to waterlogging in New Khapri, Nagpur.
Field investigations and morphometric analysis revealed key factors affecting water flow, including:
Insufficient drainage infrastructure.
Vegetation overgrowth and sediment deposition in existing channels.
Improper slopes and blockages restricting water movement.
Lack of retaining walls, leading to structural instability.
These findings emphasize the need for an improved drainage system to mitigate recurrent waterlogging and enhance stormwater management.

2) Morphometric Analysis and Rainfall Data Utilization:

Hydrological studies were conducted using GIS-based morphometric analysis to understand terrain characteristics and runoff behavior. Key observations include:
Slope Analysis: Steeper slopes contribute to high runoff, increasing flood risks, while gentle slopes enhance infiltration.
Surface Roughness: High roughness areas accelerate runoff, necessitating erosion control measures.
Drainage Network Mapping: Flow accumulation points were identified to optimize flood management strategies.

Rainfall data obtained from the Regional Meteorological Centre (RMC), Nagpur, facilitated the assessment of precipitation trends, peak rainfall events, and their correlation with flooding. These datasets were crucial for designing an efficient flood mitigation system.

3) Syphon System Design for Drainage Improvement:

A syphon system had proposed the effectively channel floodwaters beneath a bridge, preventing surface water accumulation and improving drainage efficiency.

The key features of the syphon system include:

Six syphon pipes (each 0.45 m in diameter) arranged in a trapezoidal formation.

Spacing of 0.9 meters between syphons for smooth water passage.

Total system width of 9 meters with a depth of 2 meters.

Hydraulic and Structural Efficiency

The syphon design ensures:

Efficient water conveyance by reducing flow resistance and improving drainage capacity.

Prevention of sediment deposition due to the optimized trapezoidal structure.

Reduction in flooding intensity, ensuring road usability even during heavy rainfall.

Structural stability is reinforced by adequate spacing between the syphons and sufficient depth to handle peak discharge. Periodic maintenance, including desilting and debris removal, is necessary to sustain efficiency.

4) Installation Method: Pushing Technique:

To ensure minimal disruption to the bridge's foundation, the pushing method was selected for syphon installation.

This method offers:

Structural Integrity Protection: Eliminates extensive excavation, preventing damage to the bridge.

Precision and Control: Hydraulic or mechanical pushers ensure accurate alignment.

Cost-Effectiveness and Time Efficiency: Reduces construction time and minimizes restoration costs.

Installation Procedure:

- Site Preparation: Surveys and safety measures conducted before installation.
- Trench Excavation: A controlled trench was created beneath the bridge.
- Pipe Fabrication & Alignment: Prefabricated syphon pipes were checked for structural integrity.
- Pushing Installation: Pipes were inserted gradually using hydraulic jacking.
- Backfilling & Restoration: The trench was refilled and surface conditions restored.
- Testing & Commissioning: Flow tests performed to ensure proper functionality.
- 5. Impact on Flood Mitigation:

The implementation of the syphon system in New Khapri expected to:

Significantly reduce waterlogging by facilitating smooth drainage beneath the bridge.

Enhance road safety and longevity by preventing flood-induced structural damage.

Improve urban stormwater management and resilience against extreme rainfall events.

5) Recommendations for Future Improvements:

Regular Monitoring & Maintenance: Desilting and blockage prevention to sustain efficiency.

Protective Grates Installation: To prevent debris accumulation in syphon pipes.

Hydraulic Performance Assessment: Continuous evaluation to determine the need for additional drainage enhancements.

V. CONCLUSIONS

The study on Waterlogging and Flood Mitigation in New Khapri, Nagpur aimed to assess the existing drainage system, identify key challenges, and propose an effective engineering solution. Through a comprehensive approach involving catchment area analysis, rainfall data collection, morphometric assessment, and syphon system design, the research successfully developed a flood mitigation strategy tailored to the region's hydrological conditions.

Key Findings and Outcomes:
The existing drainage infrastructure in New Khapri found to be inadequate in managing peak rainfall intensities, leading to frequent waterlogging and urban flooding.
Morphometric analysis provided valuable insights into flow patterns, runoff behavior, and hydrological characteristics, enabling the optimization of the drainage system.
A syphon drainage system was designed using peak rainfall data to facilitate smooth water conveyance, preventing water stagnation beneath the bridge.
Cross-sectional designs developed in AutoCAD helped visualize and refine the drainage solution, ensuring structural feasibility and efficiency.
The proposed syphon system has been validated for its hydraulic efficiency and is expected to effectively manage stormwater runoff, reducing flood risk in the area.
Impact and Future Implications:
Once implemented, the syphon drainage system will:
Significantly reduce waterlogging and improve flood resilience in New Khapri.
Enhance infrastructure durability by preventing prolonged water accumulation.
Improve road safety and usability during heavy rainfall events.
Contribute to sustainable urban stormwater management, supporting long-term flood mitigation.
This research provides a practical engineering solution for urban flood control, demonstrating how hydrological analysis, drainage design, and advanced installation techniques can be integrated to mitigate waterlogging and enhance urban infrastructure resilience. Future work may focus on continuous monitoring, adaptive flood management strategies, and further optimization to ensure long-term effectiveness.

VI. ACKNOWLEDGEMENT

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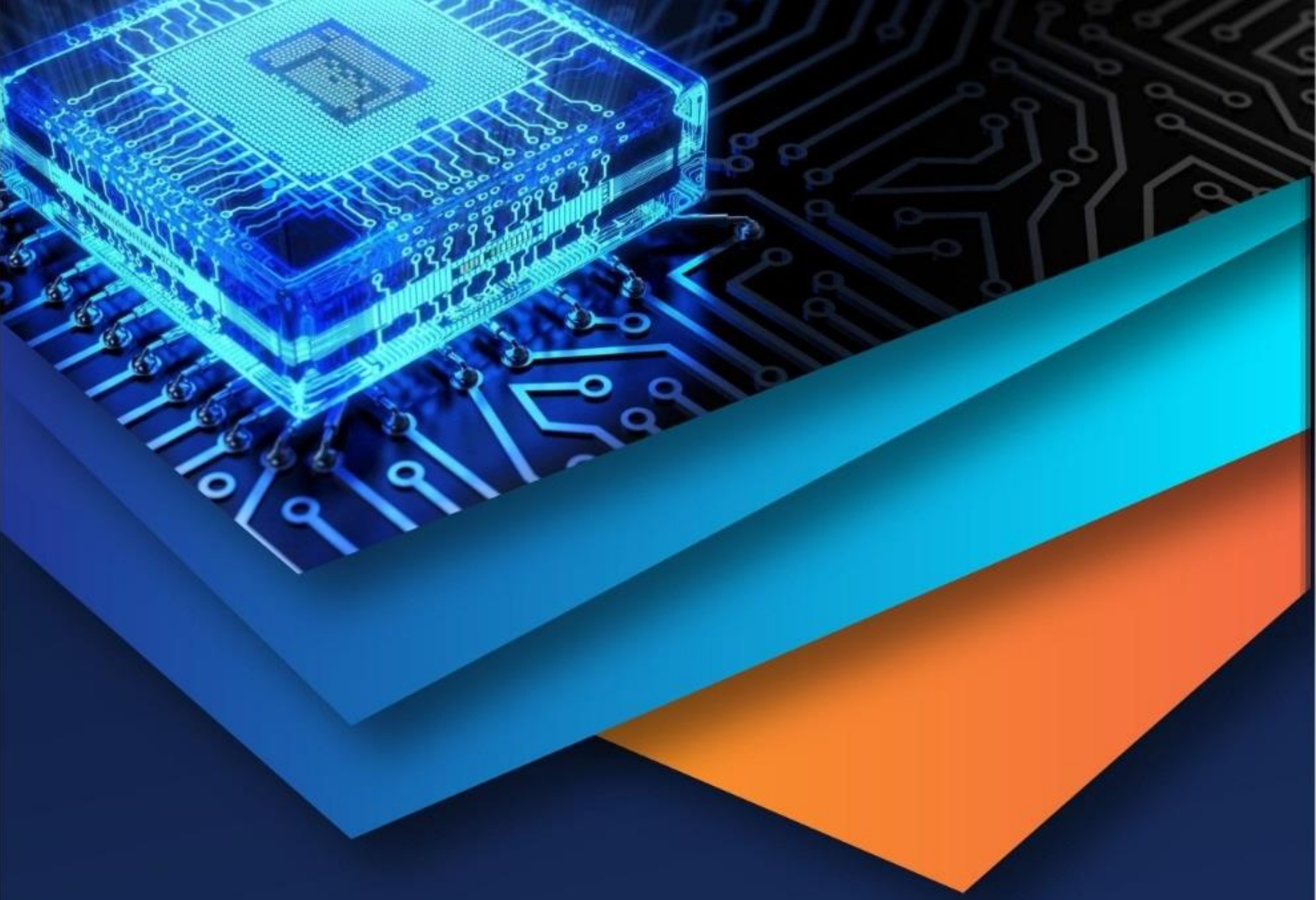

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