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Study of Structural Failure of Road after Widening and its Remedial Measures

Ajay Thombre[1], Aniket Fasale[2], Karan Thorat[3], Chakradhar Khairnar[4], Prof. R. B. Kesarkar[5]
[1, 2, 3, 4]*Student, Civil Department JSPMs Imperial college of Engineering & Research Wagholi, Pune*
[5]*Professor, Civil Department JSPMs Imperial college of Engineering & Research Wagholi, Pune*

Abstract: Road widening projects are undertaken to accommodate increased traffic volume and improve transportation infrastructure. However, in some cases, structural failures can occur in the widened road sections, leading to safety hazards and increased maintenance costs. This study aims to investigate the causes of structural failure in road sections after widening and propose remedial measures to mitigate the issues. The research methodology involved field inspections, data collection, and analysis of failed road sections. Various factors contributing to structural failures were identified, including inadequate design considerations, improper construction techniques, and insufficient soil stabilization measures. The study also examined the effects of increased traffic loads and environmental factors on road performance. Based on the analysis, several remedial measures were proposed to address the structural failures. These measures include retrofitting the road sections with additional reinforcements, improving drainage systems to prevent water accumulation, and implementing proper soil stabilization techniques. Additionally, recommendations for enhanced quality control during construction, such as strict adherence to design specifications and regular monitoring, were suggested. Furthermore, the study emphasized the importance of considering long-term maintenance requirements during the road widening process. Establishing a comprehensive maintenance plan that includes periodic inspections, timely repairs, and proactive maintenance strategies can significantly prolong the service life of the widened road sections.

The findings of this study contribute to the understanding of the factors causing structural failures in widened roads and provide valuable insights into the remedial measures that can be implemented. By adopting these recommendations, transportation authorities and road engineers can mitigate structural issues and ensure the long-term durability and safety of widened road sections, benefiting both road users and the overall transportation network.

I. INTRODUCTION

Road widening projects play a crucial role in accommodating increasing traffic volumes, enhancing transportation efficiency, and improving overall road network capacity. However, despite the benefits associated with road widening, there have been instances where structural failures have occurred in the widened sections. These failures can result in significant safety concerns, disruption of traffic flow, and increased maintenance costs. Therefore, it is imperative to understand the causes of structural failures and develop effective remedial measures to ensure the long-term performance and durability of widened roads. The objective of this study is to investigate the structural failures that occur in road sections after widening and propose appropriate remedial measures. By examining the underlying causes of these failures, valuable insights can be gained to prevent similar issues in future road widening projects. Understanding the complex interactions between various factors contributing to structural failures, including design considerations, construction techniques, traffic loads, and environmental conditions, is crucial for formulating effective remedial strategies. The widening of roads often involves altering the existing geometrical configuration, such as increasing the number of lanes, modifying shoulder widths, and realigning intersections. These modifications can introduce additional stresses on the road structure, potentially exceeding the original design limits. Moreover, inadequate consideration of soil conditions, improper construction techniques, and insufficient soil stabilization measures during the widening process can further exacerbate the risk of structural failures. The consequences of structural failures in widened roads can be severe. They can lead to premature pavement distress, including cracking, rutting, and potholes, which compromise road safety and increase maintenance requirements. Additionally, inadequate drainage systems can result in water accumulation, which weakens the pavement layers and further contributes to structural deterioration. These issues necessitate a thorough investigation into the causes of structural failures and the formulation of appropriate remedial measures. By addressing the challenges associated with structural failures in widened roads, transportation authorities, road engineers, and construction contractors can ensure the long-term durability and performance of road networks.

This study aims to contribute to the body of knowledge by providing insights into the causes of structural failures in widened roads and proposing effective remedial measures to mitigate these issues. The findings of this study will serve as a valuable resource for professionals involved in road widening projects and contribute to the overall improvement of transportation infrastructure.

II. LITERATURE REVIEW

Jianming Ling (2007) During the past decade, many low-volume roads have been rebuilt in China to accommodate a sharp increase in traffic volume. Meanwhile, pavement distresses such as pavement cracking and subgrade sliding or collapse due to highway widening caused concerns. Researchers have suggested mechanisms and reasons for many phenomena associated with various distresses; moreover, there are reports from studies indicating that treatments on subgrade are economical and effective in solving highway widening problems. Several subgrade treatment methods are available to avoid potential pavement distresses due to widening. A combination of geotextile products was applied in the reconstruction of County State Aid Highway to widen the existing roadway embankment on poor foundation soils (1); prefabricated vertical drains and geotextile reinforcement was used on I-15 in Salt Lake City, Utah (2). A test program carried out in the small geotechnical centrifuge of the University of Delft indicated that cracking of the asphalt layer could be minimized by using the gap method of construction in contrast to the horizontal widening method.

Xiaolin Weng (2011): This study introduced at first the background of numerous highways widening projects that have been developed in recent years in China. Using a large ground settlement simulator and a fiber Bragg grating (FBG) strain sensor network system, a large-scale model test, with a similarity ratio of 1:2, was performed to analyze the influence of differential settlement between new and old subgrades on pavement structure under loading condition. The result shows that excessive differential settlement can cause considerable tensile strain in the pavement structure of a widened road, for which a maximum value (S) of 6 cm is recommended. Under the repetitive load, the top layers of pavement structure are subjected to the alternate action of tensile and compressive strains, which would eventually lead to a fatigue failure of the pavement. However, application of geogrid to the splice between the new and the old roads can reduce differential settlement to a limited extent. The new subgrade of a widened road is vulnerable to the influence of dynamic load transferred from the above pavement structures. While for the old subgrade, due to its comparatively high stiffness, it can well spread the load on the pavement statically or dynamically. The test also shows that application of geogrid can effectively prevent or defer the failure of pavement structure.

Neero Gumsar Sorum (2013) Pavement design, the process of developing the most economical combination of pavement layers, mainly deals with the design of material mixtures and thickness of different pavement layers. Even if highway pavements are well designed and constructed, they may require proper maintenance; and if not, different distresses like fatigue cracking, bleeding, rutting, potholes etc occur in the pavement which is considered to be complex phenomenon because of several factors involved (like rainfall, traffic etc.). 20 km length of NH-52A was selected, starting from Nirjuli to Itanagar, to carry out survey of pavement distress. 50 important locations of 400 m interval in the highway were selected for the study. In this study, the observation showed that the most found pavement distresses in the highway were potholes, alligator cracks followed by raveling and edge failure. All the distresses found have values exceeding maximum limits. The most required probable treatments for surveyed distresses are overlay, patching and shoulder improvement. It was also observed that the side drainages were not maintained, cleaned, and even absent in some places of the NH52A.

Petri Varin (2013) This report is a part output of ROADEX IV project task D2 “Widening of Roads”. The project aims to provide practical information on the reasons why road widening fail, the critical parameters that the road engineer needs to know when designing a road widening, and the information on how to repair a widened road that is showing problems. The cost-effective widening of roads is a major challenge that all the roadex Partners are facing and new design guidelines, specifically tailored to the harsh conditions of the Northern Periphery, are required to meet the demands of modern traffic loads. The roadex road widening research task consisted of three phases. The first part was a literature review on current practices and guidelines for road widening in the roadex countries. The report entitled “Road Widening: literature review and questionnaire responses” was written by Samuli Tikkanen from Tampere University of Technology assisted by Timo Saarenketo from Road scanners, Nutty Verifies and Pauli Kolisoja from Tampere University of Technology and Ron Munro from Munro consult Ltd. Also, Heralder Sigursteinsson of the Icelandic Road Administration, Per Otto Aursand of the Norwegian Public Roads Administration and Johan Ullberg from Swedish Road Administration provided information on existing road widening guidelines for the report. The second part of the project dealt with field surveys on selected widening test sites in different ROADEX countries.

A range of widened roads were surveyed using multiple technologies such as ground penetrating radar, video, laser scanners, thermal analysis and falling weight deflectometer. Some of the sites were same as in the first ROADEX project 1998 - 2001. The final report summarizing the research results was written by Petri Varin and Timo Saarenketo from Road scanners.

Bahaaeldin Sadagah (2015) Construction of the mountain roads in Saudi Arabia is one of the most difficult tasks. Many problems faced before, during and after construction of the roads. Inhomogeneous rock masses, structural settings, steep slopes, sharp cliffs, and geomorphological constraints are the obvious obstacles to safe mountainous roads. Al-Hada mountain road is almost 22 km long shows many incidents of rockfalls. Rainfall took place day before and a week before rockfall. This cause a rockfall of few large blocks to take place, hit a car and break a light lamp. The height of the flying rock is about 12 m above the road level. The Rockfall computer program was utilized to analyze the event regarding modeling and mitigation. The necessary required rock mass parameters fed to the program. Parameters such as rock blocks size, initiation point, geomorphology and end point are the major factors determining the destructive effect of the rockfall event on the road. Remedial measures recommended according to the modeling process.

Zulfiqar Bin Rashid (2017) This paper summarizes the ongoing research about the defects in flexible pavements and the maintenance in flexible pavements. In the past, lots of researchers have already studied the defects and problems of maintaining the flexible pavements all over the world. Efforts have been made to refer some of the publications related to this topic. Various defects in flexible pavements have been identified since the existence of flexible pavement. Pavement structure can be destroyed in a single season due to water penetration. Defects in flexible pavements is a problem of multiple dimensions, phenomenal growth of vehicular traffic (in terms of no. of axle loading of commercial vehicles), the rapid expansion in the road network, non-availability of suitable technology, material, equipment, skilled labor and poor funds allocation have all added complexities to the problem flexible pavements. Maintenance is set of activities directed towards keeping a structure in a serviceable state during its design life. Maintenance of a road network involves a variety of operations, i.e., identification of deficiencies and planning, programming, and scheduling for actual implementation in the field and monitoring.

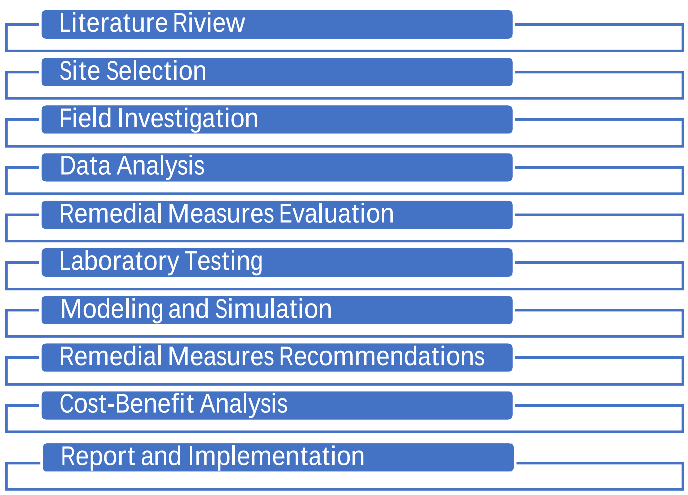
Tanuj Chopra (2017) The aim of the study is to develop Pavement Maintenance Management System (PMMS) for four road sections of urban road network (Patiala, Punjab, India) using Highway Development and Management (HDM-4) model. The HDM-4 provides a deterministic approach in data input and process data of existing road condition, traffic volume and pavement composition to predict road deterioration as per the urban road conditions in terms of International Roughness Index (IRI) value. This study presents the use of HDM-4 model for the computation of optimum Maintenance and Rehabilitation (M&R) strategy for each road section and comparative study of scheduled and condition responsive M&R strategies. The results of present study will be useful for gaining better support for decision-makers for adequate and timely fund allocations for preservation of the urban road network. Mohd AzharUd Din (2019): This Study is a survey to evaluate the flexible pavement conditions to determine and specify the types of the failures in the pavement for the selected highway. It is very significant to evaluate and identify the causes of the flexible pavement failures and select the proper and best treatment and maintenance. The study has two major and critical goals which are covered by considering the following three tasks, the first was the visual evaluation and inspection of existing flexible pavement conditions including the failures, the second to determine and find out the actual treatments and maintenance types. As a case study, of Baheerah to Doda Road (NH-1B) was selected for evaluation and inspection purpose. The field evaluation works were achieved on the existing flexible pavement conditions of the selected highway. The results were most of the damages and failures in the pavement are serious and extreme surface deformation, cracks disintegration, and surface defects. These damages and failures are caused by fatigue and other types of failures resulted from the movement of heavy vehicles and trucks, poor drainage design, unsuitable pavement layers thickness design, and improper pavement mix design and selected materials.

Sumaya Basheer (2020) Investigation and repair on highway network system are major expenses in the state budget. Generally, after the opening of newly constructed or maintained or newly widened roads which is very good in terms of level of service, but after some time due to increase of traffic volume and weather changing especially in monsoon season the road quality is decorated at every use of traffic after that the road gets completely decorated with uneven cracks, potholes etc. Road failure is because of many factors, the four primary reason of road failure are failure in design, construction, maintenance, material used and geometry of the roads. For above mentioned reason various concerned organisation are pointing out the need for developing an intelligent, well and efficient road performance model that can prioritize pavement maintenance and rehabilitation work. With weak maintenance system of the road various defects in the roads are main causes of accident. Maintenance of a road network involves a variety of operations i.e., Ideification of deficiencies and planning, programming, and scheduling for actual implementation in the field and monitoring. The essential objective should be to keep the pavement in good condition and to extend the life of road assets to its design life. So, to be a successful engineer, a person should not only able to design the road but also skillful to maintain the road.

Riyaz Khanday (2021) during this research work, emphasis was made on the defects in flexible pavement and therefore the maintenance in flexible pavements. within the past, many researchers have already studied the defects and problems of maintaining the flexible pavements everywhere the planet. Methods: Efforts are made to refer several the publications associated with this subject. Various defects in flexible pavements are identified since the existence of flexible pavement. Pavement structures are often destroyed during a single season thanks to water penetration. Findings: Defects in flexible pavements may be a problem of multiple dimensions, phenomenal growth of vehicle traffic (in terms of no. of axle loading of economic vehicles), the rapid expansion within the road network, non-availability of suitable technology, material, equipment, skilled labor, and poor funds allocation have all added complexities to the matter flexible pavements. Maintenance is about of activities directed towards keeping a structure during a serviceable state during its design life. Maintenance of a road network involves a spread of operations, i.e., identification of deficiencies and planning, programming, and scheduling for actual implementation within the field and monitoring. Application: The essential objective should be to stay the paved

III. METHODOLOGY

It is important to note that the specific methodology may vary depending on the scope and objectives of the study, available resources, and project constraints. The steps outlined above provide a general framework for studying structural failures in road widening projects and proposing remedial measures.



1) *Literature Review:* Conduct a comprehensive review of existing literature, research papers, case studies, and relevant technical documents to gather knowledge about the causes of structural failures in road widening projects and the remedial measures employed in similar situations. This step helps in understanding the existing knowledge and identifying research gaps.
2) *Site Selection:* Choose a suitable site or multiple sites where road widening projects have been implemented and have experienced structural failures. Consider factors such as the type of road, traffic volume, soil conditions, climate, and history of failures.
3) *Field Investigation:* Conduct a detailed field investigation of the selected sites to gather data and observations. This may involve visual inspections, surveys, geotechnical investigations, pavement condition assessments, and measurements of distresses such as cracks, rutting, settlements, and deformations. Collect relevant data on the original road structure, widening construction details, drainage systems, and subgrade conditions.
4) *Data Analysis:* Analyze the collected data to identify the causes of structural failures. This may involve quantitative analysis of distress patterns, correlation between failures and specific factors such as inadequate drainage, poor compaction, subgrade instability, or design deficiencies. Statistical analysis and modeling techniques can also be employed to understand the relationships between variables.
5) *Remedial Measures Evaluation:* Evaluate the existing remedial measures employed at the study sites and their effectiveness in addressing the structural failures. This may include examining the performance of repair techniques, reinforcement methods, drainage improvements, and other remedial measures adopted in the past. Assess the durability, functionality, and long-term sustainability of the implemented solutions.

6) *Laboratory Testing:* Conduct laboratory testing on collected samples of road materials, including soil, asphalt, concrete, or other components, to determine their physical and mechanical properties. This can provide insights into the material characteristics and their contribution to the structural failures.
7) *Modeling and Simulation:* Develop numerical models or use computer simulations to analyze the behavior of the road structure before and after widening. This can help in understanding the structural response under different loading and environmental conditions and assessing the impact of various remedial measures.
8) *Remedial Measures Recommendations:* Based on the findings from the field investigation, data analysis, laboratory testing, and modeling studies, propose remedial measures that are suitable for addressing the specific causes of structural failures identified. Consider factors such as drainage improvements, reinforcement techniques, compaction requirements, pavement design modifications, and material selection.
9) *Cost-Benefit Analysis:* Conduct a cost-benefit analysis of the recommended remedial measures to evaluate their economic feasibility and practicality. Consider the initial investment required, expected lifespan of the solutions, and potential long-term cost savings in terms of maintenance and repairs.
10) *Report and Implementation:* Prepare a comprehensive report summarizing the study findings, analysis, recommendations, and conclusions. Present the report to relevant stakeholders, such as transportation authorities, engineers, and policymakers, for consideration and implementation.

IV. RESULTS AND DISCUSSIONS

Widening and repairing design topography, geometry and crossfall: The topography of the existing road, its geometry and crossfall, should always be considered when designing the widening structure. The widening of a road with limited space can result in steeper side slopes. In most cases where space is not a problem, e.g., on low-volume forest roads, the best way is to create more space is by felling trees adjacent to the road. On sites where space is limited steeper side slopes may be possible in the widening using reinforcement and/or retaining walls. . It will also be important to keep in mind that the old ditch will need to be backfilled with material equal to the surrounding subgrade, such as excavated material from the new ditch. The choice of the most suitable type of drainage system will also be a major consideration for sites with limited space.

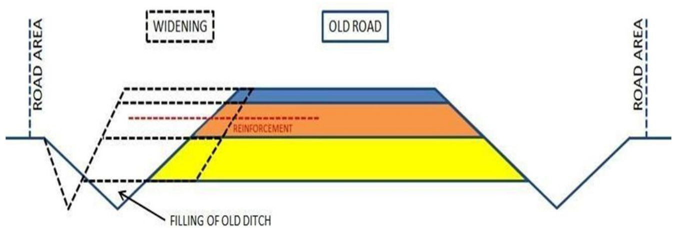


Figure. Widening can lead to steeper side slopes if the space for the road is limited.

In many cases it will be beneficial to upgrade the horizontal geometry of the existing road during at the time of widening. It should be borne in mind however that the improvement of sharp curves on the old road can lead to diagonal construction joints between the new and the old structure. These may present problems if special attention is not paid to joint construction. However, the improvement of the old road at the same time as the widening, e.g., by adding aggregate, is a good practice that can decrease the impact of traffic loading and frost action. Further, the risk of failures can also be diminished.

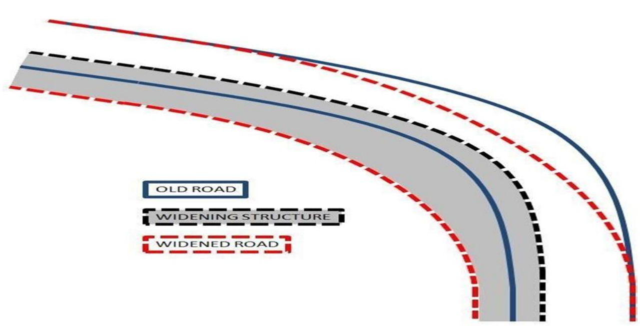


Figure. Diagram showing the upgrading the horizontal geometry of an existing road during a widening exercise.

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Figure. Diagram showing the upgrading the horizontal geometry of an existing road during a widening exercise.

Careful attention should be paid to the design and construction of inner curves during a widening exercise. The general practice in the Northern Periphery is to dimension road structures based on the centreline thickness, but this can result in the thickness of the structure in inner curves being less than the centreline. Because of this widening on the inner curve side can have a higher risk for failures than widening on the outer curve side. Widening in the inner curve side is recommended however as the road geometry can be improved at the same time.

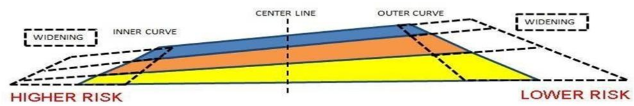

Figure. Thinner structure in inner curve

A potential error in the construction of a widening is that the crossfall is ignored when excavating into the existing embankment. If the excavation is made horizontally, this may lead to a thinner structure thickness in the side of the road compared to the centreline. This fact can lead to pavement failures, especially edge deformation, if not considered.

Old road structures: old structures below or inside the existing road structure can cause discontinuities and pose potential problems for widenings. These old structures may include for example an old gravel road below the existing structural layers, old reinforcement, old pavement layers inside the structure etc. On the other hand, the construction history of the existing road can give good information on the solutions that have worked well in the past on the existing part of the road. These same methods can be considered for use in the widening design to obtain a well working structure.

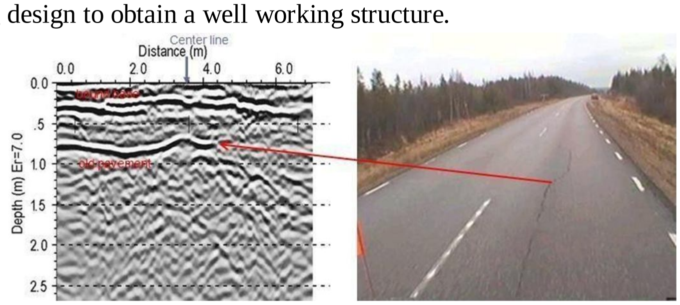

Figure. Old pavement inside the road structure causing reflection cracking.

Differential frost heave between the old road and the widening structure can be a major problem. The recommended methods to minimise this type of frost action include good consistent drainage, the use of reinforcement, and above all maximum compatibility of the structures. It is strongly recommended that the structural thickness, the material properties, as well as the degree of compaction of the widening layers should be as equal as possible to those of the existing embankment. Often it is beneficial to improve the old road at the same time as the widening, e.g., by adding aggregate. This practice decreases the impact of frost action and the risk of failures. The following "rule of thumb" is recommended: A. If the maximum frost heave on the old road is less than 10 cm, equal widening structures should be enough. B. If the maximum frost heave on the old road is 10 cm or more, the old part of the road should also be improved during widening. DRAINAGE Providing a well working drainage system is a very effective way, and absolutely the cheapest method, to improve the bearing capacity of a road and prevent frost problems. Road widening is not an exception to this, and the design of a road widening should always include a drainage design as well. Generally, drainage should always be improved to good condition in any case, no matter whether the design is for a new widening structure or repairing an existing one.

Settlement and compressive soils: When widening a road on compressive soil it is essential that a uniform settlement is achieved across the old and new part of the embankment. Assessing the settlement of the existing embankment can be difficult as it usually has already settled due to the weight of the structure and the traffic load. Settlement in the existing embankment can also be restarted or increased after widening part has been built, or during upgrading the road. It can also be difficult to evaluate the settlement of the new part of the road.

A cheaper, and less harmful, solution for widening "floating" low volume roads over peat is by preloading. This can be carried out with an overload embankment.

When using a preload/overload embankment it is essential to design the settlement time. This is essential to ensure that the old and the new parts move similarly after the overload is removed. The construction sequence for widening by preloading is given below (see also Figure.) 1. dig a new intercepting ditch 10m off the old road and use the excavated peat to refill the existing roadside ditch 2. remove any fine materials from the road shoulders, approximately 200 mm deep 3. lay a separator grade geotextile on the prepared shoulder and reform the cross-section with good material 4. lay a 5m wide reinforcement grade geotextile across the area to be preloaded 5. commence preloading of the road widening in 1m stages until the designed preloading height is reached 6. leave the preload in place for 90 days (or as instructed by the design geotechnical engineer) and monitor its performance by means of settlement plates 7. remove the excess preload material after the designed settlement has been achieved 8. construct the new widened road layers.

will be needed for this type of widening to estimate the height and duration of the preloading required together with the likely predicted settlement.

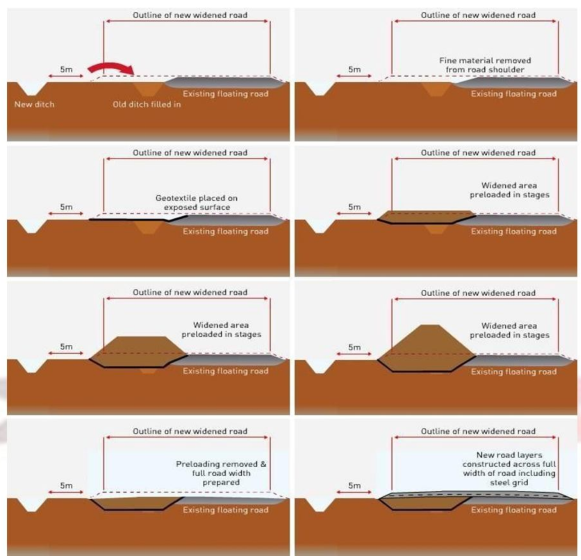

Figure . The construction sequence for widening by preloading on peat subgrade.

V. CONCLUSION

successful road widening project is dependent on several factors and considerations, as the weakest link determines the lifetime of the structure. Neglecting even a single consideration can lead to significant failures. While defects may not be immediately apparent after construction, the effectiveness of the widening becomes evident over time. Thorough surveys and diagnostics are crucial before designing road widening projects. Understanding the site conditions, such as the thickness of old road structural layers, subgrade material properties, materials used in the old embankment, road shape, surrounding areas, existing road damages, and drainage conditions, is essential. Certain measurements, such as ground-penetrating radar (GPR) scans, video recordings, laser scanner measurements, and drainage analysis, are recommended to gather accurate and objective information about the road's condition.

construction joints between the old and new parts of the embankment can be made in various ways. Stepped joints and angled joints are recommended options, while vertical joints should only be used when necessary. The details of such joints depend on the embankment structure and subgrade. Longitudinal reflection cracks between the original embankment and the widened part are common in paved roads. These cracks result from differential movement and shear problems. Achieving uniform movement on both sides of the road body can help avoid such cracks. Constructing a durable pavement joint can provide short-term relief, but the underlying vertical interface at the widening can still lead to reflective cracking. It is crucial to locate construction joints away from the wheel path to prevent reflection cracking and the subsequent infiltration of surface water that can weaken the embankment and cause frost problems. Road widening on soft soils presents significant challenges, and equal settlement between the old embankment and the widening part is essential. Often, the old embankment has already experienced partial settlement into the soft soil before the widening is added. Adding the widening portion and possibly upgrading the road can increase or restart settlement in the existing embankment.

Preloading is typically required, and the widened parts can be tied to the existing embankment using steel grids or geogrids. Settlement in soft soils can sometimes be mitigated through soil replacement or stabilization methods. In summary, careful consideration of various factors such as site conditions, materials, construction joints, drainage systems, and compaction is vital for the success and longevity of road widening projects. Addressing these aspects appropriately can help avoid failures and ensure the performance of the widened road aligns with the existing structure.

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[3] Neero Gumsar Sorum1 , Hanomansing Guite2 , Nungleppam Martina3 Assistant Professor, Civil Engineering Dept, NERIST, Nirjuli, Arunachal Pradesh, India 1 B. Tech. Student, Civil Engineering Dept, NERIST, Nirjuli, Arunachal Pradesh, India2 B. Tech. Student, Civil Engineering Dept, NERIST, Nirjuli, Arunachal Pradesh, India3An ISO 3297: 2007 Certified Organization Volume 3, Special Issue 4, March 2014 National Conference on Recent Advances in Civil Engineering (NCRACE-2013) During 15-16 November, 2013 Organized by Department of Civil Engineering, North Eastern Regional Institute of Science and Technology, Nirjuli, Itanagar, Arunachal Pradesh, India.

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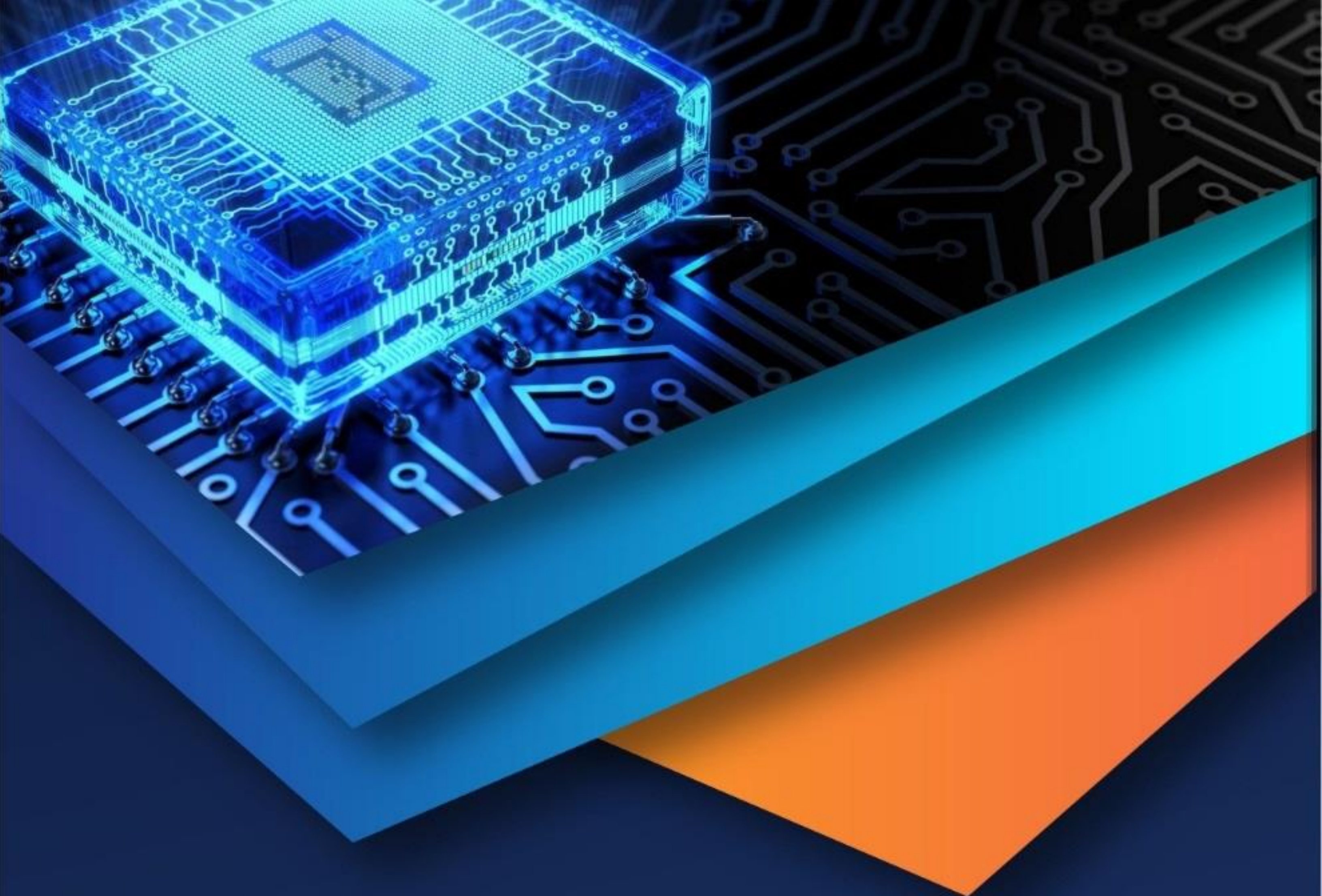

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TOGETHER WE REACH THE GOAL
IMPACT FACTOR:
7.429

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