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NHAI

Maintenance Manual

Table of Contents

PART 1: INTRODUCTION 3

1.1 Overview of Highway Infrastructure in India 3

1.2 Purpose and Objectives of the Manual..... 3

1.3 Importance of Maintenance 3

1.4 Types of Maintenance 4

1.5 Types of Highway Assets..... 5

1.6 Broad Scope of Operation & Maintenance of the Contractor/Concessionaire/O&M Agency: 6

1.7 Organizational Structure & Minimum Key Personnel for Operation & Maintenance of the Project Highway by the Contractor/Concessionaire/O&M Agency 7

1.8 Role & Responsibility Of key-personnel 8

1.9 Inspections 10

1.10 Services to be provided at Project Facilities 14

1.11 Asset Inventorisation:.....14

1.12 Structure of the Manual 15

1.13 Reference Standards, Codes and Guidelines 16

1.14 Revision of the Maintenance Manual 17

PART 2: PAVEMENT MAINTENANCE 17

2.1 Types of Pavements and Common Distresses.....17

2.2 Investigations 28

2.3 Intervention Levels and Treatments.....40

PART 3: STRUCTURE MAINTENANCE 64

3.1 Background 64

3.2 Types of Structures 64

3.3 Classification of Structures 65

3.4 Inspection Protocols 66

3.5 Distresses in Structures 68

3.6 NDT testing.....79

3.7 Data Collection Mechanism 81

3.8 Prioritization of Bridges for Maintenance 83

3.9 Maintenance Protocol 88

PART 4: ROAD SIGNAGE AND FURNITURE MAINTENANCE 93

4.1 Introduction....93
4.2 Pavement Marking....93
4.3 Road Signs....94
4.4 Traffic Blinkers and Signals....96
4.5 Highway Lighting....97
4.6 Vehicle Restraint System (VRS)....99
4.7 Guardrails....101
4.8 Anti Glazers....102
4.9 Footpath....103
4.10 Separators....104
4.11 Noise Barriers....104
4.12 Object Markers & Road Studs....105
4.13 Road Studs....106
PART 5: MAINTENANCE OF OTHER HIGHWAY ELEMENTS....107
5.1 ROW and Horticulture Maintenance....107
PART 6: SYSTEMS MAINTENANCE....114
6.1 Toll Management System....114
6.2 Advanced Traffic Management System (ATMS)....117
PART-7....129
WORK ZONE TRAFFIC MANAGEMENT PLAN AND SAFETY DURING MAINTENANCE ACTIVITIES 129
7.1 Health Safety and Environmental Policy....129
7.2 Scope of safety....129
7.3 4 M CONCEPT (SYSTEM)....129
7.4 Safety During Maintenance Operations....131
7.5 Safety & Health Expectations / Requirements....132
7.6 Work at Height....133
7.7 Electrical Management & Hazard Control....135
PART 8: TECHNOLOGY INTEGRATION....137
8.1 Maintenance Module in NHAI ONE Application....137
8.2 Bridge Inventory and Condition Rating System (BICRS)....140

PART 1: INTRODUCTION

1.1 Overview of Highway Infrastructure in India

India has the second largest road network and its National Highways span a total length of 146,195 km, forming the primary arterial network of the country. This vast network serves as a critical backbone of the nation's transportation system, facilitating the movement of goods and passengers across urban and rural areas alike. Remarkably, the road network handles high volume of the total goods transported within the country and is responsible for supporting majority of India's passenger traffic, making it an indispensable component of the country's economic and social framework.

The sheer scale of India's road infrastructure necessitates a robust, systematic approach to its management and maintenance. Effective road asset management is vital for ensuring seamless transportation, economic growth, and public safety. Given the significant dependency on roads for freight movement and commuter transit, prioritizing the upkeep of this infrastructure becomes imperative. Ensuring roads are maintained to meet required serviceability levels—defined by parameters such as roughness, durability, and traffic capacity—plays a pivotal role in sustaining the efficiency and reliability of the network. A well-maintained road network reduces travel time, minimizes vehicle operating costs, enhances safety for users, and reduces the environmental footprint by mitigating fuel consumption and emissions caused by poor road conditions.

The enormity and criticality of India's road network demand a well-planned, resource-optimized, and technologically driven approach to asset management. Ensuring roads are maintained to required serviceability standards is not just a technical necessity but a fundamental investment in the nation's progress and connectivity.

1.2 Purpose and Objectives of the Manual

The objective of this manual is to provide a comprehensive overview of the procedures involved in assessing the condition/performance of various highway assets, identifying appropriate intervention levels, and outlining treatment and rectification methodologies for these assets. The manual is designed to serve as a guide for effective management and maintenance of highway infrastructure, ensuring safety, functionality, and sustainability.

Highway Assets covered in this manual include pavement, structures, road furniture and road signage, TMS (Toll Management System) and ATMS (Advanced Traffic Management System). In Addition to the highway assets, the manual also places significant emphasis on highway safety, detailing protocols for work zone traffic management and safety during maintenance activities. Further, the manual also introduces the advanced technology integration strategies adopted by Industry to enhance the operations and maintenance of highway assets. By combining traditional methodologies with innovative technologies, it is aimed to ensure optimal performance, safety and longevity of highway infrastructure while optimising costs and environmental impact.

1.3 Importance of Maintenance

Highway maintenance plays a vital role in sustaining the safety, efficiency and longevity of road infrastructure. As highways form the backbone of transportation networks, their proper upkeep ensures smooth operations, optimises life cycle costs and supports broader socio-economic objectives. The following are the key reasons why highway maintenance is indispensable:

I. Ensure Safety: A well-maintained highway significantly reduces the risk of accidents and enhances road safety. Maintenance activities address safety hazards such as potholes and cracks that can cause vehicle damage/accidents, faded road markings and signage that can impair driver awareness and malfunctioning traffic lights and management systems that can disrupt the traffic flow.

II. Cost Efficiency: Timely and routine maintenance prevents minor issues from escalating into major, more expensive repairs. By investing in proactive maintenance strategies, the lifespan of pavements and structures

can be prolonged, the need for costly emergency repairs can be minimised, resource allocation for long term infrastructure management can be optimised.

III. Minimise Traffic Disruptions: Maintaining highways ensures uninterrupted traffic flow, which is crucial for reducing travel delays, congestion caused by road closures/damaged sections, enhancing daily commute experience for road users, supporting efficient movement of goods and services.

IV. Prolong Infrastructure Lifespan: Regular maintenance is less costly than rebuilding the roads. Addressing minor issues proactively prevents them from becoming major problem requiring full-scale reconstruction. It also ensures strength of bridges, overpasses and other highway components, reducing the likelihood of catastrophic failures.

V. Environmental Impact: Regular maintenance helps to provide smooth roads to improve fuel efficiency by reducing resistance, which helps lower vehicle emission. Regular cleanup of debris and waste along the highways help in protecting and maintaining aesthetic appeal.

Thus, highway maintenance is a critical investment in public safety, economic growth and environmental sustainability. Neglecting it can lead to higher long-term costs, reduced productivity and increased risks for all road users.

1.4 Types of Maintenance

Highway maintenance involves activities and measures to keep roads in good condition, ensuring safety, functionality and longevity. It is typically categorised into different types based on the nature of work and the urgency of repairs. The main types of highway maintenance include the following:

I. Routine Maintenance: Regular, continuous activities that preserve the roadway in its original condition and prevent minor defects from escalating. These activities are essential for preventing minor issues from escalating into major problems and are carried out continuously over the life of the highway. Which includes but not limited to Repair of pavement cracks; maintain the drains & ducts, Footpath and Cycle track, Kerbs, line marking, road furniture, lighting and signage, free of litter & debris and their disposal etc. with, reasonable measures for safety of workmen & materials. Clearing of branches and vegetation affecting visibility, checking of street lights, clearing of damaged vehicles, illegally parked vehicles, measures required in special situations like Fire, Oil spilling etc.

II. Preventive Maintenance: Preventive measures taken to prevent deterioration of the assets and extend its lifespan without any need for major strengthening. The scope includes but not limited to Minor cuts, ruts, proper Drainage of Rain water from pavement and shoulders through spots, weep holes etc. clearing of drains, weep holes spouts slab drain, damages of Project Highway which do not completely obstruct the traffic but endanger the safety of traffic, shall be attended to on an urgent basis Major breach in the roadway of any type which cause danger to safety of traffic and cause obstruction in movement of vehicle. The scope also has activities like closure/prevention of creation of Un-authorized entry to and exit from the Project Highway. Preventing encroachments on the Project Highway and preserving the Right of Way from ribbon development.

III. Periodic Maintenance: Scheduled maintenance activities performed at regular intervals to restore the road to its designed standards. Including but not limited to Profile corrective course of overlaid with the periodic renewal of the wearing course of the road pavement.

a. Separator / island shall be restored to the design cross section.

b. Cross Barrier requires minimum maintenance.

c. Concrete post/ metal beam cross barriers require repairs

d. Cleaning, repairing and maintenance of various road furniture. Inspection of rain harvesting system, drainage sanitary systems, maintenance of Electrical installations. Periodic painting will be required in some areas. Maintenance / Painting of all furniture and furnishing items.

IV. Major Maintenance: Comprehensive rehabilitation and strengthening activities conducted either at the end of the asset's life cycle or when significant deterioration necessitates substantial repairs to restore

functionality. Special repairs may also be required on account of failure of an element of Project Highway. Structures may also require rehabilitation or even re-construction.

1.5 Types of Highway Assets

Highway assets are physical components that make up the infrastructure of a highway system. These assets are critical for ensuring functionality, safety, and efficiency. Below are the main types of highway assets categorized based on their functions:

I. Roadway: Roadway includes pavement, embankment, shoulder, kerb, median and drainage

(a) Pavement – Asphalt or concrete surfaces layers designed for carrying traffic along with granular & Sub-base & base layers.

(b) Embankment – It is an elevated structure made of soil, rock or other materials designed to raise the roadway above the surrounding terrain. Embankments are commonly used in highway construction to provide a stable and elevated platform for vehicles, improve drainage and cross low-lying areas such as wetlands, rivers or valleys.

(c) Shoulders - A highway shoulder is the portion of the roadway adjacent to the travelled lanes, designed to provide additional space for vehicle-related and safety purposes. It is a critical element of highway design, ensuring functionality, safety, and emergency access.

(d) Kerb – It is a raised edge or barrier along the side of a road or highway, typically made of concrete, stone, or asphalt. It serves multiple functions related to safety, drainage, and road aesthetics. Kerbs are commonly used in urban areas, highways, and other roadway systems to delineate the edge of the pavement and provide structural and functional benefits.

(e) Median - Highway median is the area separating opposing lanes of traffic on a divided highway or road. It plays a crucial role in improving safety, managing traffic, and providing space for other roadway elements like signage or landscaping.

(f) Drainage - Highway drainage refers to the system and design of structures used to manage and remove water from the surface and subsurface of highways. Effective drainage is crucial to ensure the longevity, safety, and functionality of the roadway. Poor drainage can lead to structural damage, accidents, and costly repairs.

II. Structures: Highway structures refer to the various built elements or infrastructure that are an integral part of a highway system. Highway structures are typically built with strong materials like concrete, steel, or asphalt to withstand traffic loads, weather conditions, and environmental forces. Major types of highway structures include Grade Separated Intersections, Major Bridge, Minor Bridge and Culverts.

III. Road Signage and Road Furniture: It includes various components including pavement marking, sign boards, traffic blinkers, highway lighting, safety barriers, guardrails, anti-glazers, footpath, separator, noise barriers and object markers.

(a) Pavement Marking - Pavement markings are visible indicators placed on roads and highways to guide drivers, enhance safety, and ensure efficient traffic flow. These markings communicate important information about lane boundaries, directions, warnings, and regulations, complementing road signs and signals.

(b) Signboards - Highway signboards are essential elements of road infrastructure, designed to provide critical information to drivers and pedestrians. They guide, warn, and regulate traffic, ensuring road safety and efficient traffic management.

(c) Traffic Blinkers - Traffic blinkers are traffic control devices used to enhance road safety and provide warnings to drivers, pedestrians, and other road users. These lights are highly visible and are designed to alert individuals to potential hazards, regulate traffic, or provide guidance in various situations.

(d) Highway Lighting - Highway lighting is an essential component of transportation infrastructure designed to improve safety, visibility, and overall driving conditions during nighttime or in low-visibility environments.

Proper lighting reduces accidents, enhances road security, and improves the comfort of drivers, passengers, and pedestrians.

(e) Safety Barriers - Safety barriers are designed to protect vehicles, pedestrians, and infrastructure by redirecting or absorbing the impact of a collision. They are a critical component of road safety systems, particularly on highways, bridges, and interchanges. These barriers are installed along roadways to reduce the severity of accidents and prevent vehicles from veering off the road or colliding with fixed objects.

(f) Guardrails - Guardrails are a type of safety barrier installed along roads and highways to prevent vehicles from veering off the road, crashing into obstacles, or crossing into oncoming traffic. They are designed to absorb and redirect the force of a vehicle's impact, minimizing the potential for injury and property damage. Guardrails are critical components of road safety, especially in areas with sharp curves, steep slopes, and high-speed roads.

(g) Antiglazers – These are safety features used on highways and roads to reduce the impact of bright lights, particularly from oncoming traffic or streetlights, which can cause glare and reduce visibility for drivers. These barriers are typically installed in locations where such glare is likely to be a problem, such as along curves, intersections, and in areas where traffic flows in opposing directions.

(h) Footpath - A footpath is a pedestrian pathway provided alongside or within the right-of-way of a road or street, designed to ensure the safe and efficient movement of pedestrians. It is separated from the vehicular traffic lanes, often by a curb, grass verge, or other physical barriers, to provide a safe space for walking.

(i) Separator – It is a physical or painted structure to separate the main carriageway from the service road.

(j) Noise Barriers - Noise barriers are structures built along highways, roads, or railways designed to reduce the level of noise pollution from traffic.

(k) Object Markers - Object markers are safety devices used along highways and roadways to indicate the presence of hazards, obstacles, or objects that could pose a danger to motorists.

IV. Toll Management System/Advanced Traffic Management System

Toll Management System (TMS) is a comprehensive solution for efficiently collecting, managing, and monitoring toll charges on highways, bridges, or tunnels. It integrates technology to streamline toll operations, reduce congestion, and enhance the overall user experience while ensuring accurate revenue collection. **Advanced Traffic Management System (ATMS)** includes all the outdoor and indoor components which are responsible to indicate the traffic flow and to provide emergency services all round the clock across the highway

V. Project Facilities

Project Facilities is a collective term used to indicate the facilities available along the highways to facilitate efficient operation and maintenance of highway and user comfort. Major project facilities include bus bays, truck lay byes, toilet block/rest area, traffic aid post etc.

VI. Miscellaneous

Other miscellaneous components of highway include O&M Centre, Material testing laboratory, Toll Plaza/Administrative Building, Landscaping etc.

Highway assets are a comprehensive collection of structures, systems, and materials that work together to ensure the safe, efficient, and sustainable movement of vehicles. Proper maintenance and management of these assets are crucial for maximizing the lifespan of the highway infrastructure, minimizing traffic disruptions, and enhancing safety. Detailed procedure to inspect the condition of the assets, performance evaluation and checklist for each of the highway assets are explained in detail in the upcoming sections.

1.6 Broad Scope of Operation & Maintenance of the Contractor/Concessionaire/O&M Agency:

The scope of operation and maintenance of the project highway in accordance with relevant clauses of BOT/HAM/EPC/Item rate agreement includes the following: -

(a) Procuring and ensuring safe, smooth and uninterrupted use of the Project, including prevention of loss or damage thereto, during normal operating conditions.
(b) Minimizing disruption in the event of accidents or other incidents affecting the safety and use of the Project by providing a rapid and effective response and maintaining liaison with emergency services of the State.
(c) Carrying out periodic preventive maintenance of the Project.
(d) undertaking routine maintenance including prompt repairs of potholes, cracks, joints, drains, embankments, structures, markings, Lighting, signage and other control devices.
(e) Undertaking major maintenance such as resurfacing, repairs to structures, and repairs and refurbishment of system and equipment.
(f) Preventing, with the assistance of concerned law enforcement agencies, any unauthorized use of the Project.
(g) Preventing, with the assistance of the concerned law enforcement agencies, any encroachments on, or unauthorized entry to the Project.
(h) Protection of the environment and provision of equipment and materials thereof.
(i) operation and maintenance of all communication, control and administrative systems necessary for the efficient operation of the Project and for providing safe, smooth and uninterrupted use of the Project.
(j) Maintaining a public relations unit to interface with and attend to suggestions from the Users, government agencies, media and other agencies; and
(k) Complying with Safety Requirements in accordance with relevant Article of the Concession/Contract Agreement.
(l) The Contractor/Concessionaire should procure that at all times during the Operation Period; the Project conforms to the maintenance requirements set forth in respective Schedule/clause of the contract/Concession Agreement (the "Maintenance Requirements") such as Schedule-K in HAM/BOT Projects.

1.7 Organizational Structure & Minimum Key Personnel for Operation & Maintenance of the Project Highway by the Contractor/Concessionaire/O&M Agency

The following shall be the Organisation Structure of the O&M team of Contractor/Concessionaire/O&M Agency the with the stipulated minimum key-personnel:

For stretches under O&M Phase, the following details should be submitted by the Contractor/Concessionaire/O&M Agency before commencement of the work:

Table 1.1 Details of key-personnel and Contact Numbers

Sr No	Description	Deployed Manpower (Nos)	Name	Contact No.
1	O&M In-Charge			
2	Manager O&M			
3	Civil Engineer			
4	Electrician			
5	Route patrol officer/Safety Officer			
6	ITS Engineers Software & Hardware			
7	Paramedical/EMT Staff			
8	Supervisor			
9	Control Room Operator			
10	Office Assistant/HR Assistant			
	Total			

1.8 Role & Responsibility Of key-personnel

1.8.1 Job Description of In-charge (O&M)/ Manager (O&M): -

- Responsible for coordination of all operational and Maintenance activities stipulated under the Concession agreement.
- Responsible for liasoning with NHAI, Police, Emergency Services and all other bodies relevant to smooth operations of the project stretch.
- Responsible for all official communication with clients, government bodies and other agencies involved in operation and maintenance in consultation with seniors.
- Implementation and monitoring of all periodic and major maintenance works and ensure all work is being done in accordance to the Concession Agreement and Specification.
- Prepare all the traffic management control plans and schemes to be used in controlling the traffic flow during the maintenance works and in emergencies.
- Conducting the review meetings for all operations and maintenance activities.

1.8.2 Job Description of Route Patrol Officer: -

- The Route Patrol Officer will be responsible for proper functioning of the Control room Operations, Route Patrol Services, Ambulance Services and Crane/Towing services.
- Employees appointed should be able to read/write and maintain logbooks
- Patrolling the Highway
- Managing Incidents/Accidents
- Responsible for generating accident reports as per the manual and data collected from police stations along the stretch.
- Implementation of Lane Closer/diversion Procedure whenever required for maintenance or removal of accidents.
- Interfacing with the local agencies like Police, Fire Brigade, Hospitals etc.
- Reporting of damage on the road/Assets
- Encroachment control & removal
- Removal of illegal parked vehicles on project highway
- The Route patrol officer would be also responsible for managing and maintaining all route operations equipment's including vehicles.
- Employees appointed should undergo training including fields such as:
- Vehicle use and maintenance.
- Safety policies.
- Radio and communication procedures.
- Public relations/ customer service.
- Defensive driving.
- Public relations/customer service.
- Maintenance of traffic.
- Vehicle recovery procedures.
- Victim extrication procedures.
- Extinguishing vehicles fires.
- Basic first aid training.
- Work side protection.
- Minor vehicle repairs.

1.8.3 Job Description of Paramedical/EMT Staff: -

- The Route Patrol Officer will be responsible for proper functioning of the Control room Operations, Route Patrol Services, Ambulance Services and Crane/Towing services.
- 1 EMT should be appointed per shift per vehicle.

- Ability to read/ write & maintain logbooks.
- Employees appointed should undergo at least one training course (with duration of a minimum of one month) in a tertiary care institution or at a recognized institute with experience in handling life-saving equipment.
- Basic training of employees should include fields such as:
- Vehicle and equipment use and maintenance.
- Victim extrication from a crashed/damaged vehicle.
- Safety policies.
- Radio and communication procedures.
- Public relations/customer service.

1.8.4 Job Description of Maintenance Engineer: -

- Responsible for all Routine, periodic and major maintenance work and its implementation as per specifications described in Schedule-F
- Ensuring all quality and safety procedures are adhered to in performing the maintenance works to be executed at project highway.
- Responsible for conducting visual, close and thorough inspection in consultation with IE as per concession agreement.
- Preparation of all reports, MIS and formats for onward submission to IE.
- To ensure proper functioning and maintenance of all public utilities along the highway.
- Responsible for Plantation, maintenance of vertical gardens, fountains, functioning of FOBs and other facilities.
- Monitoring of painting of structures, kerb, crash barriers, removal of debris, Desalting of Drains, removal of vegetation affecting sight line and including all major/minor activities pertaining to maintenance of the project.
- Maintenance of Road furniture along with the project as per CA.

1.8.5 Job Description of ITS Engineer: -

- To ensure proper Functioning of the Advanced Traffic Management System including the CCTV and Central Control System.
- Preparation of MIS and all ATMS related reports as per approved formats.
- Timely attending and reporting of any major/minor fault in ATMS.
- Responsible for generating incident detection reports.
- Responsible for all ITS and IT related work on the project.

1.8.6 Job Description of HR Admin Executive/Accountant: -

- Responsible all general HR and Admin related work pertaining to the project and O&M building.
- Responsible for implementation of all HR/Statuary compliance.
- Monitoring of manpower for security services, Housekeeping, maintenance work etc.
- Responsible for general maintenance of all public facilities like public toilets, Traffic aid posts, Truck lay by Bus lay by medical aid post etc.
- Responsible for general liasioning with local agencies for providing services like water, solid waste disposal.

1.8.7 Job Description of Electrical Engineer/Foreman: -

- Responsible for attending to all minor/major faults in streetlights, high-mast, electrical panel, O&M building etc.
- Coordinating and supervision of major electrical work executed through external agency and timely reporting the same.
- Liasoning with Power Distribution Authority for smooth functioning of all electrical connections and metering.
- Attending any other electrical related issues at the project.

1.8.8 Job Description of ATMS Key personal: -

A. Routine monitoring of the Project Highway including
- Handling Emergency Calls on the Emergency Call console(s) for calls originating from roadside emergency telephones
- Traffic monitoring through visual monitoring using CCTV cameras located along the Project Highway.
- Handling of Mobile Radio communication system from the control room and giving guidance to Route Patrol Vehicle, Ambulance, Tow Crane or any other emergency requirement.
- Monitoring VIDS for any violations and submitting the report to concern.
- Generating MET reports and submitting to all concern.

B. Operation of the Traffic management and rescue console and facilitate guidance to patrolling team to perform their role on the ground.
C. Generation of Shift wise reports for submission to all concerned authorities.

1.8.9 Control Room Operations: -

The Control Room Operation shall ensure that the patrol officers perform their duties as described in the respective procedural manuals and shall always ensure compliance with the operational standards.

- Receive and log requests for assistance and other calls from all sources
- Identify the type and nature of incident or emergency
- Initiate the appropriate response according to the procedures
- Co-ordinate the traffic management and fire service resources at emergency scenes until recovery to normality
- Ensure that all Control Room equipment is fully functional
- Ensure that all equipment diagnostic functions are carried out
- Maintain a filing system for all documentation received and generated
- Copy and distribute damage reports to the maintenance department
- Ensure a clean and orderly workspace
- Maintaining all incident/accident records, received from Patrol officers as well as from road users
- Instructing an ambulance /crane operator in case of emergency
- Arranging external help if required (Police, Fire brigade, Ambulance etc.)
- Reporting faults to the Maintenance Team.

1.9 Inspections

1.9.1 GENERAL

(i) The inspections are vital for effective and efficient operations and maintenance of Highway, structures and other Facilities. Safety of the road user shall always be on top of agenda items. The main emphasis during inspection will be on the condition of the road. Identification of the locations where deterioration is occurring, measure the extent of the problem and define the action needed for rectification. Based on their nature, frequency, extent and use of tools and equipment the inspections are categorized as under:

(a) Visual,

(b) Close and

(c) Thorough.

(ii) The inspections have been programmed and are to be carried out by responsible, competent, and comprehensively trained inspectors/technicians/engineers, using predetermined checklists and formats for various elements of the Project. They shall be made fully conversant with the inspection procedures and the safety requirements.

(iii) The periodicity, timing and thoroughness of the inspections will be different and is described hereunder. The inspections have been classified into four categories – daily, monthly, quarterly, and before, during or after rainy season. These are described in the Table 1.2.

(iv) As far as possible inspections will be carried out in off-peak periods to keep traffic delays to minimal, but lane closure will be necessary whenever the pavement is being inspected.

(v) Defects identified as a result of inspections, or any other reports and complaints will be categorized into various categories as described in this manual will be programmed for maintenance, repair, rehabilitation or replacement, and will be taken up accordingly.

1.9.2 VISUAL INSPECTIONS

(i) Visual Inspections shall be broad general inspections carried out quickly and frequently by highway/bridge maintenance engineers having knowledge of road structures(CA Schedule F). The purpose of this visual inspection shall be to report the obstacles to traffic and deficiencies which could lead to accidents or maintenance problems. Such inspections should be frequent. The visual inspection shall be carried out by visual assessment with careful observation of the specific object/item of the Project Highway for identification and quantification of the deficiencies or damages of the Project Highway.

(ii) Purpose: To report the obstacles to traffic from the point of view of safety and obvious deficiencies that could lead to accidents or maintenance problems. This will bring out deficiencies/defects of obstructions, signboards, blocked drains, expansion joints, kerbs, side slopes, turfing, vegetation, Painting on fences, handrails, guardrails, delineators, and cleanliness, underpasses, ROW and the like. This inspection will also report encroachments on the Highway including ROW.

(iii) Tools & Equipment: Usually, no tools and equipment are necessary. Careful observation and visual assessment of the specific object/item of the Project are enough for identification and for quantification of the deficiencies or damages.

(iv)Inspections: The daily inspections will be done by maintenance gang men, supported/guided by Highway/bridge maintenance engineers having knowledge of highways and structures. In addition, Routine Patrol staff will also report such needs.

(v) Frequency: Quickly and frequently (see table 1.2).

1.9.3 CLOSE INSPECTIONS

(i) The close inspection shall be visual and/or supplemented by standard instrumental aids for assessment of defects / deficiencies of Project Highway with careful observation of specific element(s). The close inspection shall be daily / periodic, but it is more intensive and would require detailed examination of elements of Project Highway. It shall cover all the aspects of the specific element of Project Highway against a checklist. The close inspections shall be carried out quite frequently depending upon the nature of structure of Project Highway. This inspection shall be carried out by the Highway/Bridge Engineer having good knowledge of road structures with theoretical background to analyze the nature, and extent of defects/deficiencies, suggest suitable remedial measures to rectify/remedy them and quantify repair work.(CA Schedule)

(ii) Purpose: To report the defects / deficiencies of all aspects of specific elements of the Project Highway and recommend appropriate remedial measures. These inspections will cover Riding quality on the pavement as well as on the expansion joints, kerbs, drainage facilities, all structures including RE walls and aprons, painting on the handrails, and others.

(iii) Tools & Equipment: Close inspections may be visual and/or supplemented by standard instrumental aids for assessment of defects / deficiencies of the Project with careful observation of specific elements. These are more intensive and require detailed examination of elements of the Project. It should cover all the aspects of the specific element of the Project against a checklist.

(iv) By: Highway/bridge maintenance engineers having good knowledge of highways and structures with ability to analyze the nature and extent of defects / deficiencies and suggest suitable remedial measures to rectify / remedy them.

(v) Frequency: These may be periodic (see table 1.2).

1.9.4 THOROUGH INSPECTIONS

(i) A thorough inspection shall be comprehensive and detailed for assessment of defects / deficiencies of the Project Highway by visual inspection or with the aid of standard equipment and non- destructive testing methods where necessary. Such an inspection shall be carried out based on a comprehensive checklist of items related to the materials, condition and situation of the structure etc. The checklist shall be prepared meticulously well in advance of inspection. Thorough inspection shall be undertaken during the most critical weather conditions, which is generally rainy season in project areas. During the rainy season, the Road/Bridge structures shall stand vulnerable for the damages and therefore deficiencies of the Project Highway shall be more pronounced. The inspection carried out during the raid period shall provide the most critical evaluation of the performance of the structure. Thorough inspections shall be of importance for Bridges, Culverts and drainage structures as well as road pavements during adverse weather conditions of monsoon period.

(ii) Besides having a qualified Highway/Bridge engineer, the inspection team leader shall be familiar with design and construction features of the Highway /Bridges to be inspected so that the condition can be properly and accurately assessed for a meaningful report and quantification of repair works. The competence of team leaders to recognize any structural distress/deficiencies and assess its seriousness with complete recommendation for appropriate repairs shall be an important pre- requisite for entrusting this assignment to them.

(iii) Purpose: To report condition of materials, structures, various elements, particularly with respect to the bridges, culverts, cross drainage structures, their silting or scouring, pavement during adverse weather conditions, drainage system including catch pits, drains, etc.

(iv) Tools & Equipment: Thorough inspections will be done with comprehensive checklist/formats prepared meticulously in advance for various structures/elements, with aid of standard equipment and non-destructive testing where necessary.

(v) By: Qualified Highway/bridge maintenance engineers. Sometimes he may have to be a Specialist. The team leader must be familiar with design and construction features of the Highway/bridges. He shall accurately assess any structural distress/deficiency and assess its seriousness. He will recommend appropriate repair/remedial measures.

(vi) Frequency: These will be taken up at fixed intervals. For drainage related issues these will be during most critical weather conditions, generally rainy season when the pavement/structures are under severe condition and deficiencies are more pronounced (see table 1.2). The inspection frequency can be suitably revised (increased or decreased) in consultation with the Authority.

1.9.5 INSPECTION TEAMS

(i) Visual Inspections:

- Maintenance Engineer
- Route Patrolling Staff

(ii) Close Inspections:

- Maintenance Engineer
- Assisted by Supervisors / Workmen

(iii) Thorough Inspections:

- Project Manager
- Maintenance Engineer
- Maintenance Supervisors / Workmen

The inspection frequency of various items of Project Highway has been indicated in Table -1.2 below. The frequency of inspection shall be suitably revised in consultation with the Supervision Consultant and Authority, if the emergencies/site conditions so warranty.

Table 1.2: Objective and Frequency of Inspection

Object	Item	Daily	Weekly	Monthly	Quarterly	Before and after Rainy Season
Riding Surface	Pavement	◆		#		•
	Expansion joints	◆		#		•
Median	Kerb	◆		#		•
Side Slopes	Turfing			◆		•
	Pitching & Masonry			◆		•
	Retaining wall			#		•
Drainage	Side Slope	▯		#		
	Median drain	▯		#		
	Bridge Catch Basin	▯		#		
	Gullies and catch pits	▯		#		
Bridges	a) Superstructure /Gullies and catch pits				#	•
	b) Substructure				#	•
	c) Head / Wing walls and aprons / RE Wall				#	•
	d) Painting					•
	e) Handrail			#	•	
Culverts	RC Culvert					•
	HP Culvert					•
Guard Rails	Shoulders	▯			#	•
	Medians	▯				•
Traffic operation facilities	Signs			•		•
	Marking	▯		#		•
	Delineator	▯		#		•
	Lighting	▯			#	•
Other facilities	Vegetation / landscaping	▯		#	•	
	Toll plaza /way side amenities	▯		#	#	
Traffic Conditions		▯		•	#	
Encroachments		▯		•		

LEGENDS:

♦ Visual Inspection ▯ Thorough inspection

Close Inspection Visual Inspection During Rainy Season Only.

1.10 Services to be provided at Project Facilities

All the Facilities will be provided with services as described below:

(i) Administrative / Operation and Maintenance Building: Such building(s) will be under control of one Maintenance Engineer who will be supported and guided by other senior staff. He should also be assisted by junior staff and the workforce for day-to-day running and maintenance.

(ii) Bus Shelters and Truck Layby: At Bus shelter & Truck Layby cleaning should be done daily at the rate to repeat on every 8th day at one location in urban section, 15th day at one location in Semi urban location and once a month at one location in Rural section. Re-Painting should be done when it is evaluated to be faded away.

(iii) Electrical Services: At Administrative / Operation and Maintenance Building and project lights power supply should be provided by the Local Distribution Authority.

(iv) Medical Aid Post: Concessionaire/Contractor should operate a fully equipped Medical Aid Post along with Paramedic Staff.

(v) Traffic Aid Post: Concessionaire/Contractor operates a fully equipped Traffic Aid Post.

(vi) ATMS Control Centre: Concessionaire has provided a fully Equipped ATMS Control Centre as per the Concession Agreement

(vii) Water Supply: At Toilets water should be provided either from Bore well or shall be transported in tankers and pumped in overhead tanks on daily basis during non-peak hours of traffic movement. Storage tanks should be cleaned once every six months. In the Administration/O&M Office water dispensers shall be installed for providing good drinking water to all people visiting the office.

(ix) Solid Waste Disposal: At Administration/O&M Building, refuse collection bins should be provided. The refuse should be collected on a regular basis and disposed of as per local municipal requirement.

(x) Highway Lighting: The lighting installations should be serviced/repaired/replaced as and when required. Repair / replacement are depending on the traffic density and should be done during lean period using Main basket.

(xi) Security: Adequate security should be provided at the offices.

(xii) Surveillance: Adequate surveillance should be provided using ATMS. Its cameras should be in critical Locations. Refer ATMS for more details

(ix) First Aid: A first Aid Box should be provided at the Admin/ O&M office. Patrolling Vehicle shall be deputed for Patrolling the area round the clock for accidents. Concessionaire / Contractor should operate a fully equipped Medical Aid Post along with Paramedic Staff.

1.11 Asset Inventorisation:

An inventory of all Highway Assets should be maintained through periodic NSV surveys. The following project related information should be maintained at all site Offices/PIUs/ROs:

i)	Highway Length	:	------ Km (From CH. Km ⋯.. to ⋯⋯) of NH----/NE--	
ii)	Main Carriageway	:	.....Km	2 Lane
			.....Km	2 Lane with Paved Shoulder
			.....Km	4 Lane
			.....Km	6 Lane
			.....Km	8 Lane
			.....Km	Other (please specify)
iii)	Service Roads	:	.....Km (LHS and RHS Both)	

iv)	Central Median Width	:	.....Km	0.6 m
			.....Km	5 m
			.....Km	9 m
			.....Km	Other (please specify)

1.8.2 Details of Structures, Road Junctions and Project Facilities.

Sl. No.	Descriptions	Unit	Total Numbers	Remarks/chainage
1	Flyovers	No's		
2	ROB	No's		
3	RUB	No's		
4	Major Bridges	No's		
5	Minor Bridges	No's		
6	RCC Box Culverts	No's		
7	Slab Culverts	No's		
8	RCC Pipe Culverts	No's		
9	Underpasses	No's		
10	Major Road Junctions	No's		
11	Minor Road Junctions	No's		
12	Approach Roads	-	-	At locations
13	Toll Plazas	No's		Km
14	Wayside Amenity Complex	No's		
15	Bus Bays and Shelters	No's		
16	Truck Lay Byes	No's		LHS and RHS
17	Highway Lightings	Length, in Km		At locations
18	High Mast Lights	Nos.		
19	ATMS Works	-	-	Along the project highway
20	Landscaping and Tree Plantation	-	-	Along the project highway
21	Camp Offices	No's		
22	Administrative Base Camp	No's		Toll Plaza Building

1.12 Structure of the Manual

This manual is organised into 8 major sections. The detailed contents of each of the section is as follows:

I. Pavement

Pavement refers to the structural layers of materials constructed to provide a durable, smooth and stable surface for vehicle movement on highways. These are generally classified into three types, Flexible, Rigid and Composite Pavements. Various types of maintenance of pavement, various distresses on the pavement, decision tree and intervention levels for different types of pavements are explained in detail in ***Part 2 of this manual***.

II. Structures

Highway structures have different components and each of the component has its own importance for the safe and reliable operation of structures. Hence to evaluate structures, it is necessary to evaluate the individual components separately by considering various parameters. Major components of structures generally evaluated include wearing coat and expansion joints, deck slab, beams/girders of superstructure, bearings, substructures (Piers), substructures (Abutment), foundations, protection works, retaining walls etc. All the components of structures, assessment of condition of structures and methods of structure evaluation are explained in detail in ***Part 3 of this manual***.

III. Road Furniture

Road furniture is a collective term used for assets installed along the highway, in order to improve the safety and guide the users along the Highway. Major components of road furniture include road signage, road marking, signboards, traffic blinkers, highway lighting, safety barriers, guard rails, antiglazers, footpath, separators, noise barriers, object markers etc. These are assessed in detail in ***Part 4 of this manual***.

IV. Other Highway Elements

***Part 5* of this manual** details on highway elements including ROW and horticulture maintenance, drainage maintenance and shoulder maintenance. Details of methodology of execution, performance assessment and checklist for execution is explained in this chapter.

V. Systems – TMS/ATMS

Toll management system (TMS) includes different components/tools that are responsible for efficient toll collection. Components of Toll Management System include Traffic Lights, Automatic Boom Barrier, Operator Monitor Receipt Printer, User Fare Display, Overhead Lane Status Light, Operator Customised Keyboard, License Plate Indicatory Camera, Document Scan Camera, Incident Camera, AVCC, Weigh in Motion, Static Weigh Bridge etc.

Advanced Traffic Management System (ATMS) includes all the outdoor and indoor components which are responsible to indicate the traffic flow and to provide emergency services all round the clock across the highway. Components of ATMS include Video Surveillance System, Mobile Radio Communication System, Video Incident Detection System (VIDS), Vehicle Actuated Speed Display System, Emergency Roadside Telephone System, Variable Message Sign System, Meteorological Data System, Automatic Traffic Counter Cum Classifier, Travel Time Estimation System.

Systems related details including various components and checklists for maintenance and monitoring of these components are explained in detail in ***Part 6 of this manual***.

VI. Work zone Traffic Management Plan and Safety during Maintenance Activities

Safety in highway projects is critical to protecting workers, drivers, and pedestrians during construction, maintenance, and operation. Effective safety measures ensure the smooth execution of projects while minimizing risks. ***Part 7 of this manual*** highlights the importance of highway safety, work zone safety arrangements, traffic management plans and safety checklists.

VII. Technology Integration

Technology integration in highway operations and maintenance enhances efficiency, safety, and cost-effectiveness while improving the overall user experience. NHAI has its in-house applications viz., NHAI ONE Application to effectively manage the maintenance and NHAI ERS/IMS CARE applications for incident management on National Highways. Further, Datalake is also used extensively for monitoring, proposal submission, invoice submission and digital record repository. NHAI also operates 1033 toll free helpline number to cater to emergency and non-emergency situations of rod users on National Highways.

1.13 Reference Standards, Codes and Guidelines

I. IRC: SP: 127-2020 – Manual for performance assessment of Highway Assets during operations and maintenance stage
II. IRC: 82-2023 – Code of Practice for Maintenance of Bituminous Roads
III. IRC: 37-2018 – Guidelines for the design of Flexible Pavements

IV. IRC: SP: 83-2018 – Guidelines for Maintenance, Repair and Rehabilitation of Cement Concrete Pavements
V. IRC: 115-2014 – Guidelines for Structural Evaluation and Strengthening of Flexible Road Pavements using Falling Weight Deflectometer (FWD) Technique
VI. IRC: 117-2014 – Guidelines for the Structural Evaluation of Rigid Pavement by Falling Weight Deflectometer
VII. IRC: SP: 84-2019 – Manual of Specifications and Standards for Four Lanning of Highways
VIII. IRC: 58-2015 – Guidelines for the Design of Plain Jointed Rigid Pavements for Highways
IX. IRC: SP: 30-2019 – Manual on Economic Evaluation of Highway Projects in India
X. IRC: 5-2019 – Standard Specifications and Code of Practice for Road Bridges
XI. IRC: 78-2020 – Code of Practice on Limit State Design for Foundations
XII. IRC: 83 – 2018 – Standard Specifications and Code of Practice for Road Bridges
XIII. IRC: 112-2022 – Code of Practice for Concrete Road Bridges
XIV. IRC: SP:13-2022 – Guidelines for the Design of Small Bridges and Culverts
XV. IRC: SP: 18-1978 – Manual for Highway Bridge Maintenance Inspection
XVI. IRC: SP: 35-2024 – Guidelines for Inspection and Maintenance of Bridges
XVII. IRC: SP: 40-2019 – Guidelines on Repair, Strengthening and Rehabilitation of Concrete Bridges
XVIII. IRC: SP: 69-2011 – Guidelines and Specifications for Expansion Joints
XIX. IRC: SP: 51-2016 – Guidelines for Load Testing of Bridges
XX. MoRTH, Fifth Revision – Specifications for Road and Bridge Works
XXI. IRC: 35-2015 – Code of Practice for Road Markings
XXII. IRC:67-2022 – Code of Practice for Road Signs

1.14 Revision of the Maintenance Manual

The Maintenance Manual shall be revised and updated once every 3 (three) years or earlier as per Site conditions/ applicability of new technologies/materials/methods and contract provisions.

PART 2: PAVEMENT MAINTENANCE

2.1 Types of Pavements and Common Distresses

Pavements are commonly classified based on structural behaviour and material type. The three main types used in National Highways are:

I. Flexible Pavements

These pavements have a bituminous surface and rely on multiple layers of materials to distribute loads to the subgrade. The figure below illustrates typical layers in a flexible pavement.

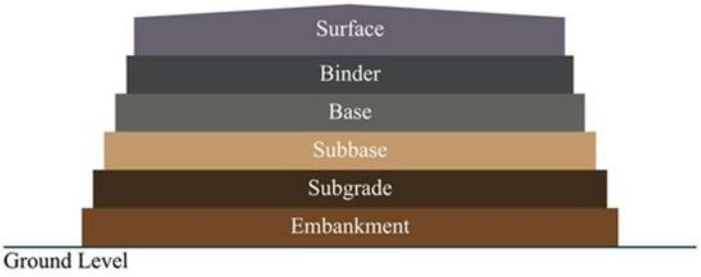


Figure 2.1: Typical cross section of flexible pavement

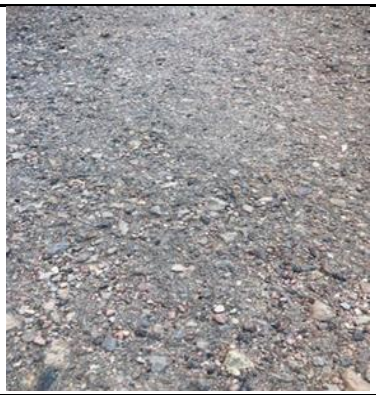
Major distresses observed in flexible pavements are tabulated as under:

Table 2.1: Distresses in Flexible Pavement

Sl. No.	Distress	Description	Possible reasons for failure	Photographs
1	**Cracks**	Cracks in bituminous pavements is classified based on the type, severity and extent of cracks.		
1.1	Longitudinal Cracks	These cracks are parallel to the direction of traffic movement.	• Poor joint matching at the time of construction • Reflective cracks from an underlying layer • HMA fatigue (onset of alligator cracks)	
1.2	Transverse Cracks	Cracks perpendicular to the pavement's centreline. It is a type of thermal cracking.	• Shrinkage of HMA surface due to low temperatures or asphalt binder hardening • Reflective cracks caused by cracks beneath the surface HMA layer	

Sl. No.	Distress	Description	Possible reasons for failure	Photographs
1.3	Alligator/ Fatigue Cracks	It is a series of interconnected cracks caused by fatigue failure of HMA surface under repeated traffic loading. It can either be Bottom-up/Top-down cracking.	• Loss of base, subbase or subgrade support • Stripping on the bottom of the HMA layer • Overloaded Traffic • Inadequate structural design • Poor construction practices	
2	**Potholes**	These are small depressions in the pavement surface that penetrate all the way through the HMA layer. It can be the end result of alligator cracks.	• Moisture Infiltration through cracks result in potholes	
3	**Patching**	An area of pavement that has been replaced with new material to repair the existing pavement. It may be created by previous localized pavement deterioration.	• Recurring failure due to structural inadequacy • Inferior materials used at the time of patchwork	

Sl. No.	Distress	Description	Possible reasons for failure	Photographs
4	**Rutting**	It is a surface depression in the wheel path. It can either be mix rutting which is restricted to the top layer or sub grade rutting which is majorly due to settlement of subgrade/ underlying layers.	• Insufficient compaction of HMA layers during construction • Subgrade rutting • Improper mix design	
5	**Delamination**	Observed in case of micro surfacing/slurry seals in which a portion of the layer gets peeled off due to lack of bond between the existing surface and the surface layer or due to moisture intrusion.	• Placement on poorly prepared surfaces particularly on unstable, cracked surface) • Improper cleaning of the surface prior to placement of micro surfacing layer	
6	**Slippage**	Crescent shaped cracks generally having two end pointed into the direction of traffic	• Inadequate tack coat spraying • Braking impact from traffic	
7	**Shoving**	It is the plastic movement of bituminous layer due to which a pavement surface bulges out and forms wave	• Weak Subgrade • Improper Rolling • Poor mixing of surface course	

Sl. No.	Distress	Description	Possible reasons for failure	Photographs
8	**Settlement/ Depression**	Localised pavement surface with slightly lower elevations than the surrounding pavement.	• Subgrade settlement resulting from inadequate compaction during construction	
9	**Bleeding**	A film of asphalt binder on the pavement surface. It usually creates a shiny, glass-like reflecting surface that can become quite sticky. It can lead to loss of skid resistance when wet.	• Excessive asphalt binder in the HMA • Excessive application of asphalt binder in bituminous surface treatment • Low HMA air void content	
10	**Ravelling**	It is generally the dislodgement of aggregate particles.	• Loss of bond between aggregate particles and asphalt binder • Mechanical dislodging due to traffic	

II. Rigid Pavements

Rigid pavements, or concrete pavements, have a stiff, durable surface that distributes loads through slab action. They consist of a single concrete layer supported by a subbase. Despite higher initial costs, they offer lower life-cycle costs, high load resistance, minimal rutting, and durability on weak subgrades.

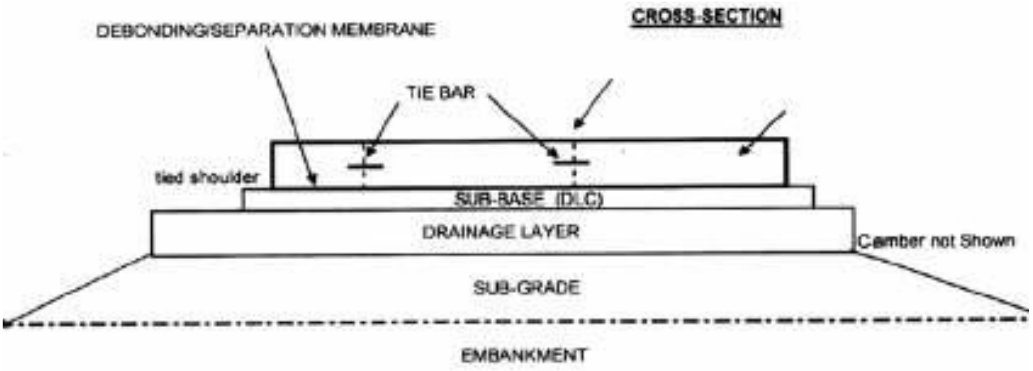


Figure 2.2: Typical cross section of rigid pavement

Types of Rigid Pavements:

1. **Jointed Plain Concrete Pavement (JPCP)** – Uses transverse and longitudinal joints to permit warping movement. Dowel bars aid load transfer, while tie bars hold slabs together.
2. **Jointed Reinforced Concrete Pavement (JRCP)** – Similar to JPCP but includes steel reinforcement to ensure that the cracking is narrow and reduce slab thickness.
3. **Continuously Reinforced Concrete Pavement (CRCP)** – Do not have regular transverse joints. It has continuous steel reinforcement to hold cracks together and the reinforcement is anchored to provide tension.

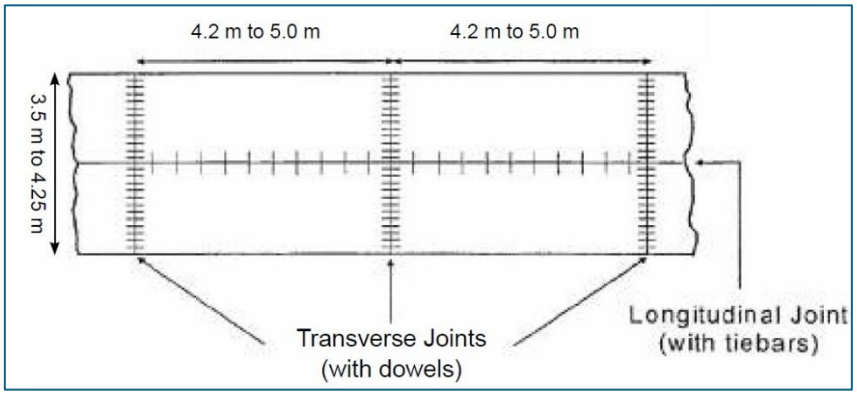


Figure 2.3: Plan view of Jointed Plain Concrete Pavement (JPCP)

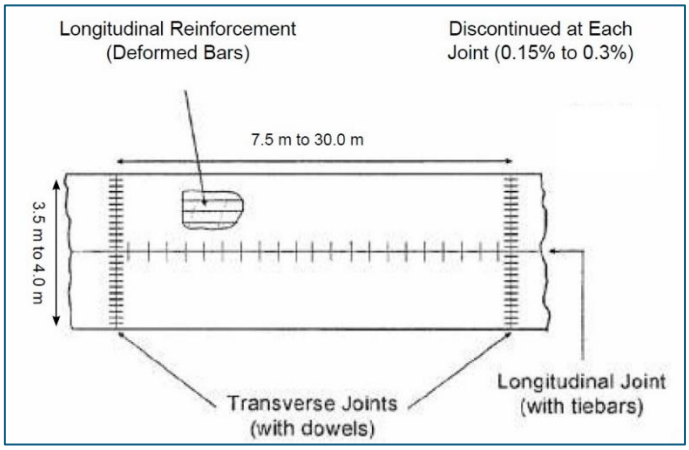


Figure 2.4: Plan view of Jointed Reinforced Concrete Pavement (JRCP)

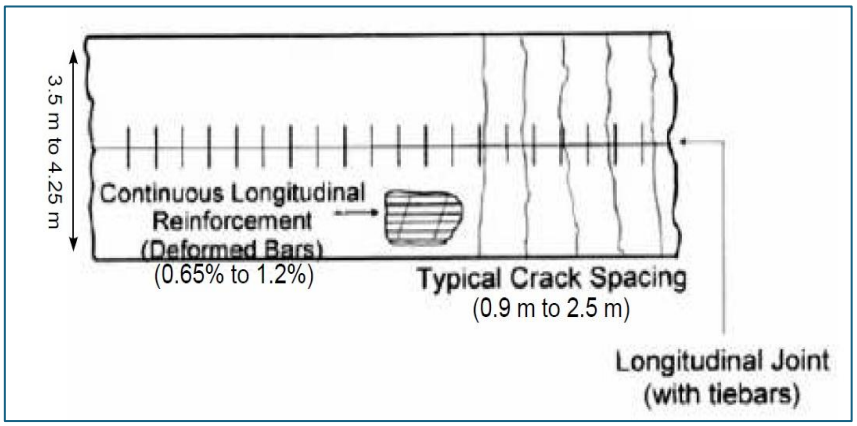


Figure 2.5: Plan view of Continuously Reinforced Concrete Pavement (CRCP)

Fibre Reinforced Concrete (FRC) enhances durability by improving crack resistance and reducing slab thickness requirements. FRC gives additional flexural toughness to the pavement and have significant residual strength at large deformations

Rigid Pavement Deterioration & Defects

Over time, all pavements deteriorate due to traffic, climate, and construction quality. Poor design or mix quality accelerates failure. Rigid pavement defects include:

- **Surface defects** (top third of the slab)
- **Structural defects** (deeper issues affecting foundation)
- **Common distresses** – Uncontrolled cracks, faulting, scaling, and loss of texture, often caused by joint failures, subgrade settlement, or poor workmanship.

For detailed defect causes, refer to Table 3.1 of IRC: SP: 83-2018

Table 2.2: Distresses in rigid pavement

Type	Defect	Description	Photographs
Cracking	Plastic Shrinkage cracks	Surface cracks formed before concrete hardens in a pattern of short cracks	
	Longitudinal cracks	Crack oriented roughly parallel to the pavement edge or longitudinal joint	
	Transverse cracks	Crack orientated roughly perpendicular to the pavement centerline	
	Diagonal cracks	Crack that traverse between perpendicular joints in slabs (length >2m)	

Type	Defect	Description	Photographs
	Corner breaks/cracks	Crack across a corner of a slab (crack length 0.3m - 2m)	
	Map cracking/ Crazing	Network of shallow narrow cracks extending only through upper surface of concrete	
Surface Defects	Popouts	Isolated loss of surface material in small area	
	Animal/Wheel impressions	Impressions on final concrete surface due to movement of animals/vehicles before setting of concrete	
	Scaling	Peeling off the upper part of slab surface (5 mm to 15 mm) following Crazing or improper surface finishing	

Type	Defect	Description	Photographs
	Ravelling	Loss of fine aggregates from matrix and hardened cement paste/laitance from the surface through abrasion that may or may not have been previously cracked.	
	Polished Surface	Wear and tear under high volumes of traffic, poor texturing	
Joint Defects	Joint Separation	Joint opening or movement due to shoulder movement/ incorrect tie bar installation	
	Joint Seal Defects	Stripping or extrusion of joint sealant	
	Spalling at joints	Breakdown of surface material within 600 mm of the joint	

Type	Defect	Description	Photographs
	Faulting/stepping	Difference in elevation across a joint or crack greater than 3 mm	
Deformation	Blowup/ Compression Failure	Localised upward movement or shattering of a slab at transverse joint or crack	
	Drop-off (Lane shoulder)	Settlement of shoulder due to erosion of unpaved shoulder	
	Slab rocking	Vertical movement at joints (or cracks) that occurs under the action of traffic loading	
	Depressions/ settlement	Localised downward differential displacement compared with the surrounding pavement	

Type	Defect	Description	Photographs
	Heave	Localised upward differential displacement because of action from pavement foundation	
Other Miscellaneous Defects	Pumping	Ejection of fine grained material and water from underneath the pavement through joints, cracks or pavement edge caused by the passage of vehicle over the slab.	
	Punchout	Partial area of a slab broken out by several cracks particular to continuously reinforced concrete slabs.	

III. Composite pavement

Composite pavement refers to a type of road structure that combines two or more distinct layers of materials—typically, a flexible Hot Mix Asphalt (HMA) layer placed over a rigid Portland Cement Concrete (PCC) base. This hybrid design takes advantage of the strengths of both materials:

- Asphalt: Provides a smooth, flexible riding surface.
- Concrete: Offers high durability and strong structural strength.

Typical Cross Section

Figure 2.6: Typical cross section of Composite pavement

Most composite pavements consist of an HMA surface over a concrete base, which may either be newly constructed or an existing concrete pavement surface (refer to above figure). However, there are cases where this structure is reversed—a concrete surface is placed over an HMA base.

- In the first case, the rigid concrete base supports the flexible HMA surface.
- In the second case, the bound asphalt base (HMA) provides better support and reduced erosion compared to traditional unbound granular bases.

Behaviour of Layers After Failure

When the concrete layer beneath the HMA cracks or fails, it loses its rigid nature and starts behaving like a granular base layer (Wet Mix Macadam, WMM). It can still distribute loads, but with reduced structural capacity.

Common Distresses in Composite Pavement

Composite pavements often face similar distresses to flexible pavements, since HMA is typically the top layer. However, due to the multi-layered structure, some additional unique issues may arise:

1. **Fatigue Cracking in the Cement Treated Base (CTB):**
   - Caused by repeated traffic loading.
   - Tensile stresses at the bottom of the concrete layer led to cracks over time.
2. **Reflective Cracking:**
   - Cracks from the underlying concrete layer propagate upward into the HMA layer.
   - This occurs due to differential movement caused by the rigidity of the concrete base.
3. **Rutting:**
   - While rutting is common in flexible pavements, in composite pavements it can occur differently.
   - If the concrete base fails early, it loses strength, causing higher stress on underlying layers.
   - If the subgrade cannot handle this additional stress, rutting develops.

2.2 Investigations

Detailed technical assessments are carried out to assess the structural and functional condition of the pavements. Technical investigations are crucial to ensure that pavements are built/maintained to meet performance expectations, are cost effective and have long service life.

The detailed technical analysis and precautions to be taken while conducting the technical surveys are detailed in the following sections:

I. Visual Investigation

(a) Frequency: Visual investigation of the project stretch is carried out on a regular basis every month. Apart from the regular assessment, detailed assessment is carried out pre-monsoon to understand any deficiencies and take up any preventive maintenance activities as per the requirement.
Apart from the detailed visual investigation and regular assessment, daily inspections are also carried out by the highway maintenance executives/supervisors to address critical distresses like potholes, cracks, rutting etc.

(b) Results and Interpretation: Detailed visual inspection is carried out for the pavement and based on the pavement condition; the suitable treatments are undertaken. Frequency of inspection and various types of distresses are as follows:

Table 2.3: Visual Investigation for pavements

Distress	Severity	Extent/Condition (All analysis done km wise)	Frequency of Inspection
Potholes	< 25mm depth – Low 25-50mm depth – Medium >50mm depth - High	1-2 potholes – Fair >2 potholes - Poor	Daily
Longitudinal Cracks	<5 mm wide – Low >5 mm wide - High	<15% - Low 15-50% - Frequent >50% - Throughout	Daily
Transverse Cracks	<5 mm wide – Low>5 mm wide - High	<15% - Low 15-50% - Frequent >50% - Throughout	Daily

Alligator Cracks	<5 mm wide – Low>5 mm wide - High	<15% - Low 15-50% - Frequent >50% - Throughout	Daily
Patching	Minimal Distress – Low Continuing Distress – Medium Extensively damaged - High	<15% - Low 15-50% - Frequent >50% - Throughout	Daily
Rutting	<5mm – Low 5-10mm – Medium >10mm - High	<10% - Low 10-20% - Medium >20% - High	Daily
Corrugation or shoving	<15mm – Low 15-30mm – Medium >30mm - High	<5% - Low 5-10% - Medium >10% - High	Daily
Bleeding	5-10% bitumen – Low 11-25% bitumen – Medium >25% bitumen - High	<20% - Low 20-50% - Medium >50% - High	Daily
Ravelling	Significant Voids – Low Patchy Areas <50% loss – Medium Significant Loss of aggregates >50% loss - High	<5% - Low 6-15% - Intermittent 16-40% - Frequent 41-75% - Extensive >75% - Throughout	Daily
Depression/ Settlement	<15mm – Low 15-30mm – Medium >30mm - High	<5% - Low 5-10% - Medium >10% - High	Daily
Roughness	<2000mm/km - Good 2000 – 2400mm/km - Fair >2400mm/km - Poor	-	Bi-Annually
Rigid Pavement			
Single Discrete Cracks	<1.5mm width – Low 1.5 - 3mm width – Medium >3mm - High	-	Weekly
Longitudinal Cracks	<0.5mm - Low 0.5 - 6mm – Medium >6mm - High	-	Weekly
Transverse/Diagonal Cracks	<0.5mm - Low 0.5 - 6mm – Medium >6mm - High	-	Weekly
Multiple Cracks	<0.5mm - Low 0.5 - 3mm – Medium >3mm - High	-	Weekly
Corner Break	<1.5mm - Low >1.5mm High	1 corner broken – Good 2-3 corners broken – Fair >3 corners broken - Poor	Weekly
Joint Spalling	<10mm – Low >10mm - High	L>25% - Poor	Weekly
Joint Seal	L<25% - Low L – 25-50% - Medium L>50% - High	-	Weekly
Faulting	h<6mm – Low h – 6-18mm - Medium h>18mm - High	-	Weekly
Blow up/Buckling	h<12mm – Low h – 12-25mm – Medium h - >25mm - High	-	Weekly
Scaling	Local areas damaged – Medium Continuous Scaling - High	<10% - Good 10 - 20% - Fair >20% - Poor	Weekly

Roughness	<2200mm/km - Good 2200 – 3000 – Fair >3000mm/km - Poor	-	Bi-Annually

(c) Checklists: Checklist vary based on the type of inspection carried out and also the type of pavement being evaluated. The following tables indicate the checklists to be adopted for both flexible and rigid pavement considering both routine and major maintenance.

Flexible Pavements

Checklist for Routine & Preventive Maintenance: This survey is carried out monthly to assess the site condition and to understand if the pavement has any deficiencies. The survey outcome is analysed in detail to understand any requirement of preventive maintenance. Detailed checklist format is attached as per **Annexure 1.**

Table 2.4: Checklist for Routine Maintenance

Date of Survey: _____

SPV Name: _____

Chainage From	Chainage To	Side	Lane	Wheel Path	Offset from kerb	Length	Width	Area	Type of distress	Severity of Distress	History of repair

Checklist for Major Maintenance: A Detailed walkthrough survey is conducted by the pavement expert team prior to start of the major maintenance works. This assessment is carried out for each lane wheel-path wise to identify the exact type of distress and the location of the distress along with images of the pavement for every 10m interval. Format for the checklist used in detailed walkthrough is presented in Table 2.5 as below and detailed excel file is attached in the **Annexure 2.**

Table 2.5: Checklist for Flexible Pavement – Major Maintenance

Date of Survey: _____

SPV Name: _____

Chainage		Length (m)	Side	Distress				
				Inner Lane - W1				
From	To			Alligator/ Fatigue crack	Rutting (mm)	Longitudinal / Transverse Crack	Other Distress	Affected Width (m)

Rigid Pavements

Checklist for Maintenance: The following checklist is generally adopted for rigid pavements. It consists of detailed walkthrough survey and each panel is assessed in detail to understand and categorise the distress type. The defects are categorised based on the classification system of IRC: SP: 83-2018. The detailed sample checklist for rigid pavements is attached as per **Annexure 3** and is as follows:

Table 2.6: Checklist for Inspection of Rigid Pavement

Date of Survey: _____ Name of SPV: _____	
	Lane Details (Slow/Centre/Fast Lane)

Panel Chainage (km)	Cracking/ Surface defect/ Joint defect	Code	Crack width/width/ Dia (mm)	Aff. Panel Length (m)	Aff. Panel Width (m)	Depth (mm)	No.of corners broken /no.of pieces/ % of joints	% Area	IRC: SP: 83-2018 Severity

II. Network Survey Vehicle (NSV)

NSV survey helps us to understand the functional/superficial condition of the pavement which reflects the comfort of the end user. Additionally, it also provides road inventory data.

As per respective Concession/Contract Agreement, the pavement must be maintained within the limits of different parameters such as roughness, cracks, rutting, etc. Some these parameters cannot be measured manually by visual survey. Hence, NSV survey is very crucial for a pavement study.

Section	**Details**			
Purpose	Evaluates pavement functional condition, provides road inventory data. Some parameters like roughness, cracks, rutting, etc. cannot be measured manually.			
Survey Frequency	Twice a year (Pre-monsoon & post-monsoon). Helps plan preventive measures before monsoon and rectify damages after monsoon.			
Measurement Intervals	Continuous measurement: results provided at 10m, 100m, and 1km intervals.			
	Parameter	Description	Analysis Interval	Remark
Key Results & Interpretation	**Longitudinal Profiling**	International Roughness Index (IRI) – Unevenness of the pavement, presented for 1km section. Higher roughness areas should be inspected for distress or undulations.	10 m, 100 m, 1 km	Roughness may be high at rumble strips or structure joints.
	Transverse Profiling	Rutting - wheel path depression due to vehicular loading. Recommended analysis at 100m sections.	10 m, 100 m, 1 km	Rut depth is averaged for sections to identify potential risks.
	Pavement Surface Distresses	Includes cracks, potholes, bleeding, shoving, and spalling (for rigid pavement) etc. Image-based assessment helps determine rectification measures.	10 m, 100 m, 1 km	Used to decide rectification methodology .
	Video Imaging	Captures roadside inventory (sign boards, MBCB, and other assets) for condition assessment.	Continuous	Helps in asset condition assessment and planning.

	Road Geometry Data	Includes curvature, gradient, and cross slope. Camber data is checked for surface drainage.	As required	
	Pavement Texture (Macrotexture)	Assesses skid resistance of pavement surface.	As required	
	Geo-tagging	GPS coordinates (X, Y, Z) help in exact issue identification and digital mapping.	Continuous	

Checklists	**Pre-Survey Checks**	Calibration of laser, camera, any other sensitive equipment for height & alignment	☐
		Check sheets in terms of vehicle, driver, data storage and safety	☐
		Trial run on known section to understand repeatability, accuracy and image visibility	☐
		Calibration for bumps	☐
	During Survey Checks	Lane-wise data collection should avoid lane deviations.	☐
		Vehicle speed 30-80 km/h	☐
		Dry pavement for laser sensors	☐
		Daylight conditions for video/image capture.	☐
	Post-Survey Checks	Data processing with minimal manual involvement.	☐
		Image processing software recommended for distress identification.	☐
		Random section verification through visual inspection.	☐

Table 2.3: Sample NSV data templates

Road Geometry data													
Chainage (km)	Grade (%)	Cross Slope (%)	Horizontal Curvature 1/km	Horizontal Curvature deg/km	Vertical Curvature 1/km	Vertical Curvature deg/km	RF (m / km)	NUM_RFS (1 / km)	Speed (km / h)	Latitude (deg)	Longitude (deg)	Altitude (m)	Survey Day

Profiler data																
Chainage (km)	IRI Right (m/km)	IRI Left (m/km)	IRI Average (m/km)	Bump Int (mm/km)	Rut Right (mm)	Rut Left (mm)	Rut Lane (mm)	SMTD MacrotextureRight (mm)	SPTD MacrotextureRight (mm)	SMTD MacrotextureLeft (mm)	SPTD MacrotextureLeft (mm)	Speed (km / h)	Latitude (deg)	Longitude (deg)	Altitude (m)	Survey Day

Distress data (Flexible pavement)										
Chainage		Survey date	Percentage							
From (km)	To (km)		Crack %	Pothole %	Patching %	Shoving %	Ravelling %	Bleeding %	Delamination (%)	Rut depth (mm)

Distress data (Rigid pavement)																		
Chainage		Side	Lane Information	Cracks					Joint Defects					Surface Defects				Remarks
From (Km)	To (Km)			Single discrete cracks	Longitudinal Cracks	Transverse/ Diagonal Cracks	Multiple cracks	Corner Cracks/ Breaking	Joint Spalling/ Joint Damage	Joint Seal Defects	Joint Separation	Faulting/ Stepping	Blow Up/ Buckling	Punchout	Ravelling	Scaling	Pothole/ Popout	

III. Falling Weight Deflectometer

Falling Weight Deflectometer (FWD) is a very essential non-destructive testing equipment for structural evaluation of flexible and rigid pavements. The use of FWD in road infrastructure projects is increasing rapidly as it can mimic real traffic loads and measure deflection very accurately. This information will give an engineer an idea of the load-bearing capacity along with possible issues below the pavement and whether it requires repair or strengthening. The IRC has published comprehensive guidelines - IRC:115-2014 for flexible pavements and IRC:117-2015 for rigid pavements-defining methods of carrying out FWD surveys. They will take into consideration the whole process from a preliminary pavement condition survey to deducing deflection data to take well-informed decisions concerning maintenance and life extension of a pavement. Pavement distresses like cracks, rutting, voids beneath lifted slabs, etc., will be detected and treated properly by FWD survey ensuring its durability and safety in the long run for road networks.

(a) Frequency

This section shall comprise of two frequency aspects of the survey, i.e., frequency of survey and frequency of data collection. These are detailed in subsequent sections.

Frequency of survey

- The best time to carry out an FWD survey is during moderate weather conditions after the offset of monsoon preferably in the month of September to October, avoiding extreme temperature and weather.
- Bituminous materials in flexible pavements are temperature sensitive. Extreme heat can soften bituminous layers, leading to higher deflection readings, while extreme cold can make them stiffer, underestimating deflections. Moderate temperatures ensure the results reflect typical pavement behaviour.
- In rigid pavements, temperature gradients across the slab thickness can cause curling or warping, affecting deflection data. Neutral temperature conditions (early morning or late evening) are preferable to minimize these effects.
- During the monsoon, excessive rainfall can saturate the subgrade and base layers, causing higher deflections and potentially misleading results. By waiting until the monsoon completes, allow the subgrade to drain the excess water and stabilize, providing more representative deflection measurements.

- Post-monsoon surveys can reveal pavement distresses that developed due to water ingress, such as weakening of layers, rutting, and cracking. These issues are critical for planning appropriate rehabilitation measures.
- Fixing a month post monsoon removes the variability of seasonal effect. This will help getting a uniform parameter to obtain the remaining life and overlay analysis.

Frequency of Data Collection

The frequency of data collection for FWD surveys is generally carried out depending on the type of pavement, its condition, and the specific guidelines outlined by the IRC.

(i) Flexible Pavement

As per IRC:115–2014, the following guideline is indicated to consider the test frequency.

Table 2.4: Spacing of points for FWD data collection

Type of Carriageway	Recommended measurement scheme	Maximum Spacing (m) for test points along selected wheel path for pavements of different classification		
		Poor	Fair	Good
Single-lane two-way	Measure along both outer wheel paths	60	130	500
Two-lane two-way single carriageway	Measure along both outer wheel paths	60	130	500
Four-lane single carriageway	Measure outer wheel paths of outer lanes	30	65	250
	Measure outer wheel path of more distressed inner lane	60	130	500
	Measure along the center line of paved shoulder (for widening)	120	260	500
Four-lane divided carriageway	Measure outer wheel paths of outer lanes	30	65	250
	Measure outer wheel path of inner lane	60	130	500
	Measure along the center line of paved shoulder (for widening)	120	260	500
Divided carriageways with three or more lanes	Measure outer wheel paths of outermost lanes	30	65	250
	Measure outer wheel path of more distressed inner lane	60	130	500
	Measure along the center line of paved shoulder (for widening)	120	260	500

However, identifying the section in such a varied frequency based on the pavement condition makes various challenges in identifying the actual pavement condition and data recording. Besides, planning for tailor made maintenance and strengthening work becomes challenging.

Therefore, a uniform lane wise frequency may be adopted to obtain the data. For each lane a data point may be considered at 200 m interval, and the analysis must be done for every lane separately.

Similarly, instead of homogeneous section, the analysis must be carried out in each lane km to get a consistent and uniform remaining life and subsequently overlay design for the project.

(ii) Rigid Pavement

As per IRC:117–2015, generally deflection is measured at 500 m interval. Also, measurements are taken at closer intervals where potential voids or joint inefficiencies are suspected. Deflection measurements are collected at the interior, corner, and edge positions of slabs. Tests at transverse joints and longitudinal joints are done in the outer lane, as heavy loads primarily affect these lanes.

(b) Results and Interpretation: The following are results and interpretation of FWD survey. Flexible pavements analysis is carried out based on IRC:115-2014 and rigid pavement analysis is carried out based on IRC:117-2014.

(i) Flexible Pavement

- ***Key Parameters Analysed***
  - Deflection Bowl Parameters (Obtained from FWD directly)
  - Elastic Modulus of Pavement Layers (Bituminous, Granular, and Subgrade)
  - Remaining Life Estimation
  - Overlay Requirements
- ***Interpretation of Results***

  Remaining Life Estimation:
  - The remaining life of the pavement is calculated by comparing the back-calculated layer moduli with allowable fatigue and rutting criteria. Sections with lower moduli or higher deflections indicate reduced structural capacity and lesser remaining life.
  - For good pavement condition (E > 3000 MPa for bituminous layers), the remaining life is typically higher. Conversely, pavements with fair or poor condition (E between 400 – 1500 MPa) require immediate attention. However, one can get an actual picture of pavement condition from remaining life after further analysis.

  Effect of Voids and Weak Subgrade:
  - High deflection values at specific points may indicate voids or weakened subgrade layers. These anomalies suggest water ingress or settlement, necessitating stabilization or undersealing to prevent further deterioration.
  - Localized deflections significantly higher than surrounding areas signal the presence of voids beneath the bituminous layer or subgrade instability.

  Overlay Design:
  - Based on the back-calculated moduli and deflection data, overlay thickness is recommended to restore structural capacity.
  - Temperature and seasonal variations are corrected to standard conditions (typically 35°C) to ensure realistic design.

(ii) Rigid Pavement

- ***Key parameters analysed***
  - Modulus of Subgrade Reaction (k-value)
  - Elastic Modulus and Flexural Strength of Pavement Quality Concrete (PQC)
  - Load Transfer Efficiency (LTE) of Joints
  - Void Detection Beneath Slabs
- ***Interpretation of Results***

  Subgrade and Concrete Moduli:

- The elastic modulus of concrete and subgrade reaction modulus are back calculated from deflection data. Pavements with E > 30,000 MPa for PQC indicate sound concrete, while values below 25,000 MPa point to potential distress.
- Low subgrade modulus (k < 50 MPa/m) suggests poor subgrade support, requiring subgrade stabilization.

Load Transfer Efficiency (LTE):

- LTE assesses the capacity of dowel and tie bars to transfer loads across joints. An LTE > 80% indicates healthy joints, while LTE < 50% signals deteriorating transverse joints.
- For longitudinal joints, an LTE below 40% indicates critical conditions requiring retrofitting or dowel bar retrofitting (DBR).

Void Detection and Remediation:

- Large deflections at slab corners or joints signify voids beneath the concrete. This can lead to corner cracking and slab rocking under traffic loads. Grouting or slab jacking is recommended to fill voids and restore uniform support.

Fatigue Life and Remaining Service Life:

- The cumulative fatigue damage principle estimates the remaining fatigue life of the pavement. If the fatigue damage exceeds acceptable limits, slab replacement or overlay may be necessary.

(c) Checklists

The detailed checklist for FWD surveys covering both flexible and rigid pavements is necessary for getting an efficient outcome from the survey. This table highlights key steps, data requirements, and analysis procedures.

Table 2.5: Checklist for FWD Survey

Stage	Checklist Item	Details and Description
Pre-Survey Preparation	Pavement Condition Survey	Conduct visual inspection to classify pavement condition (Good, Fair, Poor). Document cracks, rutting, etc.
	Chainage and Section Selection	Identify homogeneous sections (1 km for uniform segments). Note localized distress areas.
	Traffic Management Plan	Prepare traffic diversion plan. Use cones, flags, and safety measures to ensure uninterrupted survey.
	Equipment Calibration	Ensure FWD is calibrated as per IRC 115-2014 (flexible) or IRC 117-2014 (rigid).
	Weather and Temperature	Plan surveys post-monsoon or during moderate weather. Avoid pavement temperature > 45°C for flexible pavements.
Survey Execution	Deflection Testing Points	**Flexible:** Test points at each lane in every 200 m depending on condition. **Rigid:** Test interior, corner, edge, transverse joints (500 m intervals).
	Loading Plate Position	Centre load plate over marked test point. Ensure full contact with pavement.

Stage	Checklist Item	Details and Description
	Drop Testing	Perform 4 drops at each location (1 seating, 3 test drops). Ensure consistent load (typically 40 kN).
	Geophone Setup	Place geophones at 0, 200, 300, 450, 600, 900, 1200, 1500, 1800 mm from the load plate centre.
	Data Collection	Record load and deflection data digitally. Ensure temperature data is logged during each test.
Data Analysis	Back-Calculation of Layer Moduli	Use KGPBACK or similar software for flexible pavements. Use deflection basin analysis for rigid pavements.
	Modulus of Subgrade Reaction (k)	Calculate subgrade modulus from deflection basin (rigid pavements).
	Elastic Modulus of Pavement Layers	Calculate bituminous, granular, and subgrade layer moduli for flexible pavements.
	Temperature Correction (Flexible)	Apply correction for pavement moduli at non-standard temperatures (>35°C).
	Seasonal Correction	Adjust subgrade modulus for monsoon or winter conditions using IRC equations.
	Deflection Bowl Interpretation	Analyse shape and spread of deflection basin. Identify potential voids or weak layers.
	Load Transfer Efficiency (Rigid)	Evaluate joints: LTE > 80% (good), LTE < 50% (critical for dowel joints), LTE < 40% (critical for tie bars).
	Detection of Voids (Rigid)	Analyse high corner deflections to identify voids beneath slabs.
Remaining Life Estimation	Fatigue Life (Flexible)	Calculate remaining life using fatigue damage models (as per IRC 115-2014).
	Cumulative Damage (Rigid)	Estimate remaining service life of concrete slabs (as per IRC 58-2015).
	Overlay Design	Recommend overlay thickness based on deflection data. For flexible, design as per IRC 37-2018.
	Joint Retrofitting (Rigid)	Recommend dowel bar retrofitting for transverse joints showing poor LTE.
	Grouting/Slab Stabilization	Suggest undersealing or slab jacking to fill voids beneath rigid pavements.
Reporting and Documentation	Homogeneous Section Classification	Divide pavement into sections based on deflection patterns.
	Data Interpretation Summary	Summarize E-values, deflection profiles, and overlay recommendations.
	Pavement Health Grading	Classify pavement sections as Healthy, Moderate, or Critical.
	Rehabilitation Plan	Prioritize sections for rehabilitation based on distress and remaining life.

IV. Material Characterization

Material characterization involves determining the physical, mechanical and chemical properties of pavement materials. Proper material characterisation ensures that pavement will perform adequately under expected traffic and environmental conditions. Test pits and core cutting are the primary material characterisation tests carried out on pavements:

<table>
<tr><th>S. No.</th><th>Method</th><th>Section</th><th colspan="3">Details</th></tr>
<tr><td>1</td><td rowspan="6">Test Pits</td><td>Purpose</td><td colspan="3">• Assess condition of granular layers and subgrade which are critical for pavement performance.
• Helps analyse pavement damage, especially those due to issues in underlying layers, crust composition, and drainage.
• Supports FWD back-calculation.</td></tr>
<tr><td></td><td>Frequency</td><td colspan="3">• Not defined – depends on pavement condition.
• For major maintenance works the recommended frequency is 1 test pit every 5 km on the shoulder side.</td></tr>
<tr><td></td><td>Expected Results</td><td colspan="3">- WMM Layer Properties: Gradation, Liquid Limit (LL), Plastic Limit (PL), Aggregate Impact Value (AIV)
- GSB Layer Properties: Gradation, LL, PL, AIV
- Subgrade Soil Properties: Grain size analysis, CBR (%), Free Swell Index, Clay Content, LL
- Structural Data: Layer thicknesses (Bituminous/Concrete, WMM, GSB)
- Pavement Drainage: Drainage condition assessed visually and via soil condition</td></tr>
<tr><td></td><td></td><td>Issue</td><td>Interpretation</td><td>Investigation</td></tr>
<tr><td></td><td></td><td>Settlement</td><td>Presence of clay with high swell index</td><td>Subgrade layer properties to be assessed.</td></tr>
<tr><td></td><td></td><td>Pavement failing regularly, despite all layers in good condition</td><td>Draining layer are not interconnected throughout the cross section.</td><td>Investigate subsurface drainage condition i.e., non-uniform GSB layer connectivity with shoulder/median</td></tr>
<tr><td></td><td>Checklist</td><td colspan="3">The cutting should be carried out layer wise</td></tr>
<tr><td></td><td></td><td colspan="3">The sample material of each layer should be collected without any contamination of the other layers</td></tr>
<tr><td></td><td></td><td colspan="3">The crust composition should be measured after proper cleaning of each layer</td></tr>
<tr><td></td><td></td><td colspan="3">The moisture content and the in-place density of subgrade layer should be measured at site</td></tr>
<tr><td></td><td></td><td colspan="3">Proper safety shall be arranged during the test pit execution</td></tr>
<tr><td>2</td><td rowspan="3">Core Cutting</td><td>Purpose</td><td colspan="3">Controlled cutting of asphalt layer to assess bound layer condition.
Used to check crack depths, layer debonding, binder content in cases like rutting and bleeding.</td></tr>
<tr><td></td><td>Frequency</td><td colspan="3">Not defined – based on condition of pavement. Applied in locations showing distresses such as rutting, bleeding, or cracking.</td></tr>
<tr><td></td><td>Results</td><td colspan="3">• Visual condition of bound layers
• Binder content and gradation of asphalt layers
• Asphalt thickness - Evaluation of crack type (top-down vs bottom-up) and depth</td></tr>
</table>

		Interpretation	Binder content and gradation are useful to identify causes of distress formation, majorly for cases rutting and bleeding. In case of Cracks, depth of the cracks and initiation of the cracks (bottom up or top-down cracking) can be checked on the cores and this data helps in strategizing the rehab depth during rectifications.
		Checklist	• The core shall be taken to the full depth with care such that it is not damaged • The diameter of the core bit should be chosen based on the requirement (100mm/150mm size) • All the details (Chainage, condition, GPS coordinates and project stretch) should be noted along with the core photographs for future reference. • The initial observations of the core should be noted. • Proper safety shall be arranged before the execution of core cutting
3	**Ground Penetrating Radar (GPR)**	**Purpose**	Non-destructive testing using electromagnetic waves to detect and map subsurface features. Specifically used in rigid pavements and structures. for mapping reinforcement and aligning bars, assessing pavement thickness, and identifying subsurface voids or cavities.
		Advantages	Efficient data collection with minimal traffic disruption Reduced testing requirements i.e., physical core extraction and lab testing Continuous subsurface profiling for accurate condition mapping
		Errors/Limitations	**Systematic Errors**: Consistent measurement or methodological inaccuracies **Instrument Errors**: Malfunction or poor calibration of GPR device **Human Errors**: Operator error or incorrect interpretation of radar results
		Reference Standards	• AASHTO R 37-04 • ASTM D4748-10 • ASTM D6087-08 • EN 302066- ETSI • SHRP S-300

Figure 2.7: Test Pits

Figure 2.8: Core cutting

GPR requires significant expertise and timely calibration to ensure effective application at the site.

GPR is can be used for the purpose of determining the pavement thickness, presence of voids in the pavement layers and identifying the presence of moisture in sub-surface layers. Further, it is recommended to use GPR before strategizing any major maintenance to understand the wholistic condition of the pavement.

2.3 Intervention Levels and Treatments

Intervention levels and treatments in pavement management refer to predefined thresholds and corresponding actions required to maintain or restore the pavement's functional and structural performance. The levels are based on the functional pavement evaluation using NSV, structural evaluation using FWD and visual surveys.

I. Flexible Pavement

2.3.1 Routine Maintenance: It includes all the activities required for regular and general upkeep of the pavement against the normal wear and tear of the highway. As part of routine maintenance, the commonly observed pavement distresses include rutting, surface cracks, depressions, settlement, slippage, and potholes.

Strategies to rectify each distress type commonly observed in the pavement is given in the table below. The testing methods have been discussed in the previous section. The treatment methodology will be discussed in the succeeding sections.

Distress Type	Intervention Level	Indication	Testing Method	Treatment Methodology	Remarks/ Additional Information
Rutting	< 10 mm – No intervention needed	Acceptable limits	Visual Inspection Straight Edge Test Network Survey Vehicle	No treatment required	No impact on structural or functional performance
	10-20 mm – Corrective Measures required	Corrective Measures Required		Heave removal with Bobcat/Rut filling crack sealing in case of cracks	Prevents further rutting progression
	> 20 mm	Detailed investigation on possible reasons of failure needs to be investigated		Detailed investigation Milling out rut surface Inlay	Restores the pavement's surface and Structural integrity.

Special Note for Rutting	Single wheel path rut surface			Skid Steer Loader with Milling attachment to remove the heave portion, RS-1 Emulsion is also applied	Ensures even surface condition. Prevents exposure of voids to the surface and possible moisture infiltration.
Roughness	2000-2400 mm/km (within permissible IRC limits)	Within the permissible limits of IRC	Laser Profilometer	No treatment required	Pavement condition acceptable
	> 2400 mm/km	Significant surface irregularities affecting ride quality. Detailed site investigations required	Laser Profilometer, Test Pit, Core Cutting	Micro-surfacing Inlay or overlay	Ensures smooth ride quality
Surface Cracks	< 5 mm	Low & medium intensity	Crack Width Measurement	Crack sealing using RS-1 emulsion/hot bitumen sealant	Prevents water infiltration and deterioration
	> 5 mm	Large area & severe damage	Crack Mapping (NSV), Core Cutting	Rehabilitation with Bituminous Concrete	Addresses underlying pavement issues
Depressions & Settlements	< 10 mm	Within permissible limits	Visual Inspection, Level Survey	No immediate action required	Minor depressions do not affect ride quality
	> 10 mm	Risk to road user	Test Pit, Level Survey	Rehabilitation up to affected depth for smooth riding quality	Ensures user safety and comfort
Slippage	Minor slippage		Visual Inspection	Isolate affected section using Skid Steer Loader with Milling attachment, repair with bituminous emulsion mixed with dust	Minor repair prevents further failure
	Major slippage	Damage is extensive		Extensive rehabilitation to address root cause	Ensures long-term pavement stability
Potholes	Small potholes		Visual Inspection	Rectangular cutting, thorough cleaning, filling with hot mix, compacting Note: Cold mix may be used in rare conditions wherein use of hot mix is not possible.	**Repair of potholes, surface patches, cracks, minor ruts and undulations with Bituminous Mixes/Sealant**

	Extensive/recurring potholes		Core Cutting, Visual Inspection	Comprehensive rehabilitation for long-term pavement stability	**s of suitable grade as per applicable specifications of MoRTH should be done using automated Machine/Equipment as the use of automated Machine/Equipment improves the quality control of the repair and takes lesser time. Tentative Specifications of the Machine are tabulated below.**
Critical Areas (Bridge decks, recurring issues)	Severe distress		Visual Inspection	Mastic asphalt application for durable and impermeable surface	Ensures durability under heavy traffic
Service Roads & Slip Roads (Water Logging Issues)	Continuous water logging observed	Water induced pavement damage	Site Inspection,	Treated with Paver Block and White Topping for longevity	Prevents bituminous deterioration due to water stagnation

2.3.1.1 **Use of Automatic pot hole filing, compacting and patching machine**:

Repair of potholes, surface patches, cracks, minor ruts and undulations with Bituminous Mixes/Sealants of suitable grade as per applicable specifications of MoRTH should be done using automated Machine/Equipment as the use of automated Machine/Equipment improves the quality control of the repair and takes lesser time.

(i) **Generic Specifications of Automatic pot hole filing, compacting and patching machine:**

- The equipment should be contained in a single vehicle with operator/Driver cabin with Electronic controls and proper instrumented control panels for monitoring and controlling patch repair operations.

- The Machine should be able to fill the potholes and seal the cracks mechanically, in a fully automated process that should include cleaning the damaged area with a jet blast of air, spray emulsion on the patch from an in-built spraying gun, dispense Hot Asphalt Mix from an in-built chamber with heating arrangement and should have in-built vibratory compactor. The machinery should be such that it causes minimum disturbances to the movement of vehicular traffic on road.

- The Machine shall be capable of working with bituminous mixes of suitable grade, after removal of all failed materials, cleaning of surface, applying tack coat, compacting and finishing the surface to form a smooth, continuous surface and filling of cracks with bituminous emulsion using fully automated machine including removal of unusable materials / leftovers etc. The machine should have in-built provision of Cutter, Blower, Tack Coat Sprayer, Hot Asphalt Dispenser and Vibratory Roller capable of combining mechanically the processes of cutting the distressed surface to required size and depth, cleaning the surface, applying tack coat, dispensing asphalt mix and rolling.

- The equipment should be capable of pothole filling, surface repair and crack filling, rectification of spalled areas, depressions and ravelled areas of damaged pavement edges in roadway surfaces.

- The machine should have pneumatic cutter-breaker to remove loose rocks/stones, air blower to clean the damaged area, emulsion container of minimum 150 litres tank capacity with arrangement to spray, hot bituminous container of minimum 5 tons capacity with dispensing system and proper controls to ensure dispensing of right quantity, at the recommended temperature of 90-100 degrees centigrade and 8-10 tons vibratory compactor which can exert hydraulic pressure for proper compaction of mix. Safe cabin for the driver/operator, Traffic control indicator lights when the work is in progress and work lights mounted on the vehicle making it capable of working in the night.

- The equipment shall be completely controlled by one person from the driver's position of the equipment's cab with no support equipment must be used. The machine must be capable of patching while moving forward or reverse, must be capable to perform all patching functions with transmission engaged and in motion.

- The machine should also be able to capture the GPS locations as well as photographs of the repaired The Equipment should be capable of doing the road repairs during night time to avoid traffic disturbance in the day time.

- Width and height of the equipment to meet RTO requirements without requiring oversize Permits.

- Additional Features: Lights, Day time running lights, Map light, turn signal/hazard, 12-volt power outlet, Air, Coolant, Fuel, Temperature Gauge, Speed-o-meter & Trip meter, Tachometer, back up alarm, tinted glass, Tool box mounted on the equipment.

(ii) Specifications of Material to be used in the machine:

All Material used in the machine shall conform to specifications for BITUMINOUS WORK IN CONNECTION WITH MAINTENANCE AND REPAIR as per latest edition of Specifications for Road and Bridge Works issued by the Ministry of Road Transport & Highways (MORT&H), Government of India and published by the Indian Roads Congress (IRC) Specifications and Material Specifications items.

(iii) **Tentative number of machines to be deployed:**

The firm/agency should deploy, at least One Machine/Equipment for each 100 km of 4/6 lane NH and for each 200 km of 2 lane/2 Lane PS NH.

Fig 2.9 Automatic pot hole filing, compacting and patching machine

2.3.1.2 Routine Maintenance Treatments

(I) Crack Sealing

Crack sealing is undertaken to prevent water infiltration by sealing the cracks preventing possible onset of potholes and structural failures. This is applicable for longitudinal, transverse, and low-intensity alligator cracks (0–3 mm width and <10% affected area).

a. **Crack Sealing using Bitumen Emulsions –** Manual method of crack sealing

Methodology:

Step 1: Clean the cracked surface to remove dust and debris.
Step 2: Pour bitumen emulsion directly onto the cracks.
Step 3: Spread the emulsion manually using a wiper to ensure penetration into cracks.
Step 4: Spread a layer of sand over the surface to enhance adhesion and promote sealing.

Figure 2.10: Crack sealing with Bitumen Emulsions

Note: This method is cost-effective and widely adopted, though it offers relatively lesser durability compared to hot bitumen sealing.

b. **Crack Sealing using Hot Bitumen Sealant –** Mechanical method using Crack Sealing Machinery

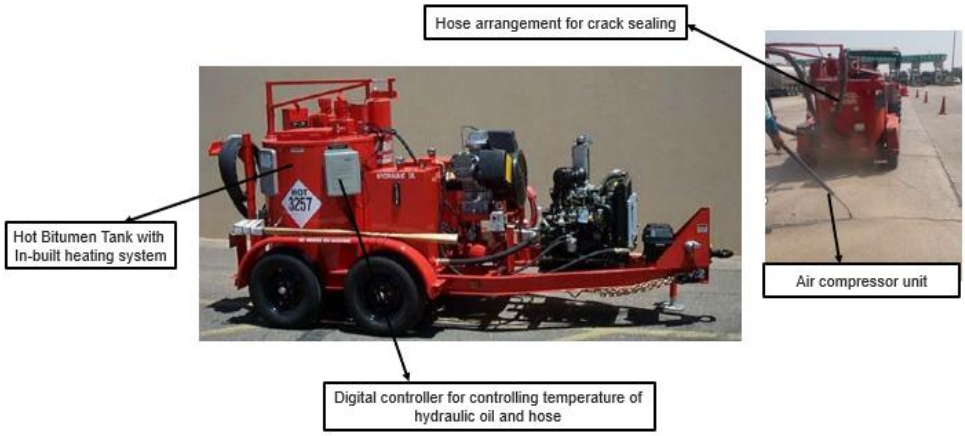


Figure 2.11: Crack sealing machine

Methodology:
Step 1: Clean the cracks thoroughly using an air compressor to remove dust and loose material.
Step 2: Apply hot bitumen sealant into the cracks using a specialized crack sealing machine.
Step 3: Remove any excess bitumen from the surface.
Step 4: Spray a mixture of sand and lime over the sealed area to enable faster setting and prevent sticking.

Figure 2.12: Crack sealing with hot bitumen sealant

Note: Core tests taken on the sealed cracks using mechanical methods have shown that hot bitumen sealant provides superior sealing performance by minimizing moisture infiltration.

(II) Pothole Filling
Pothole filling is to be carried out within 24 hours of its occurrence using cold mix, which can be sourced from external vendors or prepared in-house.

Methodology:

Step 1: Each pothole and patch repair area shall be inspected and all loose and defective material removed.
Step 2: The area shall be cut/trimmed to a regular shape. The edges of the excavation shall be cut vertically.
Step 3: The area shall be thoroughly cleaned with compressed air or any appropriate method approved by the Engineer to remove all dust and loose particles.
Step 4: Layers below the level of the bituminous construction shall be filled using material of the equivalent specification to the original construction, which shall particularly include the specified standards of compaction.
Step 5: The area and sides for bituminous construction shall be applied with a tack coat conforming to Clause 503 of these Specifications before back filing operation.
Step 6: The mixture to be used in bituminous patching shall be either a hot mix or a cold mix in accordance with the appropriate Clauses of these Specifications or any other approved patching material.
The bituminous mixture shall be placed in layers of thickness not more than 100 mm (loose) and shall be compacted in layers to the compaction standards defined in the appropriate Clauses of these Specifications.

Step 7: While placing the final layer, the mix shall be spread slightly proud of the surface so that after rolling, the surface shall be flush with the adjoining surface.

Figure 2.13: Typical cross section of flexible pavement

(III) Rutting and Shoving Repair using Skid Steer Loader with Milling Attachment

This method is suitable for minor rutting (<15 mm) and surface shoving. It is used to remove the heave of the rutting/shoving and thereby eliminate rutting on the pavement.

Figure 2.14: Bob cat repair of rutting

2.3.2 Preventive Maintenance: It includes a systematic inspection, detection, correction and prevention of incipient failures before they become actual failures. It is performed to improve or extend the functional life of the pavement. It is a strategy of surface treatments and operations intended to retard progressive failures and reduce the need for any major maintenance.

Preventive Measure	Intervention Level	Treatment Methodology	Time Limit for Rectification	Remarks/ Additional Information
Patchwork & Rehabilitation	Distressed pavement sections	**Patchwork/Rehabilitation:** Milling of distressed area and replacing it using Bituminous Concrete (BC) or Dense Bituminous Macadam (DBM)		Essential for functional maintenance
Micro-Surfacing	Surface irregularities/ undulations/ settlements	**Micro-surfacing:** clean surface, remove any undulations/settlements, and apply micro-surfacing layer		Cost-effective
Micro-Milling & Rut Box Repair	Rutting < 20mm	**Micro-milling and Rut Box Repair/Micro-surfacing**: Use micro-milling machine to remove the heave portion and to level surface, clean thoroughly, then apply micro-surfacing laid on the top of micro milled section		Ensures uniform surface
Hot Sand Spraying	Minor Bleeding on pavement	**Hot Sand Spraying**: Apply coarse sand over surface to absorb excess asphalt binder		Used to address minor bleeding

Figure 2.15: Micro-surfacing

Figure 2.16: Micro-milling and Rut box repair

2.3.3 Major Maintenance: It is performed after a deficiency occurs in the pavement such as loss of friction, moderate to severe rutting or extensive cracking. Some of the treatments considered as a part of Major Maintenance are presented below.

Treatment Method	Application Criteria	Distress Type	Description	Key Benefits
Fibre Based Micro-surfacing	Pavement has remaining life > design traffic No structural distresses Minor Functional Distresses must be treated before application	Functional Distress (No Structural Damage)	A thin 6–8 mm preventive maintenance layer comprising polymer-modified emulsion, fine aggregates, mineral fillers, water, and additives.	Seals surface cracks Restores texture and skid resistance Delays pavement deterioration
Glass Grid Rapid	Applicable only on structurally sound sections with adequate remaining life Recommended where 40mm overlays are proposed and surface cracks or functional distresses are observed	Functional cracks	A high-strength asphalt reinforcement grid with a self-adhesive bitumen-modified backing to prevent reflective cracking.	Reinforces pavement structure Reduces risk of crack propagation Enhances overlay lifespan
Bituminous Overlays	Effective for pavement rehabilitation, combining structural reinforcement and functional improvements	Functional and structural deficiencies	Placement of one or more layers of bituminous material over existing pavements to improve structural and functional conditions and extend the remaining life of the pavement	Restores strength and serviceability Extends pavement life Enhances ride quality

	Localized failures must be treated prior to overlay			
Bituminous Inlays	Recommended for pavements with surface-level distresses such as cracks but no major structural failure	Cracks, minor surface distresses	Involves full width milling and removal of the existing surface followed by laying a new bituminous layer.	Removes distressed layers Improves uniformity and performance Ideal for surface rehabilitation
Cold Central Plant Recycling (CCPR)	Suitable for large-scale pavement rehabilitation with focus on sustainability and cost-effectiveness	Rehabilitation technique	Recycling of RAP at a central facility using additives like emulsified asphalt to produce a fresh mix.	Environmentally sustainable Reduces raw material usage Cost effective and durable
Cold In-Place Recycling (CIPR)	For in-situ pavement recycling with minimal transport of materials	Surface and base distresses	Involves on-site milling and reuse of the existing pavement to create a new recycled base layer with additives (e.g., emulsified or foamed bitumen).	Time and cost efficient Minimizes environmental footprint Reduces construction time and logistics
Stone Matrix Asphalt (SMA)	Best suited for high-volume traffic roads, highways, and urban roads with heavy axle loads	Rutting, fatigue	A gap-graded structure, combined with high binder content and stabilizing additives such as fibres, ensuring fatigue resistance and long-term performance	High rut resistance Excellent durability and fatigue resistance Long term service life
White Topping	Applied to distressed pavements requiring improved structural capacity	Structural distress, surface failures	A technique involving the placement of a concrete overlay over an existing bituminous surface, strengthening the pavement structure.	Increases structural performance Reduces frequent maintenance Suitable for high load and extreme climate conditions Long service life contributes to reduced life cycle costs

The selection of appropriate treatment methods shall be based on the type of pavement distress identified. Refer to the flow chart provided below for a systematic approach to determine the recommended treatment based on the observed distress type.

Figure 2.17: Fibre based Micro-surfacing

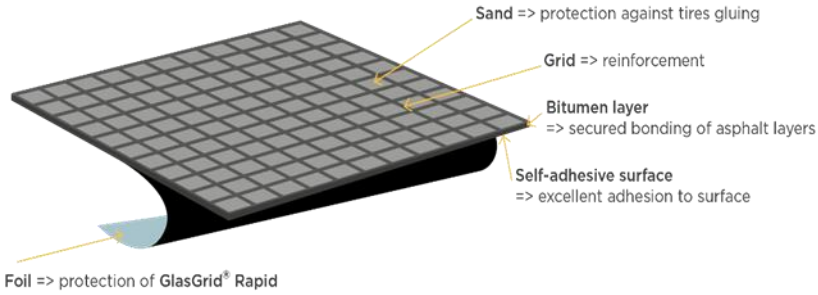


Figure 2.18: Glass grid Rapid

Figure 2.19: Execution of Glass grid Rapid

Figure 2.20: Bituminous Inlay Execution

Note: Additional treatment techniques like In-place recycling techniques are generally not preferred due to challenges in quality control whereas Hot and Cold In-plant Recycling methods are increasingly adopted for their quality assurance and sustainability advantages.

2.3.4 Intervention levels and distress – Decision Making Tree

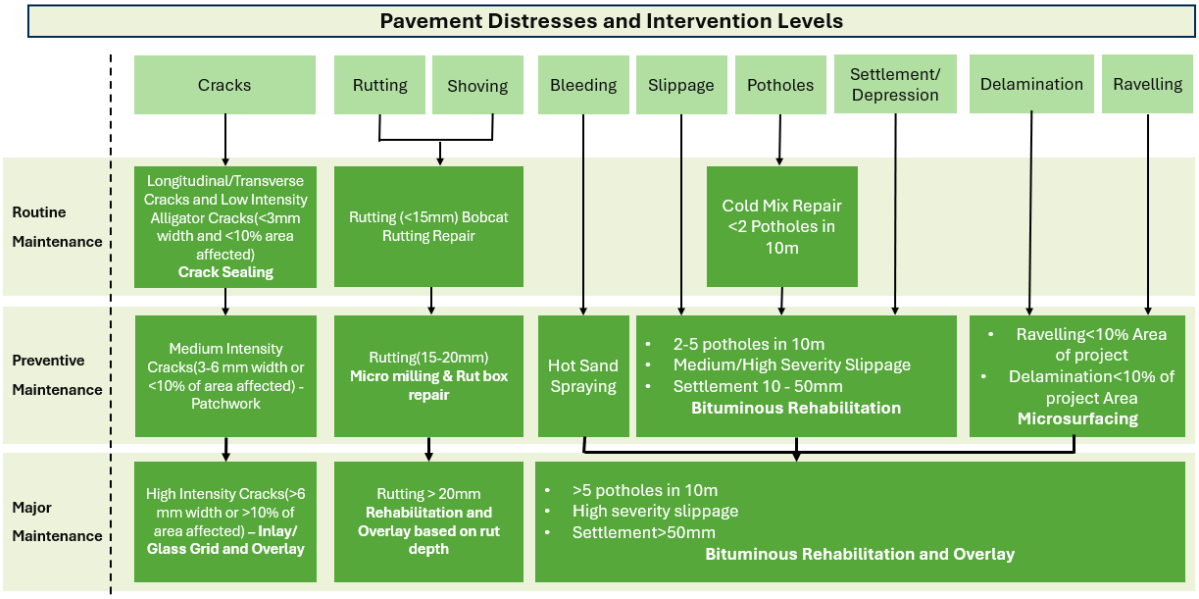


Figure 2.21: Decision Tree for Flexible Pavement

2.3.5 Maintenance Methodology for Pavement Sections Affected by Overloaded Truck Traffic

Pavement sections exposed to frequent overloading from heavy commercial vehicles are highly susceptible to premature distress. To effectively manage such sections, a two-pronged approach involving preventive maintenance and major rectification strategies is essential. The process begins with routine monitoring and quick response, followed by detailed investigations and corrective actions based on the identified root causes.

Typical Failures Observed in Overloaded Sections

1. Rutting
2. Cracking
3. Potholes
4. Surface Settlements

Preventive Maintenance Strategy

Preventive maintenance aims to arrest the progression of early-stage failures and extend the pavement's service life, especially in overloaded zones.

1. **Milling and Micro surfacing**
   This includes milling of the heave portion of the rut to level the surface of the pavement and resurfacing is done using micro surfacing.
2. **Cold Mix for Minor Cracks and Potholes**:
   Areas with smaller cracks or potholes up to 1 m^2 are rectified using conventional cold mix or appropriate crack sealing methods. These techniques are quick, economical, and effective for limited surface damage.
3. **Use of RAP with Emulsion for Preventive Treatment in Larger Distress Zones**:
   In areas exhibiting wider surface-level distress, cold mix can be replaced with a blend of Reclaimed Asphalt Pavement (RAP) and bitumen emulsion. This method acts as a preventive treatment, offering better bonding and flexibility. While not a permanent solution, it helps in slowing the progression of damage and maintaining surface usability until further investigation or major maintenance is scheduled.

(For detailed strategies refer point 2.3.1, 2.3.2 & 2.3.3)

2.3.6 Transition to Major Maintenance and Rectification

When preventive measures fail to contain recurring distress, a more detailed approach is initiated. Investigations are carried out as mentioned in section 2.1 of this manual to understand the extent of failures and to identify the depth of the issue.

Rectification Strategies Based on Investigation Findings

1. **Subgrade-Related Failures**:
   - If the subgrade is found to be inadequate, either stabilization techniques (using lime or cement) are employed, or full-depth reconstruction is undertaken.
   - In some cases, the subgrade may inherently possess good strength but still shows distress due to persistent overloading. In such scenarios, the focus shifts to surface reinforcement using stronger bituminous materials.
2. **Drainage Layer Issues**:
   - Improper drainage often leads to moisture retention and structural weakening.
   - When drainage failures are identified, the Granular Sub-Base (GSB) layer is replaced or reprofiled, and surface water flow is improved through design correction.
3. **Overloading Without Soil Related Issues**:
   - Where the subgrade is intact, but the distress is caused solely by overloading, major maintenance interventions are planned including the use of HiMA, PMB 76, or other high-performance bituminous layers designed to withstand higher stress and resist deformation.

Overall Approach to Maintain such sections

The overall approach to managing overloaded pavement sections involves:

- Monitoring for early detection.
- Timely preventive maintenance using cold mix, RAP-emulsion blends, and Bobcat resurfacing.
- Detailed investigations when failures persist.

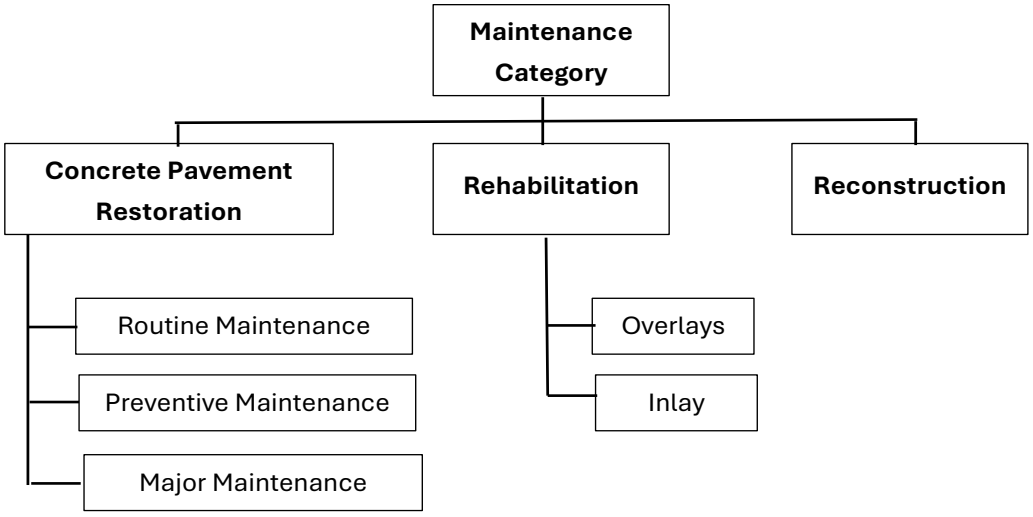
Targeted rectification based on the layer affected, whether it's subgrade, GSB, or surface layers.

2.4 Rigid Pavement

Rigid pavements are long-lasting and highly durable if the construction is done properly. The rate of deterioration is comparatively much slower than that of flexible pavements. However, the pavement is subjected to loading and environmental conditions which leads to deterioration, maintenance becomes necessary to maintain their integrity. With proper design, construction and maintenance, rigid pavement can serve for over 30 years without major repairs.

Maintenance Categories for Rigid Pavement Preservation

- **Concrete Pavement Restoration (CPR) Techniques** - Repair and maintenance operations without any overlay
- **Rehabilitation -** Strengthening involving overlay options
- **Reconstruction** - Undertaken after the end of service life or due to severe distresses in longer stretches due to faulty design/construction



Distress Type	Severity	Assessment Criteria	Maintenance Category	Treatment	Description
Single Discrete Cracks	2 and 3	w<1.5mm	**Routine Maintenance**	**Crack Sealing - Seal with low viscous epoxy**	Sawing, cleaning, and sealing cracks in concrete pavement using high-quality sealant materials.
Single Transverse Crack	1,2	w<0.5mm			
Single Longitudinal Crack	1	w< 0.5mm			
Multiple Cracks intersecting with one or more joints or cracks	1,2	w< 0.5mm			
Corner Break	1,2	w<1.5mm			
Multiple Cracks intersecting with one or more joints or cracks	3	w: 0.5-1.5mm	**Routine Maintenance**	**Route and Seal**	preparing the edges of cracks by removing deteriorated material to create a defined reservoir and filling these with a suitable sealant material
Single Discrete Cracks	4	w:1.5-3mm			
Single Transverse Cracks	3	w: 0.5-3mm			
Single Longitudinal Crack	2	w: 0.5-3mm			
Joint Seal defect	3	L: 25-50%	**Routine Maintenance**	**Clean and reapply sealant in specified locations**	Removal of existing deteriorated joint sealant materials, refacing and cleaning the joint sidewalls, and installing new material (liquid sealant and backer rod or performed compression seal).
Joint Seal defect	5	L >50%		**Clean widen and reseal the complete joint**	
Single Discrete Cracks	5	w>3mm	**Preventive Maintenance**	**Seal and Cross-stitch**	diagonally inserting deformed tie bars across cracks to maintain aggregate interlock and prevent the cracks from widening or moving at a predetermined spacing and the holes refilled with epoxy resin.
Single Transverse Crack	4	w: 3-6mm			
Single Longitudinal Crack	3	w:3-6mm			
Single Longitudinal Crack	4	w: 6-12mm		**Partial depth Repair**	

Distress Type	Severity	Assessment Criteria	Maintenance Category	Treatment	Description
Multiple Cracks intersecting with one or more joints or cracks	3	w: 1.5-3mm	**Preventive maintenance**		Removal of small, shallow (upper one-third to one-half of the slab) areas of deteriorated concrete and subsequent replacement with a cementitious or proprietary repair material.
Spalling of joints	2,3,4 and 5	w >10mm			
Corner Break	3,4 and 5	w > 1.5 mm			
Puchout					
Popout/Pothole					
Minor Surface roughness			**Preventive Maintenance**	**Diamond Grinding**	Removal of a thin layer of concrete from the pavement surface using special equipment fitted with a series of closely spaced, diamond saw blades.
Faulting		Faulting <6mm			
High speed Areas			**Preventive Maintenance**	**Grooving**	Cutting of narrow, discrete grooves into the pavement surface, either in the longitudinal direction or the transverse direction
Areas with poor drainage					
Joint Faulting		Joint faulting > 6mm	**Preventive Maintenance**	**Dowel Bar Retrofit (DBR)**	Placement of dowel bars across joints or cracks in an existing concrete pavement to restore load transfer.
Single Transverse Cracks	5	w >6mm	**Major Maintenance**	**Full depth repair**	Repair involving the replacement of part or whole slab panel to the full depth of the slab
Single Longitudinal Crack	5	w >12mm			
Multiple Cracks intersecting with one or more joints or cracks	4,5	w >3mm			
Blow up or buckling	4	h>25mm			
Multiple Cracks intersecting with one or more joints or cracks (broken into more than 2 pieces)	4,5	w >3mm	**Major maintenance**	**Slab Replacement**	removal of deteriorated concrete slabs and replacing them with new

Distress Type	Severity	Assessment Criteria	Maintenance Category	Treatment	Description
Shattered slab					concrete to restore structural integrity and functionality
Pumping	5	Area >25%			
Faulting or stepping	5	h>18mm	**Major Maintenance**	**Slab Stabilizations - Stabilize subgrade and reinstate pavement**	Filling of voids beneath concrete slabs by injecting cement grout, polyurethane, or other suitable materials through drilled holes in the concrete located over the void areas.
Depression	4,5	h>50mm			
Heave	4,5	h>50mm			
Settlement		**Differential Settlement > 12mm**		**Slab Jacketing**	Raising of settled concrete slabs to their original elevation by pressure injecting cement grout or polyurethane materials through drilled holes at carefully patterned locations.
Ravelling or honeycomb	4,5	Area >25%	**Major maintenance**	**Bonded inlay**	application of a new concrete layer directly on top of an existing pavement surface, ensuring a strong bond between the two layers
Scaling	4,5	Area >20%			
Minor to moderate Distress			**Major Maintenance – Overlay Treatment**	**Fully Bonded Overlays**	These overlays are directly bonded to the existing pavement surface. They are suitable for pavements with minor distress. The

Distress Type	Severity	Assessment Criteria	Maintenance Category	Treatment	Description
Low Skid Resistance					minimum thickness of bonded overlay is 100mm for light traffic and 150mm for heavy traffic.
				Partially Bonded Overlays	These overlays allow for some movement between the new and existing layers. They are used when the underlying pavement has significant distresses that could affect the performance of the overlay.
Widespread Cracking			**Major Maintenance – Overlay Treatment**	**Unbonded Overlays**	In unbonded systems, a separation layer is placed between the existing pavement and the new overlay to accommodate movements without transferring stresses. Unbonded overlay add structural capacity to the existing pavement and can be placed on poor and deteriorated pavements. The thickness of concrete overlays depends on the traffic loads, existing pavement conditions, and environmental factors. High-quality concrete mixes with

Distress Type	Severity	Assessment Criteria	Maintenance Category	Treatment	Description
					appropriate additives shall be used to enhance strength and longevity.

The type of treatment proposed depends on the type of defect, its severity and cause of the defect. There are various kinds of treatments available for rigid pavement as depicted in Table 2.10.

Table 2.6: Treatments for Rigid Pavement

Treatment	Description
Crack Sealing	Sawing, cleaning, and sealing cracks in concrete pavement using high-quality sealant materials.  **Figure 2.9: Crack sealing in Rigid Pavements**
Joint Resealing	Removal of existing deteriorated joint sealant materials, refacing and cleaning the joint sidewalls, and installing new material (liquid sealant and backer rod or performed compression seal).  **Figure 2.10: Joint Resealing**
Route and Seal	preparing the edges of cracks by removing deteriorated material to create a defined reservoir and filling these with a suitable sealant material
Cross- Stitching	diagonally inserting deformed tie bars across cracks to maintain aggregate interlock and prevent the cracks from widening or moving at a predetermined spacing and the holes refilled with epoxy resin.
Stapling	inserting U-Shaped steel staples or bars into cracks or joints to stabilize and reinforce the pavement and slot refilled with high performance/high strength cement mortar/epoxy mortar
Partial-Depth Repair (PDR)	Removal of small, shallow (upper one-third to one-half of the slab) areas of deteriorated concrete and subsequent replacement with a cementitious or proprietary repair material.

Treatment	Description
Full depth repair	Repair involving the replacement of part or whole slab panel to the full depth of the slab
Slab replacement	removal of deteriorated concrete slabs and replacing them with new concrete to restore structural integrity and functionality
Bonded Inlay	application of a new concrete layer directly on top of an existing pavement surface, ensuring a strong bond between the two layers
Fully Bonded Overlays	These overlays are directly bonded to the existing pavement surface. They are suitable for pavements with minor distress. The minimum thickness of bonded overlay is 100mm for light traffic and 150mm for heavy traffic.
Partially Bonded Overlays	These overlays allow for some movement between the new and existing layers. They are used when the underlying pavement has significant distresses that could affect the performance of the overlay.
Unbonded Overlays	In unbonded systems, a separation layer is placed between the existing pavement and the new overlay to accommodate movements without transferring stresses. Unbonded overlay add structural capacity to the existing pavement and can be placed on poor and deteriorated pavements. The thickness of concrete overlays depends on the traffic loads, existing pavement conditions, and environmental factors. High-quality concrete mixes with appropriate additives shall be used to enhance strength and longevity.
Slab Stabilization	Filling of voids beneath concrete slabs by injecting cement grout, polyurethane, or other suitable materials through drilled holes in the concrete located over the void areas.
Slab Jacketing	Raising of settled concrete slabs to their original elevation by pressure injecting cement grout or polyurethane materials through drilled holes at carefully patterned locations.
Dowel Bar Retrofit (DBR)	Placement of dowel bars across joints or cracks in an existing concrete pavement to restore load transfer.
Diamond Grinding	Removal of a thin layer of concrete from the pavement surface using special equipment fitted with a series of closely spaced, diamond saw blades.
Diamond Grooving	Cutting of narrow, discrete grooves into the pavement surface, either in the longitudinal direction or the transverse direction
Reconstruction	Full reconstruction of pavement shall be required at the end of its service life or due to severe distresses where concrete overlays are not feasible or slab stabilization is not advisable or feasible. If the pavement has already experienced extensive cracking, faulting, widespread pumping or other forms of distress, simply filling voids will not restore the structural integrity. Also, if the underlying soil or fill material does not provide adequate load-bearing capacity, slab stabilization may not be effective. This warrants for reconstruction.

(a) Intervention levels and distress – Decision Making Tree

Table 2.7: Treatments based on Distress Severity

Treatment	Distress	Severity	Assessment Criteria
Seal with low viscous epoxy	Single Discrete Cracks	2 and 3	w<1.5mm
	Single Transverse Crack	1,2	w<0.5mm
	Single Longitudinal Crack	1	w< 0.5mm
	Multiple Cracks intersecting with one or more joints or cracks	1,2	w< 0.5mm
	Corner Break	1,2	w<1.5mm
Route and Seal	Multiple Cracks intersecting with one or more joints or cracks	3	w: 0.5-1.5mm

Treatment	Distress	Severity	Assessment Criteria
	Single Discrete Cracks	4	w:1.5-3mm
	Single Transverse Cracks	3	w: 0.5-3mm
	Single Longitudinal Crack	2	w: 0.5-3mm
Seal and Cross- stitch	Single Discrete Cracks	5	w>3mm
	Single Transverse Crack	4	w: 3-6mm
	Single Longitudinal Crack	3	w:3-6mm
Partial depth Repair	Single Longitudinal Crack	4	w: 6-12mm
	Multiple Cracks intersecting with one or more joints or cracks	3	w: 1.5-3mm
	Spalling of joints	2,3,4 and 5	w >10mm
	Corner Break	3,4 and 5	w > 1.5 mm
	Puchout		
	Popout/Pothole		
Full depth repair	Single Transverse Cracks	5	w >6mm
	Single Longitudinal Crack	5	w >12mm
	Multiple Cracks intersecting with one or more joints or cracks	4,5	w >3mm
	Blow up or buckling	4	h>25mm
Clean and reapply sealant in specified locations	Joint Seal defect	3	L: 25-50%
Clean widen and reseal the complete joint	Joint Seal defect	5	L >50%
Bonded inlay	Raveling or honeycomb	4,5	Area >25%
	Scaling	4,5	Area >20%
Slab Replacement	Multiple Cracks intersecting with one or more joints or cracks (broken into more than 2 pieces)	4,5	w >3mm
	Shattered slab		
	Pumping	5	Area >25%
Stabilize subgrade and reinstate pavement	Faulting or stepping	5	h>18mm
	Depression	4,5	h>50mm
	Heave	4,5	h>50mm

Note: w = width of crack, Dia = Diameter, L= length, h=height

2.5 Pavement Management System:

According to AASHTO (1993), Pavement Management System (PMS) is defined as “a set of tools or methods that assist decision-makers in finding cost-effective strategies for providing, evaluating, and maintaining pavements in a serviceable condition."

With the increasing demand for efficient roadway maintenance and management, the implementation of a Pavement Management System (PMS) has become indispensable.

PMS aids agencies and decision-makers by evaluating pavement conditions, forecasting performance, and identifying cost-effective maintenance strategies. By analysing data on traffic, pavement distress and environmental factors, PMS prioritizes repairs, minimizes costs, optimizes resource allocation and ensures the safety and durability of road networks.

(a) Elements of PMS:

An effective Pavement Management System comprises key components that work together to ensure efficient road maintenance and management. These include **data collection**, which involves gathering information on pavement conditions, traffic loads, and environmental factors; **deterioration models**, which predict future deterioration and performance; **treatment effectiveness models** which describes the

improvement post applying treatment and finally **decision-making frameworks**, that prioritize maintenance and rehabilitation strategies based on cost-effectiveness and policy objectives. Together, these elements ensure optimal resource allocation and sustainable pavement management.

I. Data collection and database management:

Data collection is one of the most crucial systems, which affects decision-making, helps assess road conditions, forecast future deterioration, and prioritize repairs. It ensures efficient resource allocation, cost-effective maintenance, and enhances long-term road network performance and safety. Various data is needed in the database for proper finetuning. Figure 23 shows the data that is required.

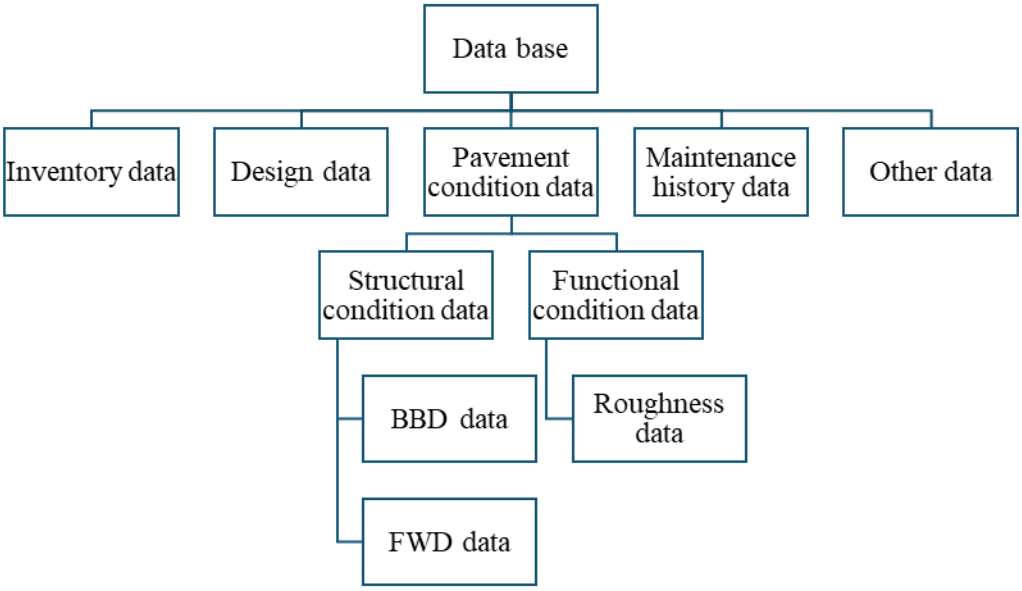


Figure 2.11: Data required for Pavement Database

i) Inventory data: Road geometrics, sections, drainage, and other amenities, if any
ii) Design data: Pavement and mix design details, material characteristics, and specifications of pavement layers
iii) Pavement condition data: Surface deflection, roughness, skid resistance, cracking, rutting, etc.
iv) Maintenance history data: Timing and methods adopted to execute previous maintenance
v) Other data: Traffic volume, speed, axle loads, seasonal correction factors, cost of maintenance operations, and vehicle operating costs required for performance prediction as well as economic evaluation of maintenance operations.

II. Deterioration model:

It is a mathematical model that represents the expected values of pavement characteristics over a defined analysis period. Deterioration can be tracked based on both structural and functional conditions. **Structural condition** refers to the ability of the road infrastructure to support the applied loads, while **functional condition** pertains to the quality of the ride. To assess structural condition, performance indicators such as **Structural Number (SN)**, and **remaining life** can be used. For functional deterioration, performance indicators like the **Pavement Condition Index (PCI)** and **Roughness Index (RI)** can be applied.

A deterioration model consists of two parts: one without any treatments applied to the road, called the **performance model**, and the other with the intervention of treatments. The performance model is an increasing function, representing the "do-nothing" scenario, which shows how the road will perform over its lifespan. When treatments are applied, the road quality improves and shows a jump of improvement in performance parameter.

General form of deterioration model can be represented as:

Conditional parameter = f (v1, v2, v3....)

Where v1, v2, v3... are independent variables.

The contribution of these variables leads to the deterioration of road conditions, and when a condition parameter reaches a threshold, a treatment is triggered. Once applied, the treatment improves the road quality, and the pavement will deteriorate at a different rate depending on the type of treatment. Therefore, it is crucial to assess the extent of improvement, known as **treatment effectiveness**, and to determine the new deterioration rate after the treatment is applied.

III. Treatment effectiveness:

Treatment effectiveness measures how well a maintenance or rehabilitation treatment improves pavement condition. Treatment effectiveness can be modelled by performing before-and-after condition studies.

After applying a treatment, the pavement will deteriorate at a different rate. A less effective treatment applied later will lead to faster deterioration, requiring more frequent treatments. In contrast, major treatments delay deterioration, reducing the need for frequent interventions and potentially lowering overall costs. Therefore, treatments should be carefully chosen to achieve an optimal balance of high serviceability and reduced costs.

IV. Life Cycle Cost:

Life Cycle Cost Analysis (LCCA) analysis is a tool that provides a comprehensive evaluation of the costs related to a pavement alternative throughout its lifespan, including both construction and maintenance expenses. This provides a framework for decision-makers to choose the most cost-effective alternative by considering all long-term costs.

2.6 SOP to develop database

(a) Purpose
The purpose of this SOP is to establish a clear and structured procedure for developing a comprehensive database to support a Pavement Management System (PMS). This database will be instrumental in collecting, storing, analysing, and reporting crucial data. The end goal is to enable informed decision-making for effective pavement maintenance and management, ultimately optimizing resource allocation and extending the life of road networks.

(a) Data Collection and Requirements
A standardized format has been established for all data collection to ensure consistency and efficiency. All field data is collected using this fixed format, minimizing the need for additional efforts to reorganize or reformat the data. Technical surveys are conducted by a designated group of agencies, which are provided with the standardized format. This approach ensures uniformity in data collection processes and eliminates inconsistencies, streamlining the subsequent stages of data processing and analysis. Further the data is regularly updated whenever new surveys are conducted ensuring that the database remains up-to-date and reflect the latest pavement condition. The database includes the following items:

1. ***Pavement Condition data:*** It includes structural condition data including surface deflection and remaining life (from FWD survey) and functional condition data including roughness, rutting and other pavement distresses (from NSV survey).
2. ***Pavement Maintenance History:*** It includes the pavement composition data from pavement design report, test pits and core cutting, previous maintenance data including details from all routine, preventive and periodic maintenance details carried out on the pavement.
3. ***Other essential data:*** This includes all the inventory data, material testing results and traffic data

All the above data helps in understanding the correlation of pavement condition to the treatment techniques adopted, performance of each technology and can be used for development of deterioration models.

(b) Importance of the database
A centralized database is essential for effective pavement management, offering several key benefits:

i) **Centralized Data Collection and Storage**: It consolidates all relevant data in one place, ensuring consistency and reducing discrepancies, which helps maintain data integrity and ease of access.
ii) **Improved Analysis Accuracy**: With comprehensive and standardized data sets, the database enhances the precision of analyses and predictions, enabling more accurate forecasting of pavement conditions.

iii) **Facilitated Maintenance Planning**: The database helps prioritize repairs by providing clear insights into pavement conditions, optimizing resource allocation, and ensuring timely interventions.
iv) **Foundation for Data-Driven Decisions**: It supports informed decision-making by offering real-time and historical data, allowing stakeholders to select the most effective maintenance strategies based on solid evidence.
v) **Enhanced Efficiency and Resource Allocation**: Streamlined processes and clear insights enable efficient resource use, reducing costs and ensuring that maintenance efforts are directed where they are most needed.
vi) **Improved Stakeholder Communication**: By providing transparent and easily interpretable data, the database enhances communication with stakeholders, fostering trust and informed decision-making.

2.7 Standard Operating Procedure (SOP) for Pavement Maintenance Execution including Latest/Innovative Technology Implementation

This section establishes a structured framework for the efficient execution of maintenance activities on project roads ensuring adherence to quality, safety and sustainability standards. It applies to all major maintenance activities including adoption and integration of advanced technologies and materials.

NHAI has implemented several innovative technologies during maintenance works of their road assets, with their performance being regularly monitored. These advanced technologies require not only technical expertise but also a well-planned quality control process during execution, managed by a specialized quality control team. The Authority is further supported by an team of Supervision Consultants, which monitors the conditions of the highway assets and monitor the rectification/operation/maintenance activities of contractors to ensure the success of all maintenance and construction activities.

The guidelines, implementation methodology and checklist during execution of all these technologies are provided in the following sections:

I. Implementation Framework

A structured methodology should be implemented for use of innovative technologies through Supervision Consultant team, who dedicatedly monitors all the works during the complete execution process of maintenance works.

(a) The Supervision Consultants should team consists of young, energetic, and well qualified engineers from esteemed institutions such as IITs, NITs and others. Their technical knowledge, enthusiasm, and innovative problem-solving capabilities drive the success of all maintenance and construction activities.
(b) Specialized Quality Control Teams: Supervision Consultants team should consist of technical expertise in mix design, field execution, and monitoring, who collaborates with contractor for successfully execution of maintenance activities. These team are full time deployed at site for monitoring during the execution of the works and they are the key members to ensure successfully implementation of SOP.

Key Advantages of the Supervision Consultant Team

- ***Dynamic Engagement:*** Proactively identify and solve problems during execution.
- ***Technological Expertise:*** Ensure precise monitoring and accurate reporting.
- ***Innovative Approaches*:** Apply cutting-edge methods for efficient project execution.
- ***Collaboration Across Teams:*** Facilitate seamless communication between contractors and the head office.

II. Execution Flow Chart

The following are the steps involved in execution of various treatments techniques as part of major maintenance works:

a. Preliminary assessment and planning
b. Mix Design
c. Execution monitoring, quality control and quality assurance
d. Monitoring and feedback

(a) Preliminary Assessment and Planning

Project Assessment: The assessment of the project is the first step in planning maintenance activities. This includes:

- Comprehensive evaluation of conditions (include traffic and environmental parameters)
- Assess severity and types of road distresses
- Review project history and prior interventions.

(b) Mix design

Once the maintenance technology is finalised, the following steps shall be followed in finalising the mix designs:

Material selection and Characterisation

- Source materials exclusively from approved vendors, ensuring strict compliance with quality standards.
- Test materials for compatibility with site-specific conditions and performance objectives.

Preparation of Mix Design

Firstly, mix design of conventional mix (BC or DBM) is performed at any reputed laboratory such as IITs, NITs, CRRI or NABL accredited laboratory. For implementation of innovative technologies, usually expert committee may be formed constituting experts from the field and researchers to ensure formulation of mix design to implementation goes smoothly.

Based on the methodology finalised by the expert committee/supervision consulta, as the case may be, Supervision Consultants monitors the end-to-end quality control process from bitumen modification to site execution. In this process, Supervision Consultants team reverifies mix deign to ensure translation from controlled laboratory to field is proper.

SOP formulation

A detailed implementation guidelines is developed comprising details related to quality control measures, monitoring protocols and Dos and Don'ts of technology implementation.

(c) Execution Monitoring, Quality Control and Quality Assurance

As a part of the execution of monitoring, the following activities should be carried by the Supervision Consultant team on ground in consultation with the NHAI.

- ***Training and Education:*** Training of contractor, supervisor and labour team is very crucial prior to implement any technology. Supervision Consultants team conduct a training program along with product/technology experts.
- ***Execution Monitoring:*** Supervision Consultants closely monitors the overall process during the execution for quality control and quality assurance, which includes:
    1. **Quality Control at Site**
        - Monitor processes from mix design to field implementation.
        - Conduct toolbox talks to address on-site challenges.
        - Perform regular quality checks and maintain records for audits.
        - Collaborate with the head office for updates and guidance.
        - Carry out quality inspections aligned with IRC guidelines and expert opinion.
    2. **Quality Assurance**
        - Field performance tests to ensure adherence to expected standards
        - Routine inspection of materials, equipment and processes
        - Daily analysis of HMP batch reports in line with ASTM D995 and IS 3066 standards to identify variability in aggregate and binder dosages
        - Addressing Non-Compliance by identifying deviations promptly and implement corrective actions immediately to mitigate risks

(d) Post-Execution Activities

Post-execution activities include the following:

- Prepare a comprehensive report detailing of materials, processes and test results
- Maintain records for audits and future reference.
- Collect feedback from contractors, the Supervision Consultants team and stakeholders
- Incorporate lessons learned into future SOP updates

PART 3: STRUCTURE MAINTENANCE

3.1 Background

Highway structures, such as bridges and overpasses, are complex engineering marvels that encompass various components, and the function of each component is vital for ensuring the safe and reliable operation of the entire structure. These components can include foundations, pier / abutments, pier caps, bearing pedestals, seismic arrestors, bearings, girders, deck slab, expansion joints, drainage spouts, approach slabs and safety barriers that collectively facilitate smooth flow of vehicular traffic crossing any obstacle such as water bodies, crossroads, rail lines, and valleys.

To guarantee the structural integrity and safety of these highway structures, a comprehensive evaluation and maintenance strategy is required. The evaluation involves a meticulous assessment of each component independently, taking into consideration a range of parameters and factors. These parameters might include smooth functioning of highway crossing (may be a stream, river, crossroad or rail lines etc.), in addition to structures own safety. Structures safety in turn depends upon its constituent material strength, load-bearing capacity, fatigue resistance, environmental conditions, and more. Each component's performance is assessed to ascertain its adequacy, ability to perform intended function and to withstand its complete design life.

The evaluation of highway structures involves a detailed examination of each component to guarantee its contribution to the overall safety, durability, and reliability. These assessments help engineers to make timely decisions regarding maintenance and contribute to the overall longevity and effectiveness of the infrastructure.

The necessary requirements, inspections and required repairs of various components highway structures are given in various IRC codes and special publications including MoRTH construction specifications. Some of the most relevant codes pertaining to inspection and maintenance of highway structures are

(a) IRC: 5-2024
(b) IRC: 78-2020
(c) IRC:83-2018
(d) IRC:112-2020
(e) IRC: SP 13-2022
(f) IRC: SP 18-1978
(g) IRC: SP 35-2024
(h) IRC: SP 40-2019
(i) IRC: SP 69-2011
(j) IRC: SP 127-2020
(k) IRC: SP 35-2024

3.2 Types of Structures

The highway structures were categorized based on the usage of bridges, specifically:

Table 3.1: Type of Structures

Sl. No.	Utilisation category for bridge	Classification of structure
1	Water bodies	Major Bridge / Viaducts/ Minor Bridge/ Culverts
2	Crossroads	Elevated corridor / Flyovers / VOP / VUP/ LVUP/ SVUP
3	Railway lines	ROB / RUB
4	Pedestrian crossing	FOB / PUP
5	Animal crossing	AUP/EUP

Definitions:

1. Major Bridge (MJB): A bridge with a total length exceeding 60 meters.

2. Minor Bridge (MNB): A bridge with a total length of 6 meters to 60 meters.
3. Elevated Corridor: A bridge to cross a highway over at grade road with project highway elevated to cross two or more crossroads / obstacles.
4. Flyover (FO): A bridge to cross a major at grade highway in which project highway is elevated over at-grade road.
5. VOP (Vehicle Over Pass): A grade-separated structure for the crossroad above the Project Highway.
6. VUP (Vehicle Underpass): A grade-separated structure for the crossroad below the Project Highway.
7. LVUP (Light Vehicle Underpass): A grade-separated structure specifically for the crossroad permitting light vehicle traffic below the Project Highway.
8. SVUP (Small Vehicle Underpass): A grade-separated structure for the crossroad permitting small vehicle traffic below the Project Highway.
9. PUP (Pedestrian Underpass): A grade-separated structure allowing pedestrian path to cross below the Project Highway.
10. AUP (Animal Underpass): A grade-separated structure allowing animals to cross below the Project Highway.
11. EUP (Elephant Underpass): A grade-separated structure specifically designed for elephants to cross below the Project Highway.
12. ROB (Road Over Bridge): A structure built over railway lines to carry the Project Highway.
13. RUB (Road Under Bridge): A structure built under railway lines to carry the Project Highway.
14. Viaduct Multi span structure with high piers crossing deep Valley.
15. Culverts: Structures with a total length of up to 6 meters, categorized as follows:
    a. Box Cell Culvert
    b. Slab Culvert
    c. Masonry Arch Bridge
    d. Hume Pipe Culvert

3.3 Classification of Structures

The classification of structures is given in detail in chapter 3 of IRC: SP 35-2024. The salient features of the same is furnished in this manual for ready reference.

The bridges can be classified based on their various attributes:

Table 3.2: Classification of Structures

Sl. No.	Attributes	Types
1	Functionality	Road, Rail, Viaduct, Aqueduct, Railroad, Pipeline, Pedestrian etc.
2	Construction Material	Masonry: Brick/Stone/Plain Concrete blocks
		Reinforced Cement Concrete
		Pre-Stressed Concrete, Steel
		Timber bridges
		Plastic, Fibre
		Steel Composite bridges
3	Inter-span Relations	Simply supported, Continuous, Cantilever etc.
4	Relative Level of High Flood Level	Submersible, Non-Submersible, Causeways
5	Span Length	Culvert, Minor, Major, long
6	Type of Super Structure	RCC T Beam, Arch, PSC I Girder, Stiffened Girder, Truss bridges, PSC Box Girder, Steel composite Girder and Box Girder
7	Structural Form	Arches, simply supported spans, continuous spans, Rigid frame type with decking integral with substructure, Cantilever or balanced cantilever, Suspension, Cable stayed and Extra-dosed, I/T-beam, Box girder, Composite Girder, segmental etc.
8	Method of Connections	Welded, Riveted, Rigid, Pin

9	Relative Position of Bridge Floor	Through, Semi- Through, Deck
10	Clearance for Navigation	Navigable/non-navigable, moveable, Bascule, Transporter, Swing bridges etc.
11	Type of Loading	70R, 40R, Class AA, Special Vehicle, Class A and Class B
12	Life and Service	Temporary, Permanent
13	Degree of Redundancy	Determinate, Indeterminate

3.4 Inspection Protocols

3.4.1 Types of Inspections: Inspection protocol for highway structures within the project highway is categorized as follows to ensure effective operation, maintenance, and implementation of the Asset Management System:

I. Routine Inspection

Routine visual inspections are to be carried out by highway/bridge maintenance engineers who have knowledge of highway/road structures. The purpose of visual inspection is to report the defects, and deficiencies of pavement/structure, missing or damages to safety barrier (crash barriers), obstacles to traffic and traffic signs installed or erected on highway. Such inspections should be conducted daily. Periodically minimum twice a year Pre and Post monsoon. The visual inspection may be carried out by visual assessment with careful observation of the specific object/item of the Project Facilities for identification and for quantification of the deficiencies or damages of the Project Facilities. Geotagging Cameras and Distance Measuring Devices shall be used to update base asset performance parameters on a daily basis. If timely inspection and safety issues are not reported or documented, it could lead to accidents or severe maintenance issues.

The following structure components and parameters shall be inspected as part of routine inspection,

- Potholes on wearing coat.
- Stagnation of rainwater on bridge deck.
- Physical damage to crash barrier / safety barrier.
- Missing sign boards.
- Overtopping of marks at structure location if any.
- Approach settlement.
- Cleaning of Drainage spouts

II. Periodic Close Inspection

Close inspections of Highway structures for assessment of defects/deficiencies shall be periodic in nature and would require detailed examination of all elements of the Project Highway at specific intervals with pre-defined check lists. The frequency of close inspections would depend upon the nature of the elements of the Structure. This is to be done before bridge is open to traffic and second DLP contract expires.In between to be done in every three years. Details check list for each type of structure prepared duly considering the IRC: SP 35-2024 are furnished in this manual for guidance. Close inspection may be visual or may involve investigations to be carried out using instruments. However, minimum one such inspection should be carried out once in six months (like pre and post monsoon). This inspection is to be carried out by the Bridge Expert team having good knowledge of Structures with theoretical background to analyse the nature, and extent of defects/deficiencies, suggest suitable remedial measures to rectify/remedy them and quantify repair work. Under water inspection also to be done similar to principal inspection for components submerged in water.

III. Thorough/Special Inspection and Investigation

A thorough / Special inspection and investigation is a comprehensive and detailed assessment of defects/deficiencies of the bridge with the aid of specialized investigative equipment and / or non-destructive testing. Such an inspection is to be carried out at intervals of once in 5 years or notice of severe and complex defects / distress identified during periodic close inspection or after any natural disaster like earthquake, floods, highwinds, unusual forces.

3.4.2 Inspection Methods:

The various methods for Bridge Inventory and Condition survey are given below:

i) Field Inventory & Visual Condition Survey
ii) Photo/video Log
iii) Integrated GPS/GIS Mapping Systems-NSV &MBIU
iv) 360-degree Drone survey
v) Any other latest technological tool

Table 3.4 Tools and equipment for inspection

Table 3.3: Tools and equipment for inspection			
Sl.	**Tools**	**Tentative Equipment**	**Tentative Numbers**
1	Tools for Cleaning	Wisk broom, Wire brush, Scrapers (2 inch or 50mm), Flat bladed, screw driver, Shovel	3
2	Tool for Visual Aid	Binocular, Flashlight, Lighted magnifying glass, Inspection mirrors, Dye penetrate. Crack scopes, Vernier callipers'	3
3	Tools for Inspection	Pocket knife, Ice pick, Hand brace and bits, Increment borer, Chipping hammer with leather holder, Plumb bob, Tool belt with tool pouch, Chain drag, Range pole/ Thin steel rod to probe (8-20 mm diameter) emery papers, piano-wire	2
4	Tools for Measuring	Measuring tape 5m, 30m, 50m and 100m, Laser Measuring Device, Callipers, Optical crack gauge, Paint film gauge, Tilt meter and protractor, Thermometer, D-Meter (ultrasonic thickness gauge), Electronic Distance Meter (EDM), Line level and string line. 2-meterstraight edge and calibrated wedge for measuring rut depth Feeder Gauges, micrometer gauges, calipers, torque winches Straight edge, protractor, spirit level Thermometers etc.	1
5	Tools for Documentation	Tablet, Note-Pad, Plastic jar, bags for keeping samples Clip-boards, ball-point pens or pencils and note book, Inspection forms, inspection reports	1
6	Tools for Access	Boat, Ladders, Ropes Hangers etc.	As per the Requirement

7	Miscellaneous equipment	"C"-clamps, Penetrating oil, Insect repellent, Wasp and homet killer, First-aid kit, Dust masks or respirators. A box of chalk for marking, markers clamp	These should be provided as per Man power deployed during inspection
8	Safety Tools	PPE	These should be provided as per Man power deployed during inspection
9	Visual Aids	Inspection mirror, binoculars, magnifying glass, Camera, camera flash light etc.	

3.4.3 Implementation of Bridge Inventory and Condition Rating System (BICRS) for recording Asset and Health of Structures of all Projects

To ensure the Systematic management and safety of its Infrastructure Assets, the Bridge Inventory and Condition Rating System (BICRS) is developed based with the following key-features:

a) Inventory of Structures:

- Establishment of a unified repository of all structures, each assigned with a Unique Asset Identification Number.
- Comprehensive Recording of Structural Specifications, geographical Coordinates, AS-IS Drawings and related Documentation.

b) Condition Assessment:

- Systematic evaluation of Structural Health based on Predetermined Rating Parameter.
- Identification of Traffic Restrictions or Suspension of Heavy Vehicle Movement, as applicable.

c) Inspection and Reporting:

- Consolidation of historical inspection data, condition rating, recommendations, and maintenance requirements into a centralised dashboard.

Supervision Consultants shall record one-time structural specification details of projects on BICRS Platform using NHAI ONE Application and AS-IS Drawing and related documents can be uploaded on Data Lake Portal. Thereafter, structural health condition shall be recorded and reported on BICRS platform in all structure related inspections. Detailed SOP to facilitate use of BICRS related modules on NHAI ONE and Data Lake is available in Data Lake Helpdesk menu for easy reference and Guidance.

3.5 Distresses in Structures

3.5.1 Distress-

Deterioration is a complex phenomenon and it may not be possible to include all the distress types into one mechanism. Deterioration is any adverse change of the normal mechanical, physical and chemical properties, either on the surface or on the whole body of concrete, generally through separation of its components.

The deterioration of concrete bridges takes place mainly because of four types of action i.e., chemical, physical, mechanical and electrochemical. The details of the various elements acting on the bridge and corresponding deterioration along with the remedial measures are given in SP:40.

Usually, a bridge deteriorates from the deck downwards. The deck is the first element of a bridge that is impacted by the traffic. It is also exposed to the worst environment and temperature variations. The Commonly Occurring Distresses of Typical Bridge Components have been detailed in following paras.

3.5.2 Distress in concrete Bridges

* Deterioration/aging: Deterioration is any adverse change of normal mechanical, physical and chemical properties, either on surface or on whole body of concrete, generally through separation of its components.

* Disintegration: Disintegration into small fragments or particles due to any cause, collision by vehicle or impact.

* Honeycombing: Condition of irregular voids caused by failure of the mortar to effectively fill the space between coarse aggregate particles. This may be due to congested reinforcement, insufficient cement content, improper fine/coarse aggregate ratio or inadequate placement technique.

* Delamination: It occurs over a large area of corroding reinforcing steel and results in a plane separation within the concrete immediately over the plane of reinforcing steel.

* Scaling: Is the loss of surface-mortar in concrete. This procedure exposes the aggregate particles and, in its advanced stages, results in the loss of aggregate and loss of section. Scaling is often indicative of inadequate air entrainment.

* Join Spalls: An elongated depression along an expansion, contraction, or construction joint.

* Spalling: Spalling is a depression, resulting from the dislodgement surface of concrete. Spalling is the local disintegration of a portion of a concrete surface. The predominant cause of spalling is the corrosion of reinforcing steel in concrete.

* Leaching: Water seeping through concrete, dissolves water-soluble components (such as calcium hydroxide) in the concrete, which appear on the underside of the deck, as stains or efflorescence.

* Cracking: A crack is an incomplete separation of concrete into one or more parts to a variable depth, but visible at surface. Cracks can be identified with their length, width, type and location of crack. They may be: Longitudinal cracking, Transverse cracking/Vertical cracking Diagonal cracking Bending cracking on the corner and Map cracking.

* Pop Outs (Plain Cement Concrete): Conical fragments that break out from the surface of the concrete leaving voids which may vary in size from 25mm to as much as 300 mm in diameter at concrete surface.

* Pitting (Plain Cement Concrete): Loss of thin coats of surface mortar directly over coarse aggregate particles, without apparent damage to the aggregate particles. The pits are usually not over 3mm in depth.

* Mud Balls: Small holes in the surface of concrete left by dissolution of mud balls that get mixed with the concrete will dissolve with time and leave holes in the concrete, either by deterioration or by adherence to forms.

* Discolouration: Departure of colour from that which is normal or desired.

* Efflorescence: A white (salt) deposit on concrete (or brick) caused by precipitation of dissolved salts brought to the surface by the capillary action (leaching) of moisture.

* Exudation (stalactites): A liquidity or viscous gel-like material discharged through a crack or opening in the concrete by the leaching water.

* Corrosion Stain: Stain is formed due to the corrosion of reinforcement.

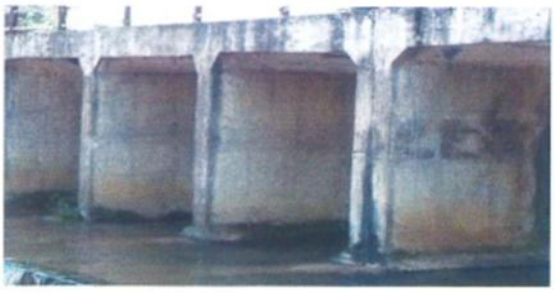
* Wear & Tear: Wear of concrete surface can be due to moving vehicles or due to high hydraulic gradient.

* Segregation: Condition in which the coarse and fine aggregate and cement paste, become separated.

* Excessive Deflection: This could be due to deficiency in the structural capacity of the superstructure under passage of normal loads. Time dependent stresses also can cause such deflections if the estimated values of shrinkage and creep are different from the actual values.

* Tilting

* Staining



* Corrosion & Exposed Reinforcement

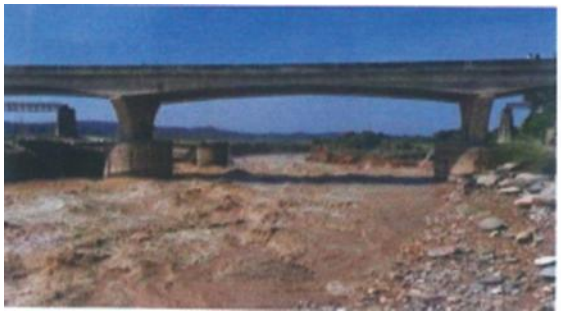
* Reduction in Area/Section Loss

*Unevenness/Depressions/Deformation

*Pot Holes

*Erosion

* Excessive Scour



* Choking by blocking /damage collection of dust & dirt

* Vegetation growth

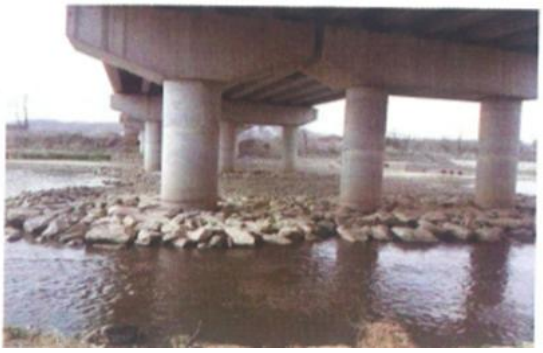
* Ponding

* Aging

* Leakage of at joints

* Dampness

* Settlement or bulging of crates

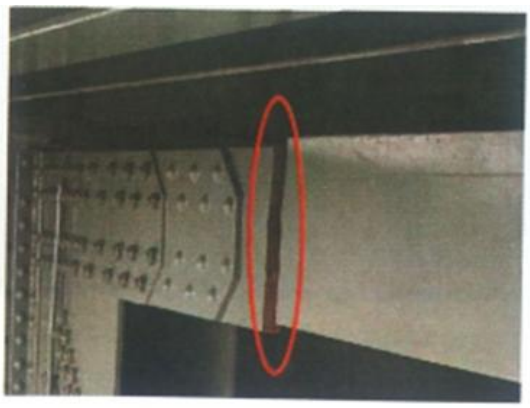


* Damaged or loose kerbs
* Missing elements
* Chemical attack

3.5.3 Distress in steel Bridges

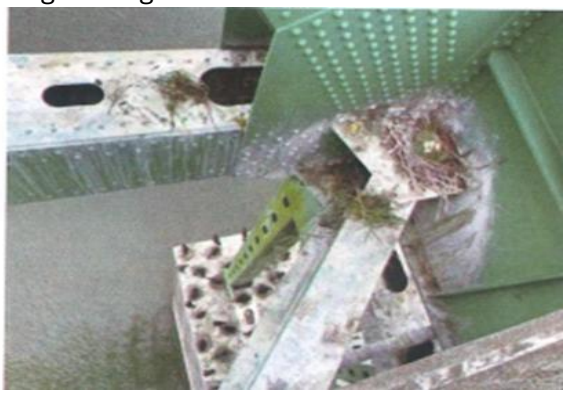
* Corrosion/Rust

* Fatigue Cracking

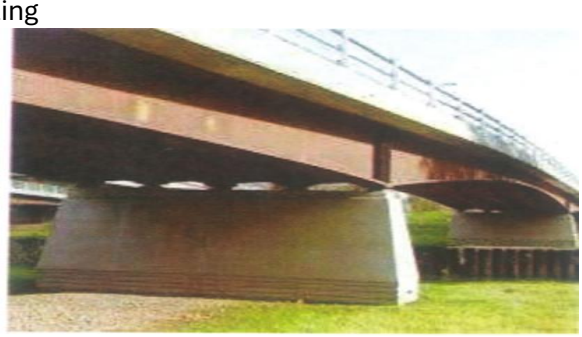


* Loose bolt or rivet or and loose weld near welds and bolt


* Debris on the joints of the steel works/breaking leading to corrosion

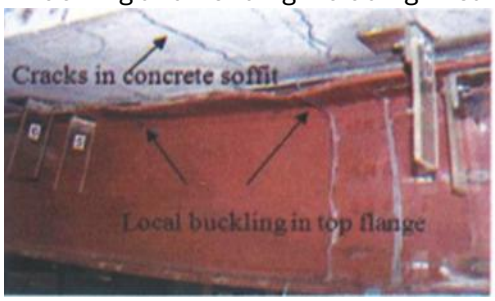
* Deterioration of paint or galvanizing/metalizing

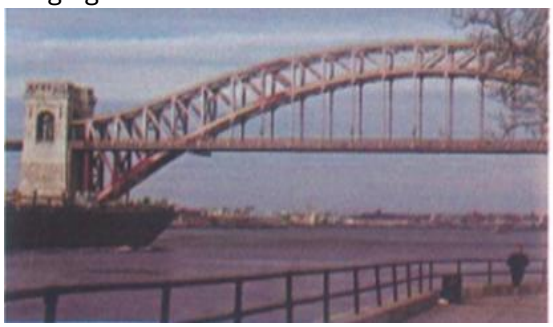
* Bend in steel members and joints, usually caused by barges or logs/trees impacting


* Loss of section

* Buckling and Bending including misalignment

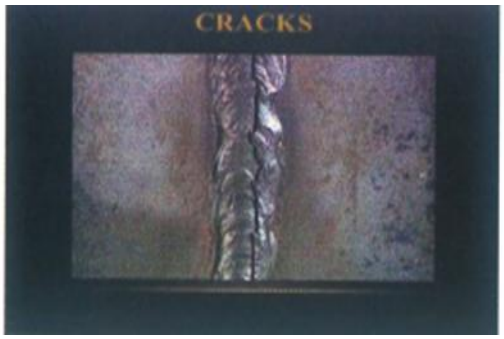


* Aging

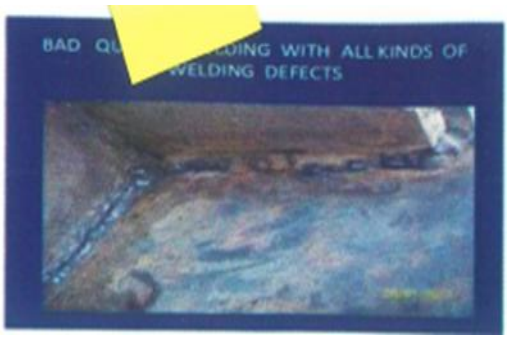


* Damaged connections

* Weld Cracks



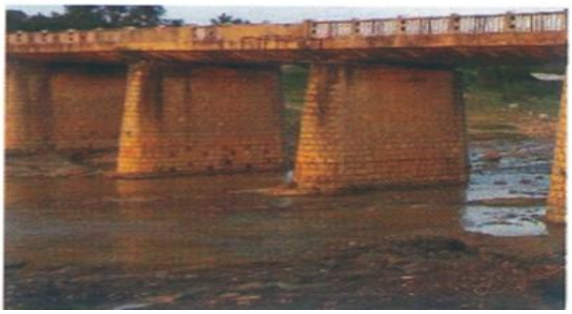
* Loss



* Cracking near the bearings
* Loose base plates
* Unusual Vibration
* Excessive deflection

2.4.2 Distress in Masonry Bridges

* Loosening/Loss of mortar/Poor pointing of joint



* Cracks: (vertical cracks due subsidence, Lateral and diagonal cracks indicative of dangerous state, in the vicinity of bearings)

* Scaling

* Stains

* Bulging

* Carbonation
* Delamination
* Leaching
* Deterioration of Stone/Bricks

3.5.5 Pre-stressing Steel

* Loss of pre-stress
* Cable Corrosion
* Loose anchorages

3.5.6 Timber

* Cracking and splitting of members due to overload, ageing or under-designing of members.
* Abnormal deflections due to overloads or under designing or imperfect joint.
* Infestations decay etc. due to environmental aggressiveness.
* Loosening of joints due to lack of good workmanship.

3.5.7 Commonly Occurred Distresses of Typical Bridge Components

3.5.7.1 Wearing Surface

It may be affected due to cracks, disintegration, potholes, tell-tale rings etc. As per IRC: SP 83 and IRC: 82 may be refereed to for rigid and flexible pavements respectively.

3.5.7.2. Substructure

* Scour

- Damage near the base
- Movement of Piers (Titting and or shifti
- Damage due to impact from boats, vessels, floating blocks or trees or vehicles passing under the bridge
- Debris resting against piers
- Vegetation growth on the pier
- Leakage of water from the expansion joints damaging the piers
- Dampness on the pier
- Leaching on the piers

- Silting

3.5.7.3 Foundation

* Settlement
* Abnormal scour
* Tilting
* Cracking
* Disintegration
* Decay of foundation
* Erosion
* Cavitations/honeycombing
* Damage due to impact of floating bodies, boulders etc.
* Seepage damaging the foundation
* Vehicle impact damaging the foundation
* Damaged or loose earthquake restraints

3.5.7.4 Bearings and Seismic Stoppers

* Improper functioning

* Tilting

* Movements restricted or excess
* Splitting
* Jumping off guides
* Missing rollers
* Non-effectiveness of anchor bolts
* Deterioration of materials by process of ageing
* Level of oil
* Abnormal flattening
* Bulging
* Displacement of pads
* Misaligned deck joint
* Shearing of hold down bolts
* Shaking of bed block
* Elastomeric Bearings
* Improper Seating of Hearings
* Bearing deflected permanently
* Separation between Rubber and Steel
* Debris around the Bearing Seat
* Colour change of Elastomeric Pads
* Corresponding of steel parts
* Deterioration of bed block

3.6 NDT testing

3.6.1-Various NDT test and their reference codes are tabulated as under:

Table 3.4

Sl. No.	Name of the Test/Technique	Application and properties measured	Extent of damage to concrete surface	Type of Equipment used	Reference Codes
1	Pull-out Test (Hole drilled & insert placed in old concrete)	In-situ Compressive Strength	Minor	Hydro-Mechanical	1. E DIN EN 12399 2. ISO/DIS 8046 3. ASTM C 900
2	Penetration Resistance/Windsor Probe Test	In-situ Compressive Strength	Minor	Mechanical	1. ASTM C 803
3	Resistivity Measurements	Probability/Risk of Reinforcement Corrosion	Minor	Electrical	1. BS 1881
4	Half -Cell Potential Measurements	Rate of Reinforcement Corrosion	Nil	Electro-Chemical	1. ASTM C876 2. BS 1881-Part 201
5	Ultrasonic Pulse Velocity	Homogeneity and Quality	Nil	Electronic	1. IS13311 (Part I)
6	Acoustic Emission	Internal cracks, voids & other defects	Nil	Electronic	1. ISO/TC 135/ SC 9
7	Dynamic Response Technique	Pile Integrity & Voids	Nil	Electro Mechanical	1. IS 14893
8	Ground Penetrating Radar	Location of Voids, Thickness of Members, Delamination	Nil	Electro-Magnetic	1. ASTM D6432
9	Radiography	Location of Reinforcement, Voids, Cracks Grout defects in Pre-stressed cables	Nil	Electro-Magnetic	1. IS 2595
10	Carbonation Test	Depth of Carbonation	Minor	Chemical	1. AFPCAFREM 2. JIS A 1153 3. UNI 9944 4. ASTM C876
11	Crack Measurement	Monitoring of crack width & length	Nil	Mechanical	1. Using special Microscopes & Crack Gauges

3.6.2 NDT Test Results Analysis

The following table gives the capability of Defect Detection through different types of NDT Tests:

Table 3.5

Sl. No.	Test Name	Cracking	Scaling	Corrosion	Wear and Abrasion	Voids	Strength
1	Pull-out Test (Hole Drilled & insert placed in old concrete)	N	N	N	N	N	Good
2	Penetration Resistance/ Windsor probe Test	N	N	N	N	N	Good
3	Resistivity Measurements	N	N	Good	N	N	N
4	Half-Cell potential Measurements	N	N	Good	N	N	N
5	Ultrasonic Pulse Velocity	Good	N	N	N	Good	N
6	Acoustic Emission Test	Good	N	N	N	Good	N
7	Dynamic Response Test	Good	N	N	N	Good	Good
8	Ground Penetrating Radar	Good	Good	N	Fair	Good	N
10	Radiography	Good	N	N	Fair	Good	N
11	Carbonation Test	N	N	Good	N	N	N
12	Crack Measurement	Good	N	N	N	N	N
13	Trepanning Test	N	N	N	N	N	Good
14	Endoscopic Test	Fair	N	Fair	N	Good	N
15	Thermography	Fair	Good	Poor	Fair	Good	N
16	Petrography	N	N	Poor	N	N	N
17	Impact-Echo	Fair	N	N	N	Fair	N
18	Schmidt/Rebound Hammer Test	N	N	N	N	N	Good
19	Permeability	N	N	N	N	Good	N
20	Cover Meter	N	N	N	N	N	N
21	Chemical Analysis (Sulphate & chloride Content)	N	N	Good	N	N	N
22	Hammer Rap/Heavy Chains	N	N	N	N	Fair	N
23	Linear Polarization Resistance (LPR)	N	N	Good	N	N	N
24	Galvano-Static Pulse Method	N	N	Good	N	N	N

3.6.3 Following non-destructive tests and special investigation should preferably be carried out at indicative intervals specified in the table below as per the suitability and requirement of any element of the bridge.

Table 3.6: Testing Methodology of Structures

Sl. No.	Name of Tests	Indicative Minimum no. of tests sample per span/pier/ abutment	Indicative Minimum no. of spans to be tested in a bridge	Indicative Frequency of testing (Year)
1	Ultra-Pulse Velocity Test	3	1 span for every 3 spans	5
2	Rebound Hammer Test / Core test	3	1 span for every 3 spans	5
3	Half Cell Potential Test	3	1 span for every 3 spans	5
4	Carbonation Depth	3	1 span for every 3 spans	5
5	Transient Dynamic Response test	3	1 span for every 3 spans	5
6	Laser vibrometer test (only for span greater than 30 m)	1 at mid span	1 span for every 3 spans	10

However, these tests or special investigation techniques shall also be carried out either all or few tests based on the severity and criticality of the nature of defect / distress and type of the element of bridge that is affected based on the findings from the periodic inspections.

3.7 Data Collection Mechanism

The data collection mechanism shall be followed as per PERFORMA mentioned in IRC: SP 35-2024.

Table 3.7: Performa for Inspection Report

PROFORMA FOR INSPECTION REPORT									
(from IRC SP 35: Manual for Bridge management, Inventory, Inspection and maintenance)									
Id	**Sub components**	**Distress type**	**Location**	**Extent of Distress**	**Severity of Distress**	**Condition state no**	**Probable reasons**	**Maintenance actions required**	**Urgency**
2	**Substructure**								
2.1	Abutment								
2.2	Abutment Cap								
2.3	Dirt wall								
2.4	Weep holes								
2.5	Wing walls								
2.6	Abutment protection works								
2.7	Pier								
2.8	Pier cap								
2.9	Pier protection works								
3	**Waterway/ Channel**								
3.1	River/Chanel bed								

PROFORMA FOR INSPECTION REPORT									
(from IRC SP 35: Manual for Bridge management, Inventory, Inspection and maintenance)									
Id	**Sub components**	**Distress type**	**Location**	**Extent of Distress**	**Severity of Distress**	**Condition state no**	**Probable reasons**	**Maintenance actions required**	**Urgency**
3.2	Guide bunds								
3.3	Spurs								
3.4	Retaining wall								
3.5	Toe walls								
3.6	RE walls								
3.7	Floor/Channel protection								
3.8	Apron								
3.9	Curtain/cut off walls								
3.10	Ground/rock anchors								
4	**Foundations**								
4.1	Foundation (raft/open/pile/well)								
4.2	Apron								
4.3	Foundation protection								
5	**Superstructure**								
5.1	Girders/Main beams/Cables								
5.2	Cross beams/diaphragms/Suspenders								
5.3	Articulation								
5.4	Deck slab								
5.5	Cantilever slab								
5.6	Joints								
6	**Appurtenances/Auxiliary works**								
6.1	Wearing surface								
6.2	Footpaths								
6.3	Expansion joints								
6.4	Pre-stressing elements (anchorages etc.)								
6.5	Median								
6.6	Kerbs/cornices								
6.7	Light posts								

PROFORMA FOR INSPECTION REPORT									
(from IRC SP 35: Manual for Bridge management, Inventory, Inspection and maintenance)									
Id	**Sub components**	**Distress type**	**Location**	**Extent of Distress**	**Severity of Distress**	**Condition state no**	**Probable reasons**	**Maintenance actions required**	**Urgency**
6.8	Drainage sprouts								
6.9	Parapet/railing/guard stones/crash barrier								
6.10	Waterproofing system								
6.11	Painting system								
6.12	Utilities								
7	**Bearings**								
7.1	Bearings								
7.2	Bearing seats/caps								
7.3	Earthquake restraints								
7.4	Top Plate								
7.5	Bottom Plate								
8	**Culverts**								
8.1	Bed								
8.2	Apron								
8.3	Cut off wall								
8.4	Type of culvert- Pipe, Slab, Box etc.								
8.5	Parapet/railing/guard stones/crash barrier								
8.6	Signs & marking								
8.7	Wearing course								
8.8	Slope protection								
8.9	Shoulder								
8.10	Any other								

3.8 Prioritization of Bridges for Maintenance

3.8.1 Weightage of various bridge components

Table 3.8 Relative Weights of Bridge Component and their Subcomponents

Sl. No.	Bridge component	% Weights	Bridge sub-component	% weight in a group	Overall % *weights
1	2	3	4	5	6
	C1-Approaches	3.6	C1.1 Alignment	16.0	0.58

			C-1.2 Signages	5.8	0.21
			C-1.3 Embankment/cutting	12.9	0.46
			C1.4 Railing/crash barriers/guard stones/parapet	15.2	0.55
			C1.5 Approach slab	9.7	0.35
			C1.6 Approach joint	9.9	0.36
			C1.7 Side drains	10.3	0.31
			C1.8 Slope protection	20.1	0.72
2	C-2 Substructure	18.0	C2.1 Abutment	14.2	2.55
			C2.2 Abutment cap	11.1	2.00
			C2.3 Dirt wall	5.2	0.94
			C2.4 Weep holes	4.5	0.81
			C2.5 Wing walls	7.1	1.28
			C2.6 Abutment protection works	9.0	1.62
			C2.7 Pier	21.8	3.92
			C2.8 Pier cap	14.6	2.63
			C2.9 Pier protection works	12.5	2.25
3	C-3 Waterway/channel	5.8	C3.1 River/Channel	4.0	0.23
			C3.2 Guide bunds	13.0	0.75
			C3.3 Spurs	8.4	1.24
			C3.4 Retaining wall	15.0	0.87
			C3.5 Toe walls	7.6	0.44
			C3.6 Floor/channel protection	12.0	0.70
			C3.7 Apron	11.3	0.65
			C3.8 Curtain/cut off walls	14.7	0.85
			C3.9 Ground/rock anchors	14.0	0.81
4	C-4 Foundation	32.7	C4-1 Foundations (raft/open/pile/well)	66.0	21.58
			C4.2 Apron	13.9	4.55

			C4.3 Foundation protection	20.1	6.57
5	C-5 Superstructure	21.7	C5.1Girders/Main beams	35.0	7.60
			C5.2Cross beams/diaphragms	14.2	3.10
			C5.3Articulation	12.7	2.75
			C5.4 Deck slab	15.1	3.28
			C5.5Cantilever slab	13.2	2.85
			C5.6 Joints	9.8	2.12
6	C-6 Appurtenances/Auxiliary works	4.1	C6.1 Wearing surface	7.9	0.32
			C6.2 Footpath	7.3	0.30
			C6.3 Expansion joints	17.8	0.73
			C6.4 Prestressing elements (anchorages etc.)	18.7	0.77
			C6.5 Median	4.8	0.20
			C6.6 Kerbs/cornices	4.6	0.19
			C6.7 Light posts	3.7	0.15
			C6.8 Drainage spouts	7.4	0.30
			C6.9 Parapet/railing/guard stones/crash barrier	11.9	0.49
			C6.10 Waterproofing system	7.6	0.31
			C6.11 Painting system	4.3	0.18
			C6.12 Utilities	3.9	0.16
7	C-7 Bearings	14.0	C7.1 Bearings	50.0	7.00
			C7.2 Bearing seats/caps	25.4	3.50
			C7.3 Earthquake restraints/Stoppers	24.6	3.44

3.8.2 Range of values for various distress

Table 3.9 Distress Type and Range of Values Corresponding to Condition States of Bridge Components

Sl. No.	Distress type	Range of values for Condition States					
		Unit	I (Excellent)	II (Good)	III (Fair)	IV (Poor)	V (Critical)
1	Erosion	%	Nil	0-10	11-20	21-30	>30
2	Abrasion	%	<10	10-20	21-40	41-50	>50
3	Scour (depth)from Ground level	M	Nil	<0.25	0.26-0.50	0.51-1.0	>1.0
4	Vegetation	NO/%	Nil	2/<10-25	5/26-50	10/51-75	>10/75
5	Deformations (deflection/tilt)	mm	Nil	<5	5-10	11-50	>50
6	Honeycombing	%	Nil	<5	5-15	16-25	>25
7	Delamination	%	Nil	<5	5-15	16-25	>5
8	Spalling	%	Nil	<5	5-10	11-20	>5
9	Staining/ scaling/ leaching	%	Nil	<10	10-25	26-50	>50
10	Rust	%	Nil	<5	5-10	11-25	>25
11	Cracking(width)	mm	Nil	<0.3	0.3-1.0	1.1-2	>50
12	Exposed reinforcement	%	Nil	<5	5-10	11-15	>25
13	Reduction in area of reinforcement	%	Nil	<5	5-10	11-20	>2
14	Section loss	%	<5	5-10	11-15	16-25	>15
15	Efflorescence	%	Nil	<10	11-25	26-50	>20
16	Crushing	%	Nil	Nil	<5	5-10	>25
17	Rutting	Mm	Nil	<10	10-25	26-50	>50
18	Unevenness	%	Nil	<5	5-15	16-25	>10
19	Degradation (wear and tear)	%	Nil	<10	10-20	21-50	>50
20	Missing elements	No.	Nil	<2	2-5	6-10	>10
21	Leaning/bulging	mm	Nil	<5	5-15	16-25	>25
22	Loose joints	No.	Nil	<2	3-5	6-8	>8

23	Undesired restraints	No.	Nil	Nil	1	2-3	>3
24	Marine boars	%	Nil	<10	10-25	26-50	>50
25	Inadequate drainage spots	No.	Nil	<2	3-5	6-8	>8
26	Silting	%	Nil	<10	10-25	26-50	>50

3.8.3 Distress values for approaches

Table 3.10 Distress Types corresponding to Condition States for Approaches/Wearing Course

Sl. No.	Distress type	Range of values for Condition States					
		Unit	I (Excellent)	II (Good)	III (Fair)	IV (Poor)	V (Critical)
1	Alligator (Fatigue) cracking	%	Nil	1-5	6--15	16-30	>30
2	Longitudinal cracking	Mm	Nil	<5	6-10	11-20	>20
3	Transverse cracking	Mm	Nil	<5	6-10	11-20	>20
4	Block cracking	%	Nil	1-5	6-15	16-30	>30
5	Reflection cracking	Mm	Nil	<5	6-10	11-20	>20
6	Edge cracking	Mm	Nil	1-5	6-15	16-30	>30
7	Slippage	%	Nil	1-5	6-15	16-30	>30
8	Bleeding	%	Nil	<10	10-20	21-50	>50
9	Settlement/Bumps/ Heave	No./ mm	Nil	1/<15	2/16-30	3-5/31-50	>5/>50
10	Potholes	No.	Nil	<2	2-5	6-8	>8
11	Patching	%	Nil	0-5	6-15	16-30	>30
12	Pumping	%	Nil	<10	10-15	16-25	>25
13	Ravelling	%	Nil	<25	25-50	51-75	>75
14	Rutting	Mm	Nil	<5	5-15	16-25	>25
15	Shoving/corrugation	Mm	Nil	<5	5-10	11-25	>25
16	Rain cuts	No.	1-5	6-10	11-15	16-20	>20
17	Lane/Shoulder drop	Mm	Nil	<25	25-50	51-100	>100

18	Missing elements	No.	Nil	<5	5-10	11-15	>15
19	Erosion	%	<5	5-15	16-30	31-50	>50
20	Silting of Joints	%	<5	5-15	16-30	31-50	>50
21	Damage to drainage components like wall etc.	% severity	<10	10-25	26-45	46-60	>60
22	"D" Cracking	m2	Nil	<5	5-10	11-15	>15
23	Faulting	Mm	Nil	<5	5-10	11-25	>25
24	Joint damage	%	Nil	<10	10-30	31-50	>50
25	Blow up	Mm	Nil	<6	6-25	26-50	>50
26	Scaling	%	<5	10-15	16-30	31-50	>50
27	Pop out	m2	Nil	<3	3-6	7-9	>9
28	Punch out	mm	Nil	<75	75-110	111-150	>150
29	Lane/Shoulder Separation	mm	Nil	<10	10-20	21-50	>50
30	Shatlered Slab	No.	Nil	<3	3	4-6	>6
31	Corner Spalling	mm	Nil	<25	25-35	36-50	>50
32	Vegetation	%	Nil	<25	25-50	51-75	>75
33	Corner Break	%	Nil	<25	25-35	36-50	>50
34	Polished Aggregate	%	Nil	<20	20-45	46-70	>70

3.9 Maintenance Protocol

Based on the type of distress and elements of the bridge, which is identified as part of routine inspection, periodic close inspection and special inspection, the repair and rehabilitation has to be decided and implemented within the time frame as well as specifications furnished specified in Table 3.5.

Table 3.11: Maintenance Criteria for structures and Culverts

Asset Type	Performance Parameter	Level of Service (LOS)	Frequency of Measurement	Testing Method	Recommended Remedial measures	Time limit for Rectification	Specifications and Standards
	Protection works in good condition	Damaged of rough stone apron or bank revetment not more than 3 sqm, damage to solid apron	2 times a year (before and after the rainy season)	Condition survey as per IRC: SP 35-2024	Repairs to damaged aprons and pitching	30 days after defect observation or 2 weeks before onset of rainy season	IRC: SP 35-2024, IRC: SP 40-2019, and IRC: SP 13-2004.

Asset Type	Performance Parameter	Level of Service (LOS)	Frequency of Measurement	Testing Method	Recommended Remedial measures	Time limit for Rectification	Specifications and Standards
		(concrete apron) not more than 1 sqm				whichever is earlier.	
Bridges	Riding quality or user comfort	No pothole in wearing coat on bridge deck	Daily	Visual inspection as per IRC: SP 35-2024	Repairs to BC or wearing coat	15 days	MORT&H Specification 2811
Bridge - Super Structure		No bump at expansion joint	Daily	Visual inspection as per IRC: SP 35-2024	Repairs to BC on either side of expansion joints, profile correction course on approach slab in case of settlement to approach embankment	15 days	MORT&H Specification 3004.2 & 2811.
	User safety (condition of crash barrier and guard rail)	No damaged or missing stretch of crash barrier or pedestrian hand railing	Daily	Visual inspection and detailed condition survey as per IRC: SP 35-2024.	Repairs and replacement of safety barriers as the case may be	3days	IRC: 5-1998, IRC: 119-2015, IRC: SP 35-2024, and IRC: SP 40-2019.
	Rusted reinforcement	ot more an 0.25 sqm	Bi-Annually	Detailed condition survey as per IRC SP: 35-2024.	All the corroded reinforcement shall need to be thoroughly cleaned and applied with anti-	15 days	IRC: SP 35-2024, IRC: SP 40-2019 and MORTH Specification 1600.
	Spalling of concrete	Not more than 0.50 sqm					
	Delamination	Not more than 0.50 sqm			Corrosive coating, before carrying out the repairs to affected concrete portions with epoxy mortar/concrete.		
	Cracks wider than 0.30 mm	Not more than 1m total length	Bi-Annually	Detailed condition survey as per IRC: SP 35-2024.	Grouting with epoxy mortar, investigating causes for cracks development and carry out necessary rehabilitation.	48 Hours	IRC: SP 35-2024, IRC: SP 40-2019 and MORTH Specification 2800.
	Rainwater seepage through deck slab	Leakage - nil	Quarterly	Detailed condition survey as	Grouting of deck slab at leakage areas,	1 months	IRC: SP 35-2024, MORTH

Asset Type	Performance Parameter	Level of Service (LOS)	Frequency of Measurement	Testing Method	Recommended Remedial measures	Time limit for Rectification	Specifications and Standards
				per IRC: SP 35-2024.	waterproofing, repairs to drainage spouts		specifications 2600 & 2700.
	Deflection due to permanent loads and live loads	Within design limits.	Once every 10 years for spans more than 40 m	Load test method	Carry out major rehabilitation works on bridge to retain original design loads capacity	6 months	IRC: SP 35-2024, and IRC: SP 51-2015.
	Vibrations in bridge deck due to moving trucks	Frequency of vibrations shall not be more than 5 Hz	Once every 5 years for spans more than 30m and every 10 years for spans between 15 to 30 m	Laser displacement sensors or laser vibro-meters	Strengthening of super structure	4 months	AASHTO LRFD Specifications
	Leakage in Expansion joints	No damage to elastomeric sealant compound in strip seal expansion joint, no leakage of rainwater through expansion joint in case of buried and asphalt plug and copper strip joint.	Bi-Annually	Detailed condition survey as per IRC SP:35-2024.	Replace of seal in expansion joint	15 days	MORTH specifications 2600, IRC: SP 35-2024 and IRC: SP 40-2019.
	Debris and dust in strip seal expansion joint	No dust or debris in expansion joint gap.	Monthly	Detailed condition survey as per IRC SP:35-2024.	Cleaning of expansion joint gaps thoroughly	3 days	MORTH specifications 2600, IRC: SP 35-2024 and IRC: SP 40-2019.
	Drainage spouts	No down take pipe missing/broken below soffit of the deck slab. No silt, debris, clogging of drainage spout	Monthly	Detailed condition survey as per IRC SP: 35-2024.	Cleaning of drainage spouts thoroughly. Replacement of missing/broken down take pipes with a minimum pipe extension of	3 days	IRC: SP 35-2024, and MORTH Specification 2700.

Asset Type	Performance Parameter	Level of Service (LOS)	Frequency of Measurement	Testing Method	Recommended Remedial measures	Time limit for Rectification	Specifications and Standards
		collection chamber.			500mm below soffit of slab. Providing sealant around the drainage spout if any leakages observed.		
Bridge-substructure	Cracks/spalling of concrete/rusted steel	No cracks, spalling of concrete and rusted steel	Bi-Annually	Detailed condition survey as per IRC SP: 35-2024.	All the corroded reinforcement shall need to be thoroughly cleaned from rusting and applied with anti- corrosive coating before carrying out repairs to substructure by grouting/guiniting and micro concreting depending on type of defect noticed	30 days	IRC: SP 35-2024, IRC: SP 40-2019 and MORTH specification 2800.
	Bearings	Delamination of bearing reinforcement not more than 5%, cracking or tearing of rubber not more than two locations per side, no rupture of reinforcement or rubber	Bi-Annually	Detailed condition survey as per IRC SP: 35-2024.	In case of failure of even one bearing on any pier/abutment, all the bearings on that pier/abutment shall be replaced, in order to get uniform load transfer on to bearings.	3 months	MORTH specification 2810, IRC: SP 35-2024 and IRC: SP 40-2019.
Bridge Foundations	Scouring around foundations	Scouring shall not be lower than maximum scour level for the bridge	Bi-Annually	Condition survey and visual inspection as per IRC SP:35-2024.	Suitable protection works around the pier/abutment	1 month	IRC: SP 35-2024, IRC: SP 40-2019, IRC: 83-2018, MORTH Specification 2500
Pipe/ box/ slab culverts	Waterway / Vent way	At all times 85% of vents are	Two times a year (before and after the rainy season)	Visual inspection in	Cleaning silt up soils	15 days before the onset of	IRC: 5-2024, IRC SP: 35-

Asset Type	Performance Parameter	Level of Service (LOS)	Frequency of Measurement	Testing Method	Recommended Remedial measures	Time limit for Rectification	Specifications and Standards
		free from any obstruction such as silt, debris, vegetation, wooden logs etc.		accordance with IRC SP: 35-2024.	and debris in culvert barrel after rainy season, removal of bushes and vegetation, U/s of barrel, under barrel and D/s of barrel before rainy season.	monsoon and within 30 days after the end of rainy season.	2024, IRC SP: 40-2019 and IRC: SP 13-2022
	Free waterway/unobstructed flow section	85% of culvert normal flow area to available.	2 times a year (before and after the rainy season)	Inspection by Bridge Engineer as per IRC SP: 35-2024 and recording of depth of silting and area of vegetation.	Cleaning silt up soils and debris in culvert barrel after rainy season, removal of bushes and vegetation, U/s of barrel, under barrel and D/s of barrel before rainy season.	15 days before the onset of monsoon and within 30 days after the end of rainy season.	IRC: 5-2015, IRC: SP 35-2024, IRC: SP 40-2019 and IRC: SP 13-2022
	Leak-proof expansion joints if any	No leakage through expansion joints	Bi-Annually	Physical inspection of expansion joints as per IRC SP: 35- 2024, for leakage strains on walls at joints.	Fixing with sealant suitably	30 days or before the onset of rains whichever comes earlier	IRC: SP 40-2019 and IRC: SP 69-2011
	Structurally sound	Spalling of concrete not more than 0.25 sqm	Bi-Annually	Detailed inspection of all components of culvert as per IRC SP:35-2024 and recording the defects	Repairs to spalling, cracking, delamination, rusting shall be followed as per IRC: SP:40-1993.	15 days	IRC: SP 35-2024, IRC: SP 40-2019 and MORTH Specifications clause 2800
		Delamination of concrete not more than 0.25 sq.m.					
		Cracks wider than 0.3 mm not more than 1m aggregate length					

PART 4: ROAD SIGNAGE AND FURNITURE MAINTENANCE

4.1 Introduction

Road furniture plays a critical role in ensuring safety, efficiency, and usability of highways. These essential components, including signage, guardrails, road markings, lighting, delineators etc provide crucial guidance, warnings, and protections to road users. Proper installation, maintenance, and periodic inspections of road furniture are integral to preserving its functionality, physical structure and effectiveness. These manual outlines best practices, standards, and procedures for maintaining road furniture, ensuring it remains in optimal condition to support safe and seamless highway operations.

4.2 Pavement Marking

Road markings play a crucial role in ensuring the safety and efficiency of highway. They provide essential guidance, delineation and warnings to drivers and pedestrians, contributing to the efficient functioning of the road network. Effective road markings enhance visibility under various conditions, regulate traffic, and improve highway safety. This section focuses on the maintenance practices for road marking. Through consistent maintenance and precise application, road markings reinforce the trust of road users on highway infrastructure.

I. Parameters

Parameters to be investigated:

- Wear
- Luminance Coefficient
- Retro-reflectivity (Dry and Wet)
- Skid Resistance

II. Method of Inspection

Above parameters of Pavement Markings shall be measured along entire length with randomly selected sampling through automatic digital measurement tools or measured manually shall be supported by GPS coordinates and video back-up. Performance Based Assessment shall be carried as mentioned below:

- To measure the performance parameters of continuously marked sections, the project stretch shall be divided into 5 km sections and minimum 20 random reading (randomly generated chainages before survey) shall be taken combinedly from the longitudinal markings (keeping in mind equal readings from each) and 10 random readings shall be taken combined from the arrow, chevron and other markings (excluding transverse bars). The 80 percentiles of the values shall be considered to check the performance of the road marking. (E.g. If 20 test points are taken in a section of 5 km, minimum 16 points should pass in performance evaluation).
- Most traffic sections and exclusions mentioned below shall be excluded from this sampling process and method as mentioned in IRC:35-2015 shall be followed.
- If the marking is carried out at intermittent locations, at each such locations, 10 random points shall be selected within 5 km and the parameters shall be checked in every 5 km. All the exclusion points (as per Annexure — 8) shall be excluded from this. The 80 percentiles of the values shall be considered to check the performance of the road marking.
- The wear durability shall be applicable for all the pavement marking, day and nighttime visibility shall be measured on white paint and skid resistance shall be measured on zebra crossing, pedestrian crossings, bus bay, bus stop, cycle track, intersection delineation etc.
- The Luminance coefficient and retro reflectivity shall be measured as per Annexure D and E of IRC 35-2015 respectively.
- Any other general performance standard of the road marking shall be as broadly per Chapter 15 and 16 of IRC:35-2015

Most Trafficked sections and exclusions:

- Intersections, side roads approaches, Speed breakers, Median openings, Pedestrian crossings, Dhaba and fuel stations region having count of commercial traffic 6 vehicles per peak hour crossing the road marking, Transverse Bar Marking.
- Any location where the road marking was asked to be carried out within 14 days (including) of bituminous work.

III. Physical & Functional parameters, Frequency

Pavement marking shall be visually inspected every week and cleaned for dust and debris especially at intersections, median openings, side road approaches, dhaba's, fuel stations, construction sites and any other critical locations.

Table 4.8: Maintenance Criteria for Pavement Marking

<table>
<tr><th>Parameter</th><th>Observation</th><th>Level of Service</th><th>Frequency</th><th>Rectification</th><th>Timeline</th></tr>
<tr><td>Wear</td><td>Visual Assessment as per Annexure- F of IRC:35- 2015 or by image processing</td><td><70% of Area remaining</td><td>Bi-annually</td><td>Re-Painting</td><td>Cat-1 Defect– within 24 hours
Cat-2 Defect – within 2 months</td></tr>
<tr><td>Daytime Visibility</td><td>As mentioned in the section II</td><td>As per section 15.5 of IRC:35-2015
During expected life Service Time
• Cement Road - 130mcd/m2/lux
• Bituminous Road - 100mcd/m2/lux</td><td>Initially and bi-annually thereafter</td><td>Re-Painting</td><td>Cat-1 Defect – within 24 hours
Cat-2 Defect – within 2 months</td></tr>
<tr><td>Nighttime Visibility</td><td>As mentioned in the section II</td><td>As per section 15.5 of IRC:35-
<table>
<tr><th rowspan="2">Sl.No.</th><th rowspan="2">Design Speed (kmph)</th><th colspan="2">RL (mcd/m²/lx)</th></tr>
<tr><th colspan="2">Min. Threshold up to warranty period (preferrable 2years)</th></tr>
<tr><td>1</td><td>Up to 65</td><td>200</td><td>80</td></tr>
<tr><td>2</td><td>65-100</td><td>250</td><td>120</td></tr>
<tr><td>3</td><td>>100</td><td>300</td><td>150</td></tr>
</table>
2015
Initial and Minimum Performance for Night Visibility under wet condition (Retro reflectivity):
• Initial 7days Retro reflectivity:100mcd/m²/lux
• Minimum Threshold Level: 50 mcd/m²/lux</td><td>Initially and bi-annually thereafter</td><td>Re-Painting</td><td>Cat-1 Defect – within 24 hours
Cat-2 Defect – within 2 months</td></tr>
<tr><td>Skid Resistance</td><td>As per Section 15.6 of IRC:35-2015</td><td>Initial and Minimum performance for Skid Resistance
•Initial (7days): 55BPN
•Min. Threshold: 44BPN
*Note: shall be considered under urban/city traffic condition encompassing the locations like pedestrian crossings, bus bay, bus stop, cycle track intersection delineation, transverse bar markings etc.</td><td>Initially and bi-annually thereafter</td><td>Re-Painting</td><td>Within 24 hours</td></tr>
</table>

*Cat-1 and Cat-2 as defined in section 16.6 of IRC:35-2015

4.3 Road Signs

1.1.1 Road signboards are the language that establishes communication between road users and road infrastructure that conveys important information to road users. They provide clear instructions, warnings, and guidance to ensure safe and efficient travel across the road network. Properly designed, installed, and maintained signboards enhance driver awareness, reduce accidents, and facilitate smooth traffic flow. This

section focuses on the maintenance practices for road signboards, emphasizing their role in meeting regulatory requirements and addressing the evolving needs of modern highways. Ensuring the visibility, accuracy, and durability of road signboards is fundamental to fostering a safe and reliable transportation system.

I. Parameters

Parameters to be investigated

i) Shape, Position and Visually conspicuous
ii) Retro-reflectivity

II. Method of Inspection

i. The parameters of Signboards shall be measured for each Signboard (including overhead, toll plaza canopy etc). Measurements shall be through automatic digital measurement tools or through Network Survey Vehicle capable of inventory Inspection or if measured manually shall be supported by GPS coordinates and Video backup. It should also be noted to identify the colour of the measured signboard using chromaticity coordinates.
ii. The retro-reflective surface of signboard after cleaning with soap and water and in dry condition shall the minimum coefficient of retro-reflection as per IRC:67-2022. This shall be determined in accordance to ASTM D 4956-09: Standard Specification for Retroreflective Sheeting for Traffic Control.
iii. Recording format for periodic testing shall be followed as mentioned in Annexure-VIII of IRC:67-2022
iv. NHAI is also conducting independent video surveys wherein AI based analysis of ROW videos is done to assess the actual position and nature of the road signages which is compared with requirement stipulated in the contract/concession agreement as well as assessment of requirement by a qualified road safety auditor. All the data is time and geo-stamped and uploaded on a dedicated GIS Dashboard. Similar approach should be replicated for inspection of road signages on regular intervals.

III. Investigation Parameters & Frequency

Following schedule shall be followed for inspection during maintenance.

Table 4.9: Maintenance Criteria for Sign Boards

Parameter	Observation	Level of Service	Frequency	Rectification	Timeline
Visually conspicuous	Clear of dust, bills and free from obstruction like branches, advertising boards etc. Visual observation with image or video backup of observed issues		Daily Basis	Cleaning and removal of obstruction	Within 24 hrs
Physical Condition (Shape, Position and Condition)	Shape,Position and Condition as per IRC:67-2012. Signboard should be clearly visible for the design speed of the section. Visual observation with image or video backup of observed issues in Condition of Signboard.		Shape and Position shall be verified and corrected at the time of installation. Physical Condition, shall be verified on daily basis.	Improvement of shape / condition, in case if not inline with requirements.	48 hours in case of Mandatory Signs, Cautionary and Informatory Signs (Single and Dual post signs), 15 Days in case of overhead and canopy Sign boards

Parameter	Observation	Level of Service	Frequency	Rectification	Timeline
Retro-reflectivity	As per specifications in IRC:67-2022		Every two years	Replacement of signboard	48 hours in case of Mandatory Signs, Cautionary and Informatory Signs (Single and Dual post signs), one month in case of overhead and canopy Sign boards
Painting of Posts	Post shall be free of rust, weeds, shrubbery, mud etc. Visual observation with image or video backup of observed issues		Bi-annually	Repainting of signboards posts	48 hours in case of Mandatory Signs, Cautionary and Informatory Signs (Single and Dual post signs), 15 Days in case of overhead and canopy Sign boards
Pasting 5cm retro-reflective sheets on posts	Sheets shall be completely intact around the posts with no signs of tear Visual observation with image or video backup of observed issues		Monthly (during night visit)	Repasting of retro-reflective sheets on posts	Within 48hrs

4.4 Traffic Blinkers and Signals

Solar blinkers are an innovative and energy-efficient solution designed to enhance road safety by providing clear and continuous visual warnings to drivers and pedestrians at high-risk locations. Powered by renewable solar energy, they play a critical role in alerting road users to hazards, guiding traffic in adverse conditions, and improving visibility at intersections and construction zones. This section provides guidelines on the maintenance practices for solar blinkers, focusing on their durability, sustainability, and compliance with safety standards.

I. Parameters

Parameters to be investigated

i) Physical Condition: Position, Orientation and Visually conspicuous
ii) Visual Condition: Flashing rate, dimming
iii) Functional Condition: Battery, wiring, solar panel, LEDs

II. Method of Inspection

(i) Above parameters of Traffic Blinkers/Signals shall be measured for each Traffic Blinkers/Signal. Measurements shall be through automatic digital measurement tools or through Network Survey Vehicle capable of Inventory Inspection or if measured manually shall be supported by GPS coordinates and video back-up.

(ii) Physical and visual condition of Solar blinker shall be checked visually every night by responsible route operations & maintenance teams (preferably during route patrolling operations) and shall be reported to relevant maintenance members for rectification on the very next day. This activity becomes critical especially in low visibility or foggy weather situations.
Routine check on the electrical components and solar panels shall be checked every six months by qualified electrician and maintenance teams. Functional condition shall include

1. Crack or discolouration of solar panels
2. Inspect battery compartment for voltage, charge levels and corrosion

3. Weatherproofing

III. Investigation Parameters & Frequency

Following schedule shall be followed for inspection during maintenance.

Table 4.10: Maintenance Criteria for Solar Blinker and Signals

Parameter	Observation	Level of Service	Frequency	Rectification	Timeline
Physical Condition	• Position and orientation of blinker shall be directed towards traffic. • Solar panels shall be orientated as per initial installation for optimal sunlight exposure		Daily	Required Rectification	Within 24 hrs
Visibility	• Blinker shall be free from obstruction like vegetation, signages or other structures.		Daily	Required Rectification	Within 24 hrs
Working	• Flashing rate (1 per sec) • Dimming / non-working of few or all LEDs		Daily	Required Rectification	Within 24 hrs
Cleaning	• Ensure blinker and solar panel are free of dust, dirt, bird droppings, or debris		Monthly	Cleaning	Within 7 days
Functional Condition of solar panel / battery	• Crack or discolouration of solar panels • Inspect battery compartment for voltage, charge levels and corrosion • Weatherproofing of all components including posts		Bi-annually	Required Rectification	Within 7 days

Note: Frequency shall be improved at locations with higher dust deposits like mining areas, sand storms etc

4.5 Highway Lighting

Highway lighting is a critical component of road infrastructure, designed to enhance visibility and safety for drivers, pedestrians, and other road users, particularly during nighttime or adverse weather conditions. Properly planned and maintained highway lighting reduces the risk of accidents and facilitates smooth traffic flow. This section provides guidance on the maintenance

of highway lighting systems. By ensuring reliable and well-maintained lighting, highway authorities can foster safer and more accessible transportation networks.
Highway lighting covers street poles on main carriageway and service roads, High mast light at junctions, median openings, toll plazas etc, and toll plaza canopy lighting.

I. Parameters

Parameters to be investigated

i) Working Conditions: minor failures or non-functional lighting fixtures
ii) Physical Condition: Alignment of fixture, boom angle
iii) Illumination
iv) Other: Obstructive elements (vegetation, encroachment etc), cleaning solar panel, lens

II. Method of Inspection

Above parameters of Highway Lighting shall be measured for entire length of Highway. Measurements shall be through automatic digital measurement tools or through Network Survey Vehicle capable of Inventory Inspection or if measured manually shall be supported by GPS coordinates and video back-up. Each section of highway lighting shall be measured and section wise maintenance requirement shall be documented.
Working conditions of highway lighting shall be checked visually every night during route patrolling operations and be reported to maintenance team for rectification the very next day
Frequency of maintenance shall be enhances for regions affected with adverse weather conditions like fog, rain, snow etc.

III. Investigation Parameters & Frequency

Following schedule shall be followed for inspection during maintenance.

Table 4.11: Maintenance Criteria for Highway Lighting

Parameter	Observation	Level of Service	Frequency	Rectification	Timeline
Working Condition: Minor failures	• Minor failures in lighting system	All lights shall be working at night and non-working lights shall be reported to maintenance very next day for rectification	Daily	Rectification of failure	Within 24 hrs
Working Condition: Major failures	• Major failures in lighting system		Daily	Rectification of failure	Within 48 hrs
Physical Condition	• Position and orientation of fixtures and boom angle shall be checked for efficiency of illumination and solar charging.		Monthly	Required Rectification	Within 24 hrs
Illumination	• Satisfy illumination levels as per the Concession Agreement.		Monthly	Improvement in Lighting System	Within 7 days
Others: Obstructive elements	• Overgrown vegetation or temporary encroachment obstruct the cone of illumination		Bi-monthly	Trimming of vegetation and removing any obstruction	Within 24 hrs

Parameter	Observation	Level of Service	Frequency	Rectification	Timeline
Other: Cleaning solar panel, lens	• Dust, debris on solar panel and lens may reduce the efficiency of lighting		Bi-annually (may be reduced depending on environmental and weather conditions)	Cleaning solar panel, lens	Within 7 days

4.6 Vehicle Restraint System (VRS)

Vehicle restraint systems, commonly referred to as safety barriers (rigid, semi-flexible and flexible barriers), end terminals and crash cushions. are essential components of highway infrastructure designed to enhance road safety by reducing the severity of accidents. These systems function to prevent vehicles from leaving the roadway, crossing into opposing traffic lanes, or colliding with roadside hazards. This section outlines the maintenance practices for vehicle restraint systems as these systems play a vital role in protecting road users, minimizing damage, and maintaining the overall safety and efficiency of highway operations.

Decision on Repair, Replacement or Upgrade of Vehicle Restraint System shall be based on risk assessment and exposure of hazardous.

I. Parameters

Parameters to be investigated

i) Routine Maintenance
   a. Vegetation control, occasional cleaning and painting
   b. Reflectors and reflective stickers
ii) Collision Maintenance
iii) Height of barriers
iv) End terminals and connections between self and different barrier systems
v) Structural Integrity of each component of VRS
   a. nut, bolt, fasteners are secure and not lose or missing, free of rust.
   b. end terminals and anchorage systems are intact and functioning properly.
   c. Inspect for surface cracks and repair spalling or exposed reinforcement for rigid barriers
   d. Wire tension on Wire Rope

II. Method of Inspection

Above parameters of Safety Barrier shall be measured in linear length. Measurements shall be through automatic digital measurement tools or through Network Survey Vehicle capable of Inventory Inspection or if measured manually shall be supported by GPS coordinates and video back-up.

All VRS elements must undergo visual checks for obvious accident damage during routine safety inspections. Inspections should be conducted on foot where feasible. For long stretches of barriers or sections on high-speed roads, visual assessments may be performed from a slow-moving vehicle, provided the sections are clearly visible to the inspector from within the vehicle. For VRS installations associated with structures—such as crash barriers at toll gates, bridge piers and abutments, or bridge parapets—inspections can be integrated into the routine assessment of the corresponding structural assets

A basic inspection can be done by the highway patrolling team if it includes personnel who are properly trained for VRS inspection. VRS installation being inspected must be checked for Visible accident damage, Integrity of connections and the condition of each element to see if they are still up to specifications.

III. Investigation Parameters & Frequency

Following schedule shall be followed for inspection during maintenance.

Table 4.12: Maintenance Criteria for Vehicle Restrain System

Parameter	Observation	Level of Service	Frequency	Rectification	Timeline
Routine Maintenance	• occasional cleaning and painting, and right-of way vegetation control	Functionality: Functioning of Safety Barriers as intended	Daily	Rectification of failure	Within 7 days
	• Reflectors and Reflective stickers		Daily	Rectification of failure	Within 48 hrs
Height of barrier	• Height of barrier shall be as per the certification	Functionality: Functioning of Safety Barriers as intended	Every Major Maintenance cycle and after any overlay / pavement height raising related activities	Rectification of height	Within 30 days
End terminals and connections between self and different barrier systems	• End terminals and connections are intact as per initial installation and certification	Functionality: Functioning of Safety Barriers as intended	Daily	Rectification of failure	Within 7 days
Collision Maintenance	• Damages of VRS due to accidents	Functionality: Functioning of Safety Barriers as intended	Daily	Required Rectification	Within 7 days – For Safety Barriers including end treatment Within 7 to 30 days – depending on type traffic impact attenuators
Structural Integrity of VRS	4.2.2. nut, bolt, fasteners are secure and not loose or missing, free of rust. • end terminals and anchorage systems are intact and functioning properly. • Inspect for surface cracks and repair spalling or exposed reinforcement for rigid barriers		Every Major Maintenance cycle and bi-annually	Required Rectification	Within 7 days

Parameter	Observation	Level of Service	Frequency	Rectification	Timeline
	• Wire tension on Wire Rope				

4.7 Guardrails

Pedestrian guard-rails are an important design element to prevent indiscriminate crossing and spilling over of pedestrian on to the carriageway. Their judicious use help to ensure that pedestrian cross the streets or highway at predetermined and safe locations. This section outlines the maintenance practices to be followed for guardrails.

I. Parameters

Parameters to be investigated

i) Guardrail painting and Cleanliness (free of vegetation and debris)
ii) Reflective stickers
iii) Structural integrity:
   a. Damages or breaks
   b. Alignment: straight and continuous
iv) Safety Consideration: No sharp edges or protruding bolts
v) Height of Guardrail
vi) Collision maintenance

II. Method of Inspection

The above parameters of Guardrail shall be measured in liner length. Measurements shall be through automatic digital measurement tools or through Network Survey Vehicle capable of Inventory inspection or if measured manually shall be supported by GPS coordinates and video back-up.

III. Investigation Parameters & Frequency

Following schedule shall be followed for inspection during maintenance.

Table 4.6: Maintenance Criteria for Pedestrian Guardrails

Parameter	Observation	Level of Service	Frequency	Rectification	Timeline
Routine Maintenance	• occasional cleaning and painting, and right-of way vegetation control	Functionality: Functioning of guardrails as intended	Daily	Rectification of failure	Within 7 days
	• Reflectors and Reflective stickers		Daily	Rectification of failure	Within 48 hrs
Structural Integrity	• Check for Damages or breaks • Alignment: straight and continuous	Functionality: Functioning of guardrails as intended	Daily	Rectification of failure	Within 48 hrs
Safety Consideration	• No sharp ends or protruding bolds that can harm pedestrians		Daily	Rectification of failure	Within 48 hrs
Height of guardrails	• Height of guardrails shall be as per the design.	Functionality: Functioning of Safety Barriers as intended	Daily	Rectification of height	Within 7 days

Parameter	Observation	Level of Service	Frequency	Rectification	Timeline
Collison maintenance	• Damages due to accidents	Functionality: Functioning of Safety Barriers as intended	Daily	Required Rectification	Within 7 days

4.8 Anti Glazers

Anti Glazers or Anti-Glare are types of measures to restrict the headlight glare from the opposite side of traffic by providing anti-glare screens like metal or plastic material. The total height of the screen, including the barrier should be 1.5 meters. These types of metal/plastic screens shall be provided majorly on flush-type medians. This section outlines the maintenance practices to be followed for guardrails.

I. Parameters

Parameters to be considered for the maintenance of Anti glazers are:

i) Antiglazer cleanliness
ii) Physical condition and functioning of Antiglazer

II. Method of Inspection

Above parameters of Antiglazer shall be measured for each Glazer. Measurements shall be through automatic digital measurement tools or through Network Survey Vehicle capable of Inventory Inspection or if measured manually shall be supported by GPS coordinates and video back-up.

III. Investigation Parameters & Frequency

Following schedule shall be followed for inspection during maintenance.

Table 4.7: Maintenance Criteria for Anti-Glare Screens

Parameter	Observation	Level of Service	Frequency of observation	Rectification	Timeline
Routine Maintenance	• occasional cleaning and painting, and right-of way vegetation control	Functionality: Functioning of guardrails as intended	Daily visual inspection with image or video backup of observed deviations.	Rectification of failure	Within 7 days
	• Reflectors and Reflective stickers		Daily	Rectification of failure	Within 48 hrs
Structural Integrity	• Check for Damages or breaks • Alignment: straight and continuous	Functionality: Functioning of guardrails as intended	Daily	Rectification of failure	Within 48 hrs
Safety Consideration	• No sharp ends or protruding bolds that can harm pedestrians		Daily	Rectification of failure	Within 48 hrs
Height of Anti Glare Screens	• Height of Anti Glazers shall be as per the design.	Functionality: Functioning of Safety Barriers as intended	Daily	Rectification of height	Within 7 days

Parameter	Observation	Level of Service	Frequency of observation	Rectification	Timeline
Collison maintenance	• Damages due to accidents	Functionality: Functioning of Safety Barriers as intended	Daily	Required Rectification	Within 7 days

4.9 Footpath

Footpaths segregate and protect pedestrians from motorized vehicles on urban streets to provide safe walking and help to improve vehicle flow. Footpaths are to be provided on all street types where vehicular speed exceeds 15kmph. The height of the footpath should be 150mm from the adjoining finished carriageway level to ensure comfortable access to all pedestrians. This section outlines the maintenance practices to be followed for footpaths.

I. Parameters

Parameters to be considered for the maintenance of footpaths are:

i) Footpath encroachments
ii) Footpath cleanliness
iii) Physical condition of the Footpath

II. Method of Inspection

Above parameters of Footpath shall be measured continuously. Measurements shall be through automatic digital measurement tools or through Network Survey Vehicle capable of Inventory Inspection or if measured manually shall be supported by GPS coordinates and video back-up.

III. Investigation Parameters & Frequency

Following schedule shall be followed for inspection during maintenance.

Table 4.8: Maintenance Criteria for Footpath

Parameter	Observation	Level of Service	Frequency	Rectification	Timeline
Encroachment	• Clearing the passage of footpath and will avoid any damages	Functionality: Functioning of footpath as intended	Daily	Rectification of failure	Within 24 hrs
Routine Maintenance	• occasional cleaning and painting, and right-of way vegetation control	Functionality: Functioning of guardrails as intended	Daily	Rectification of failure	Within 7 days
Safety Consideration	• No open pits or damaged tiles that can harm pedestrians		Daily	Rectification of failure	Within 48 hrs
Height of Footpath Screens	• Height of Footpath shall be as per the design.	Functionality: Functioning of Safety Barriers as intended	Daily	Rectification of height	Within 7 days
Collison maintenance	• Damages due to accidents	Functionality: Functioning of Safety Barriers as intended	Daily	Required Rectification	Within 7 days

4.10 Separators

Footpaths segregate and protect pedestrians from motorized vehicles on urban streets to provide safe walking and help to improve vehicle flow. Footpaths are to be provided on all street types where vehicular speed exceeds 15kmph. The height of the footpath should be 150mm from the adjoining finished carriageway level to ensure comfortable access to all pedestrians. This section outlines the maintenance practices to be followed for footpaths.

I. Parameters

Parameters to be considered for the maintenance of footpaths are:

iv) Footpath encroachments
v) Footpath cleanliness
vi) Physical condition of the Footpath

II. Method of Inspection

Above parameters of Footpath shall be measured continuously. Measurements shall be through automatic digital measurement tools or through Network Survey Vehicle capable of Inventory Inspection or if measured manually shall be supported by GPS coordinates and video back-up.

III. Investigation Parameters & Frequency

Following schedule shall be followed for inspection during maintenance

4.11 Noise Barriers

Noise Barriers cover the abatement of noise generated by the movement of vehicles on roads in both urban and rural areas. Since sound energy falling on the barrier will either be reflected, absorbed, or transmitted by the barrier depending on the type of barrier and material, it is important to choose the correct type of barrier depending on the site and project conditions. This section outlines the maintenance practices to be followed for Noise Barriers.

I. Parameters

Parameters to be considered for the maintenance of footpaths are:

i) Physical Condition.
ii) Noise Barrier shall be constructed in removable structural modules to allow for easier and cost-effective maintenance.
iii) Transparent Panels Inclusive of embedded stainless–steel cable retaining structure for silver retention and restrain fragments due to breakage are permitted or required as per site conditions.
iv) No Direct Bolting of Transparent Panels will be allowed to prevent tearing under wind load.

II. Method of Inspection

The above parameter of Noise Barriers shall be measured for linear length. Measurements shall be through automatic digital measurement tools or Network Survey Vehicle capable of Inventory Inspection or if measured manually shall be supported by GPS coordinates and video back-up.

III. Investigation Parameters & Frequency

The following schedule shall be followed for inspection during maintenance.

Routine maintenance requirements can be minimized by self-cleaning provisions like transparent sections should be kept clear of splash zones, but will need cleaning regularly, and regular trimming of vegetation.

Space should be allowed between planting and the face of a barrier sufficient to give access for maintenance. However, in some locations, there will be a need to consider restricting public access to the protected side to prevent vandalism.

Periodic Inspection of the installed Noise Barrier must be carried out to check for

a. Any gaps that may have been formed over a period of time.
b. Structural Damage to Panels due to Vehicular Crash/wind load
c. Stability of Foundations
d. Any other damage due to forces of Nature such as damage to absorbing materials due to heavy rainfall.

4.12 Object Markers & Road Studs

Object Markers are the type of road delineators illuminating all physical objects above the finished road Level (FRL) that are falling within m from the carriageway edge added with Object Hazard Markers (OHM). The Object Hazard Markers shall be either left OHM or right OHM or two wat Hazard Markers with respect to the position of the object to the traffic. This section outlines the maintenance practices to be followed for Object Markers.

I. Parameters

Parameters to be considered for the maintenance of Object Markers are:

i) Cleanliness
ii) Physical Condition
iii) Night Visibility

II. Method of Inspection

Above parameters of Object Markers shall be measured for each Object Marker. Measurements shall be through automatic digital measurement tools or if measured manually shall be supported by GPS coordinates and video back-up.

III. Investigation Parameters & Frequency

Following schedule shall be followed for inspection during maintenance

Table 4.9: Maintenance Criteria for Object Markers

Parameter	Observation	Level of Service	Frequency	Rectification	Timeline
Visually conspicuous	Clear of dust, bills and free from obstruction like branches, advertising boards etc. Visual observation with image or video backup of observed issues	Rating of sign board shall be more than 9.5 as per table 14 of IRC:SP:127-2020	Daily Basis	Cleaning and removal of obstruction	Within 24 hrs
Physical Condition (Shape, Position and Condition)	Shape,Position and Condition as per IRC:67-2012. Signboard should be clearly visible for the design speed of the section. Visual observation with image or video backup of observed issues in Condition of Signboard.	Rating of sign board shall be more than 9.5 as per table 14 of IRC:SP:127-2020	Shape and Position shall be verified and corrected at the time of installation. Physical Condition, shall be verified on daily basis.	Improvement of shape / condition, in case if not inline with requirements.	48 hours in case of Mandatory Signs, Cautionary and Informatory Signs (Single and Dual post signs), 15 Days in case of overhead and canopy Sign boards
Retro-reflectivity	As per specifications in IRC:67-2012	Rating of sign board shall be more than 9.5 as per table 14 of IRC:SP:127-2020	Bi-annually	Replacement of signboard	48 hours in case of Mandatory Signs, Cautionary and Informatory Signs (Single and Dual post signs), one month in case of overhead and canopy Sign boards

Parameter	Observation	Level of Service	Frequency	Rectification	Timeline
Painting of Posts	Post shall be free of rust, weeds, shrubbery, mud etc. Visual observation with image or video backup of observed issues		Bi-annually	Repainting of signboards posts	48 hours in case of Mandatory Signs, Cautionary and Informatory Signs (Single and Dual post signs), 15 Days in case of overhead and canopy Sign boards
Pasting 5cm retro-reflective sheets on posts	Sheets shall be completely intact around the posts with no signs of tear Visual observation with image or video backup of observed issues		Monthly (during night visit)	Repasting of retro-reflective sheets on posts	Within 48hrs

4.13 Road Studs

Retro-reflective studs are used to supplement longitudinal/transverse reflectorized road markings, which would improve visibility in night-time and adverse weather conditions. Road studs are also used across the carriageway to serve as Speed Arrestor coupled with eschewing warning through the creation of the rumbling sensation to the user. This section outlines the maintenance practices to be followed for road studs.

I. Parameters

Parameters to be considered for the maintenance of Road Studs are:

iv) Cleanliness
v) Physical Condition
vi) Night Visibility

II. Method of Inspection

Above parameters of Road Studs shall be measured for each Road Studs. Measurements shall be through automatic digital measurement tools or if measured manually shall be supported by GPS coordinates and video back-up.

III. Investigation Parameters & Frequency

Following schedule shall be followed for inspection during maintenance

Table 4.10: Maintenance Criteria for Road Studs

Parameter	Observation	Level of Service	Frequency	Rectification	Timeline
Routine Maintenance	• Occasional cleaning dirt accumulated on median and shoulder side.	Functionality: Functioning of Road studs as intended	Daily	Rectification of failure	Within 2 months
Structural Integrity	• Check for Damages or breaks • Alignment: straight and continuous	Functionality: Functioning of guardrails as intended	Daily	Rectification of failure	Within 2 months

PART 5: MAINTENANCE OF OTHER HIGHWAY ELEMENTS

5.1 ROW and Horticulture Maintenance

Right of Way (ROW) and Horticulture maintenance is a critical component of roadway management that ensures the safety, functionality, and visual appeal of transportation infrastructure. Proper maintenance of the median, roadside areas, and other associated structures is essential to prevent hazards, maintain traffic flow, and enhance the overall driving experience. This chapter provides detailed standards and guidelines for ROW maintenance to help maintain optimal road conditions and ensure long-term sustainability of the infrastructure.

S. No.	Category	Scope of Work	Frequency		Execution
			Description	Criteria	
HORTICULTURE MAINTENANCE					
1	Median Maintenance	Maintenance of vegetation and structures in the median, trimming, debris removal, pit hoeing, manure spreading, and cleaning of PCC surfaces.	Trimming of Plants/Shrubs	Achieve Height of 1.2m	Use mechanical or power tools for plant trimming and grass cutting. Prepare plant basins: loosen soil, apply manure, and treat with pesticides/insecticides. Ensure systematic and regular activity to prevent overgrowth and maintain visual appeal.
			Grass Cutting • Cutting unwanted grass at medians, islands, rotary intersections, interchanges, toll plazas, and truck lay-bys. • Removal of branches, undesirable vegetation, debris, and garbage.	Summer (March – September) – Once Winter (October – February) – Twice	
			Basin Preparation • Pit hoeing/basin making for plants	Once every 3months	
			Application of manure and insecticides/ pesticides as needed.		
			Clearing vegetation from the PCC surface.		
2	Roadside Maintenance	Cleaning and upkeep of roadside areas up to boundary pillars.	Cutting of undesirable vegetation up to ROW boundary pillar	Once in a month	Utilize mechanical/power tools for overgrown vegetation removal and grass cutting. Dispose of waste as per
			Cutting of unwanted grass/weeds inside of tree guards	Once in every 3 months	

			Cutting of Unwanted plants/ grasses in RE wall, RCC retaining wall, stone pitching	Once in a month	environmental regulations and local directives.
			Cleaning of garbage and litter	Once in a month	
			Basin preparation	Once in every 6 months	
			Branches of Avenue plant should be trimmed	Once in a year	
3	Plant Maintenance	Regular watering, pest control, and replacement of damaged plants in medians and avenue plantations. To ensure healthy and thriving vegetation by watering all plants and shrubs and replacing damages plants in median and avenue areas for environmental and aesthetic purposes.	Inspection and Maintenance of Plants	Once in a month	Conduct joint inspections with service providers for plant count and condition. Apply water, fertilizers, and pesticides as required. Replace damaged plants with those of the same species, size, and height. Monitor for over/underwatering and adjust schedules accordingly.
			Watering Median Plants	Once in every 4 days (20 litres per plant)	
			Watering Avenue Plants (Small, <6ft)	Once in every 6 days (30 litres per plant)	
			Watering Avenue Plants (Large, >6ft)	Once in every 10 days (30 litres per plant)	
			Pesticide Spraying	As directed by the site in-charge	
			Casualty Replacement	Twice a year	
SURFACE AND FURNITURE MAINTENANCE					
4	Road Furniture Cleaning	Cleaning of various road furniture elements that include, delineators, signboards, MBCB, guard rails, kerbs, KM/HM stones, crash barriers, shelters, etc.	Cleaning of Road Furniture in medians, roadside and service roads	Once in a month	Use manual or mechanical methods. Remove dust, dirt, and debris. Ensure visibility of markings and reflective surfaces. Pay special attention to areas prone to accumulating grime, such as signboards and gantry boards.
			Cleaning of Bus Shelter	Twice in a Month	
			Cleaning of Delineators	Once in a month	
			Cleaning of Signboards	Once in a month	
			Cleaning of MBCB	Once in a month	
			Cleaning of PGR	Once in a month	
			Cleaning of Gantry Boards	Once in a month	
			Cleaning of KM, HM, 5th KM Stones	Once in a month	
			Cleaning of Guard Post	Once in a month	
			Cleaning of Boundary Pillars	Once in a month	
5		Sweeping of main carriageways,	Wet cleaning of kerb	Once in a month	Use of Mechanised Road Sweepers

	Road Cleaning	shoulders, service roads, junctions, and disposal of debris.	Main Carriageway and Service Road cleaning	Once in a month	should be done. Minimum tentative specifications of the Mechanised Road Sweepers have been provided in Table 5. Wet cleaning of kerbs and shoulders as necessary.
			Cleaning of Median opening, Junctions, Urban area, Structure, Transverse barcode, Barricades areas	Twice in a month	
			Cutting and removing of all unwanted grass/plants at kerb edge and RCC crash barrier edge	Once in a month	
7	Toll Plaza Cleaning	Cleaning of toll pavement, crash barriers, bull nose, separators, and road furniture.	Cleaning of Toll Plaza pavement area	On daily basis	Manual cleaning using brooms and/or mechanical brooms.
			Cleaning of Toll Plaza ROW	On daily basis	
			Cleaning of Toll lanes	On daily basis	
			Cleaning of Separators	On daily basis	
			Cleaning of Bull Nose	On daily basis	
			Cleaning of Crash Barriers	On daily basis	
			Wet Cleaning of Road furniture	On daily basis	
DRAINAGE MAINTENANCE					
6	Drain Cleaning	Cleaning of Lined and earthen roadside drains, Median drains, Cut drains (median/divider chutes), Side slope drains and removal of sediments, garbage, and stagnant water from site whenever requires	Cleaning of Median Chute & Divider Chutes should be cleaned	Once in a month	Thorough cleaning of all drains pre- and post-monsoon cleaning to avoid blockages. Use hand tools or machinery depending on site conditions.
			Cleaning of roadside (Lined Drain & Earthen Drain, Median Drain, Cut Drain, Side Slope Drain)	Twice in a year (before and after monsoon)	
8	Waterway Structures	Desilting and cleaning of culverts, flyovers, underpasses, RE walls, and other waterway structures; removal of vegetation and sediment.	Cleaning of Box culvert	Twice in a year	Use rakes, shovels, nets for removal of accessible debris. Use excavators /loaders/water jets for sediment and sludge in culverts. Manual cleaning of structures (flyovers, ROBs, etc.) and surfaces (crash barriers,
			Cleaning of Pipe culvert	Twice in a year	
			Cleaning of Slab culvert	Twice in a year	
			Cleaning of Underpass	Once in 5 days	
			Cleaning of Bridges	Twice in a year	
			Cleaning of Flyovers	Once in 5 days	

			Cleaning of Headwall	Twice in a year	handrails, etc.) where necessary to remove sand and debris.
			Cleaning of Parapet wall	Twice in a year	
			Crash Barrier	Twice in a year	
			Cleaning of Handrail	Twice in a year	
			Cleaning of Quadrant Pitching	Twice in a year	
			Cleaning of Drain Spout	Twice in a year	
			Cleaning of Expansion Joint	Twice in a year	
			Cleaning of Stone Pitching	Twice in a year	
			Cleaning and removal of vegetations from RE Wall Panel	Once in a month	
			Note: Twice a year depicts before and after monsoon		
SANITIZATION					
9	Toilet Block Cleaning	Daily hygiene and cleanliness of public toilet blocks and septic tank cleaning.	General Cleaning	Continuous throughout the day	One manpower round-the-clock per toilet block. Also, provide cleaning materials and consumables. Deploy 1 attendant per shift (3 per block daily). Ensure frequent cleaning septic tank to prevent overflow and maintain hygiene.
			Septic Tanks	As required	
SHOULDER AND EARTHWORK MAINTENANCE					
10	Shoulder Maintenance	Maintenance of earthen shoulders: • Grading and vegetation control.	Routine inspection	Once in a week	Loosened and Strip existing shoulder and mix new material (RAP) and dump uniformly over it

		• Removal of plants/weeds obstructing visibility/ drainage. • Filling ruts/gullies, debris clearance. • Maintain level with no edge drop at pavement junction.	Filling of ruts and gullies	As required, particularly post monsoon	Level with grader, water to achieve OMC, and compact with roller or rammer. Refer figure 5.1
			Renewal of shoulders	As required	

Figure 5.1: Earthen Shoulder Maintenance

Table 5: Minimum Tentative Specifications for Mechanised Road Sweepers

Description	Generic Specifications
Purpose	Road Vacuum Sweeping, Street Sweeping
Vehicle Engine	BS 6 or better
Drive	RHD
Type	Truck Mounted Vacuum Road Sweeping Machine
Sweeping Area/Hr	36000 Sq. Mtr/Hr at a speed of 12 km/h. (Including side Brushes) (If the brushes are opened from 2 sides)
Debris Hopper Capacity	Effective 10 Cu. Mt for each 100 km of 4/6 lane NH
Number of Main Brushes	Total 3 brushes: 1 Central brush and 2 side brushes
Additional Front Brushes with High pressure washing system	There will be two additional brushes in front of the vehicle with the high pressure washing spraying system with mist technology
Sweeping Side Brushes	Two side brushes of dia 600 mm made of Nylon bristles. All Brushes are driven directly by hydraulic motors
Sweeping Central Brush	One horizontal brush min 1200 mm long with Dia 400 mm. To avoid conical wearing, It should not be carried by the truck chassis directly, but by a 3-point bracket, 2 points of which are carried by the axle of the truck.

Manual Sweeping with Wander House	Hand held vacuum with a wander house with A 5mt-long flexible suction hose which is 150mm diameter with nozzle to be provided at the rear of machine for manual cleaning of areas where the machine cannot reach. It's equipped with hanger apparatus with pneumatic system.
Sweeping Width without front brushes	3000 mm with One Centre Brush+ Two side rotary brushes
Sweeping Speed	0 To 20 Km/hr depending on road conditions
Suction Fan	High efficiency multi bladed dynamically balanced vacuum Fan impeller is driven by the auxiliary engine via a disc type clutch which is of automotive type for availability and gear box for ensuring sufficient Vacuum Power for sweeping system at low noise Levels
Suction Power	Shall be capable of 17500 m3/hour at 1350 rpm/min
Suction Rating	Min. 260 M3/Minute.
Suction Nozzles	Operated openings for large objects capable of lifting stones up to 100 mm, leaves, sand and other material from the road
Hydraulic System	Reservoir capacity 80 Lt. Hydraulic pump PTO driven with protection relief valve Control Valve-Solenoid Operated from the control panel. Filtration system 28 micron
Water tank	900 lt made of stainless steel. The water tank must be suitable for entering in and cleaning the mud inside it thoroughly which is very likely to precipitate in time, even the garbage tank is full with garbage.
Water Pump Pressure	150 bar
Lights For Night Work	Search lights on side brushes and rear of the machine to be provided.
Sweeping Controls	All sweeping and unloading controls are provided on control panel. Brushes up down and on off is controlled from the Cabin with the help of a remote control
Control Panel	PLC control system with touch screen which enables all operations plus additional mechanical control buttons in the vehicle cab for running brushes
Filtration Standard	Sweepers must have PM2.5 label as certified by National/International Certification Agencies
Cleaning System	With Water sprinkling nozzles at minimum 25 places
CCD Camera System	Atleast 700TVL CMOS Cameras, one on Sweeping Head and Second at rear of machine to be provided to monitor the sweeping and ensuring safe reversing of machine
Washing Gun	10 metre washing gun with min.150 bar
Controls and Others	Easily accessible PLC Touchpad Screen and keypad on control panel mounted in front of operator that controls the following: 1) Suction Fan Drive ON/OFF 2) Roller & Rotary Brush ON/OFF 3) Sweeping Head & Brush UP/Down 4) Debris Hopper Tipping 5) Water Spray ON/OFF 6)LCD Monitor 7)Equipment Lights ON/OFF 8)Emergency Stop 9)Air Pressure Gauge 10) Floodlights for easy sweeping

Figure 5.2: Mechanised Road Sweepers

PART 6: SYSTEMS MAINTENANCE

6.1 Toll Management System

Components of TMS

The FASTag system has 3 major components: AVCC, Lane Equipment, Transaction Processing and Validation.

(a) Automatic Vehicle Counter cum Classification (AVCC):

Recording count and class of vehicles for lane traffic validation. Tolling industry mainly utilises the following three types of AVCCs:

- **IR Sensor (Rx and Tx):** The system is equipped with Infrared (IR) Sensors (Rx and Tx) embedded at axle height, which are used for vehicle classification through axle count detection. The IR sensors accurately detect and count the number of axles of each vehicle as it passes through the sensor zone. Also, detect the axle spacing between them.
- **Profiler:** The profiler utilizes IR/Laser sensors to create a virtual image of the vehicle, specifically measuring the vehicle from axle height. The IR/Laser sensors capture data from the vehicle's axle height to generate a precise virtual image of the vehicle's structure.
- **Vision Based:** The system utilizes video-based technology to capture images of vehicles and classify them based on the following criteria:
- **Axle Count:** The system identifies and counts the number of axles of each vehicle.
- **Shape/Size:** The system classifies vehicles based on their shape and size, enabling accurate vehicle type identification.

(b) Lane Equipment:

Toll Plaza consists of variety of equipment's:

- OHLS (Over Head Lane Signal)
- ETC reader
- Traffic Light
- UFD (User Fare Display)
- Boom Barrier
- LPIC Camera
- ICS Camera
- TLCs
- Lane Receipt Printer
- Webcam
- Lane UPS
- AVCC
- WIM and SWB
- Foot Switch and Violation Alarm

(c) Transaction Processing and Validation:

The FASTag process is a as follows:

- **Vehicle Detection:** The plaza system is equipped to captures and process the FASTag details for accurate vehicle identifications and classifications, the system captures key information from the FASTag, including the TagID, TID, License Plate number, Vehicle Class and other relevant information.
- **Vehicle Upload:** After vehicle detection, Plaza systems check for TagID status and if status is active then upload that vehicle on acquirer Bank portal. In case tag status is low balance/ Blacklisted, Cash transaction need to be performed for that vehicle.
- **Validation Request:** The acquiring bank initiates a process to validate FASTag details through the NETC Mapper system. The acquiring bank sends a request to the NETC Mapper to validate the FASTag associated with the vehicles.

- **Tag ID Validation:** Upon successful validation of the FASTag, the NETC Mapper provides the relevant details associated with the tag. If the tag ID is recognized, NETC mapper responds with details such as the vehicle class, VRN and tag status.
- **Toll Fare Calculation:** The acquirer host calculates the applicable toll fare based on the vehicle class, journey details, and other relevant parameters. Once the fare is determined, the acquirer host initiates a debit request to the NETC system to process the payment.
- **Debit Request:** The NETC system sends a request to the issuer bank to debit the calculated toll fare from customer's FASTag wallet. The issuer bank processes the request and verifies the availability of funds in the customer's account to complete the transaction.
- **Confirmation:** The issuer bank debits the toll fare from the FASTag wallet associated with the FASTag. After the transaction is processed, the issuer bank sends an SMS alert to the tag holder, notifying them of the successful debit and transaction details.
- **Transaction Complete:** The NETC system sends the necessary transaction details to the toll plaza system to confirm the payment and complete the tolling process. Once the communication is successfully received, the Toll plaza system updates the transaction status and finalizes the payment process.

II. Lane Equipment Maintenance Schedule

(a) Vision Based AVCC Systems:

- Open Lane-wise AVCC GUI to verify the time synchronization. If the AVCC Server Time is synchronized with NTP time, the NTP date and time will be displayed otherwise local AVCC server time will be displayed. The system should always display the NTP date and time to ensure consistent and accurate time across the network.
- Ensure all cameras are correctly aligned for optimal vehicle coverage. Check for any misalignment that might affect vehicle classification or counting. Verify that the camera housing is intact, securely mounted, and free of damage or wear.
- Open Lane-wise AVCC GUI, Camera angle should be properly aligned including red and green boxes and provide the clear visibility of all relevant data. Confirm that the camera resolution, focus, and field of view are correctly set for optimal performance.
- Inspect the captured images for clarity, focus, and proper exposure. Verify that lighting conditions (e.g., during night-time operation) do not affect image quality and classification accuracy.
- Regularly clean the camera lenses using appropriate cleaning solutions and tools to prevent dirt, rainwater, or dust from affecting image clarity.
- Immediately report any errors or malfunctions in the vision system to the technical support team for further investigation and resolution.
- Open the Lane-wise AVCC GUI to monitor the system's performance metrics. Look for the Average FPS metric displayed in the GUI, Average FPS should be equal or greater that our desired FPS. If Average FPS are less than desired FPS, immediately report to technical support team and post a message in particular groups.
- Keep checking Telegram groups/relevant groups to ensure that the hourly vehicle count is accurate and as expected. Check if there are any alerts related to AVCC insertion or connectivity issues. If any issues or alerts are observed, report them immediately to the concerned team for resolution.
- Assess if the issue related to AVCC insertion can be resolved at the site, Fix the Issue locally to ensure the AVCC system is functioning correctly. If the issue cannot be resolved at the site level, report the issue to the HO Team (Head Office Team) for further assistance as well Post in WhatsApp Group to inform the team about the ongoing issue and request immediate action.
- Continuously check the AVCC Camera ping status from the control room to ensure proper connectivity. Ensure there is no RTO (Request Time Out) or delay in the camera ping response. The cameras should be responding promptly. If any RTO errors or delays are detected, immediately address and rectify the issue to restore proper camera connectivity and investigate and resolve any underlying connectivity issues or hardware malfunctions causing the problem.
- Keep a log of all maintenance actions taken, including inspection results, sensor adjustments, and replacements.

(b) IR Sensor (RX and TX) based AVCC Systems:

- Verify that the RX and TX sensors are properly aligned. Ensure there are no obstructions between the sensors.
- Verify that the sensor alignment is within the defined parameters for accurate axle count and vehicle classification.
- Ensure that the signal strength between the RX and TX sensors is within operational limits.
- Ensure the AVCC system software is configured correctly to process inputs from the IR sensors.
- Keep checking Telegram groups/relevant groups to ensure that the hourly vehicle count is accurate and as expected. Check if there are any alerts related to AVCC insertion, connectivity or alignment issues. If any issues or alerts are observed, report them immediately to the concerned team for resolution.
- Periodically clean the sensor lenses using appropriate tools and cleaning agents.
- Keep a log of all maintenance actions taken, including inspection results, sensor adjustments, and replacements.
- Open AVCC GUI or System Interface and check time is synchronized with NTP time, it should be synched with NTP time.

(c) Profiler based AVCC System:

- Verify that the vehicle profiler (IR/Laser or other sensors) is aligned correctly with the vehicle detection zone. Ensure that there are no physical obstructions in the profiler's path.
- Ensure that the profiler sensors (IR/Laser) are aligned according to the required parameters for vehicle profiling.
- Conduct regular functional tests by passing a test vehicle through the profiler zone to ensure proper profiling (correct classification, size, and axle count).
- Ensure the AVCC system software is correctly configured to receive and process data from the profiler sensors.
- Periodically clean the sensor lenses using appropriate cleaning tools and agents to prevent debris buildup.
- Keep checking Telegram groups/relevant groups to ensure that the hourly vehicle count is accurate and as expected. Check if there are any alerts related to AVCC insertion, connectivity issues pr alignment issues. If any issues or alerts are observed, report them immediately to the concerned team for resolution.
- Keep detailed records of all maintenance activities, including inspections, calibrations, component replacements, and software updates.
- Open AVCC GUI or System Interface and check time is synchronized with NTP time, it should be synched with NTP time.

III. Lane-wise Checklist

Sl. No.	Lane Equipment	Activity	Responsibility	Periodicity
1	Boom Barrier	Check for Physical Damage	TMS Shift Engineer	Once in a Shift
		Unnatural shaking during up/down cycle	TMS Shift Engineer	Once in a Shift
		Orientation should be parallel to road surface in rest mode (i.e. horizontal)	TMS Shift Engineer	Once in a Shift
		Time lag in Up/Down Cycle	TMS Shift Engineer	Once in a Shift

Sl. No.	Lane Equipment	Activity	Responsibility	Periodicity
2	OHLS	Check status Red or Green	TMS Shift Engineer	Once in a Shift
3	UFD	Check all information toll amount, vehicle class, Tag Status are displaying	TMS Shift Engineer	Once in a Shift
4	Traffic Light	Check status Red and Green are working properly	TMS Shift Engineer	Once in a Shift
5	Lane UPS	Check Input/Output	TMS Shift Engineer	Once in a Shift
6	RFID	Check for physical alignment	TMS Shift Engineer	Once in a Shift
7	LPIC/Back Camera	Check for physical alignment	TMS Shift Engineer	Once in a Shift
8	TLCs	Check for C-Drive Storage	TMS Shift Engineer	Once in a Shift
		Lane Firewall Status	TMS Shift Engineer	Once in a Shift
9	Lane Services	ETC Blacklist download services	TMS Shift Engineer	Once in a Shift
		Merge AVCs service	TMS Shift Engineer	Once in a Shift
		Image Copy Lane to Server	TMS Shift Engineer	Once in a Shift
		Insert discount files	TMS Shift Engineer	Once in a Shift
		Read blacklist XML's	TMS Shift Engineer	Once in a Shift
		Read participant list XML	TMS Shift Engineer	Once in a Shift
		WIM data receiver	TMS Shift Engineer	Once in a Shift
		Windows update	TMS Shift Engineer	Once in a Shift
10	WIM and SWB	Check for Vehicle Separator Alignment	TMS Shift Engineer	Once in a Shift
		Weight reflecting in controller	TMS Shift Engineer	Once in a Shift
		Weight reflecting in lane module	TMS Shift Engineer	Once in a Shift
		Weight reflecting in SWB module	TMS Shift Engineer	Once in a Shift
		Queue merging transactions	TMS Shift Engineer	Once in a Shift

6.2 Advanced Traffic Management System (ATMS)

I. Components of ATMS

Advanced Traffic Management Systems (ATMS) are a set of technologies and techniques that are used to improve the efficiency, safety, and reliability of traffic on roads and highways. They use a variety of sensors,

communication systems, and software to collect, process, and distribute real-time information about traffic conditions. Some of the key components of ATMS include:

- **Traffic Monitoring Camera System (TMCS):** The Traffic Monitoring and Control System (TMCS) utilizes PTZ (Pan-Tilt-Zoom) cameras to monitor traffic conditions along the project road. The main objective of the TMCS is to provide continuous surveillance of traffic patterns and conditions throughout the day and night. The TMCS ensures that the entire project road is covered, providing real-time insights into traffic flow and congestion. PTZ cameras are employed to capture dynamic, high-resolution footage of traffic, allowing operators to remotely adjust the camera's pan, tilt, and zoom to focus on specific areas as needed.
- **Video Incident Detection System (VIDS):** The Vehicle Incident Detection System (VIDS) is designed to automatically detect incidents occurring on the Project Road in real-time. VIDS continuously monitors traffic conditions to identify accidents, congestion, or other incidents as they happen. The system triggers immediate alerts to notify operators of detected incidents, allowing for quick responses and timely interventions.
- **Vehicle Speed Detection System (VSDS):** The Vehicle Speed Detection System (VSDS) is a traffic management system designed to monitor, measure, and track the speed of vehicles traveling on the road. The system employs advanced sensors and technologies to capture real-time vehicle speed data, ensuring compliance with speed limits and improving overall road safety.
- **Variable Message Signs (VMS, Full and Compact):** A Variable Message Signboard (VMS) is an electronic traffic sign used to provide real-time, dynamic information to drivers on road conditions, traffic alerts, and other critical information. VMS units can display different types of messages, which are changed remotely depending on the current situation on the road, such as accidents, traffic jams, construction work, or changes in speed limits.
- **Emergency Call Box (ECB):** An Emergency Call Box (ECB) is a communication device installed along roads, highways to provide a direct and immediate means of contacting emergency services in case of an accident, breakdown, or other urgent situations. ECBs are designed to ensure that drivers, passengers, or pedestrians can quickly alert authorities and request assistance, especially in remote or high-risk areas where mobile network connectivity may be limited.
- **Traffic Management Centre (TMC):** A Traffic Management Centre (TMC) is a centralized control facility used to monitor, manage, and optimize traffic flow across an entire road network. It is equipped with advanced technologies and systems to collect data, detect incidents, monitor traffic conditions, and provide real-time information to both drivers and authorities. The TMC's role is to ensure the safe, efficient, and smooth operation of traffic, reduce congestion, enhance road safety, and support emergency responses. Powerful servers would be deployed at TMC to process the data – particularly to process videos from VIDS. TMC will send out alerts to various devices in the field with the information generated by processing the data received. A TMC Control Centre including the equipment (hardware, software, and local networking) will be provided at one of the Toll Plazas.
- **Communication System:** The Communication System in an Advanced Traffic Management System (ATMS) is a crucial component that facilitates real-time data exchange and seamless interaction between various elements of the traffic management infrastructure. This system ensures that all parts of the ATMS, such as cameras, VMSs, incident detection systems, and control centres, work together efficiently. It enables the transmission of traffic-related information, alerts, and control signals in real-time, helping to optimize traffic flow, manage incidents, and improve road safety.
- **Power supplies for field equipment:** Power supplies for field equipment in an Advanced Traffic Management System (ATMS) are critical to ensure the continuous operation of various traffic management and monitoring components such as cameras, variable message signs (VMS), VIDS, VSDS, traffic controllers, and other roadside devices. Reliable, uninterrupted power is essential for the effective functioning of these field equipment devices, as ATMS relies on real-time data collection, processing, and communication to monitor and manage traffic conditions.

II. Checklists

(a) ATMS Checklist (Periodicity: Every day in General Shift)

Equipment	PTZ	VIDS	VMS	ATCC	VSDS	MET	ECB
Locations	Equipment Chainage	Equipment Chainage	Equipment Chainage	Equipment Chainage	Equipment Chainage	Equipment Chainage	Equipment Chainage
Day							
Date							
Is the camera lens focused and adjusted correctly?	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Not Applicable	Not Applicable
Is the road stretch visible in the camera?	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Not Applicable	Not Applicable
Is the camera lens free from dust, stains, water droplets and smudges?	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Not Applicable	Not Applicable
Are all camera functions like zoom, tilt and pan working correctly?	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Not Applicable	Not Applicable
Check for Network status and ping the camera to check the delay	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Not Applicable	Not Applicable
Grid Alignment	Not Applicable	Yes/No	Not Applicable	Yes/No	Not Applicable	Not Applicable	Not Applicable
VMS displaying sent message	Not Applicable	Not Applicable	Yes/No	Not Applicable	Not Applicable	Not Applicable	Not Applicable
VSDS: Captured images are proper and in focus with speed stamp	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Yes/No	Not Applicable	Not Applicable
ECB: ECB speaker, mic check	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Yes/No

(b) ATMS Checklist (Periodicity: First Week of Every Month)

Equipment	PTZ	VIDS	VMS	ATCC	VSDS	MET	ECB
Locations	Equipment Chainage	Equipment Chainage	Equipment Chainage	Equipment Chainage	Equipment Chainage	Equipment Chainage	Equipment Chainage
Day							
Date							
Lightening arrestor present	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No
Are the cables in good condition	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No

Equipment	PTZ	VIDS	VMS	ATCC	VSDS	MET	ECB
and free of exposed wires							
Are all cables connected correctly	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No
Structure: Any impact, signs of buckling or leaning	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No
Corrosion to components, particularly at welds and connections to the gantry beam, base plates/gusset	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No
Warping or bending in the base plate	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No
Condition of coating/paintwork	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No
Footing: Movement or settlement of the footing	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No
Anchor Bolts: Failed or missing holding down bolts	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No
Anchor Bolts: Washers missing or insufficiently covering the hole	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No
Anchor Bolts: Nuts missing, not fully tightened or unevenly seated	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No
Anchor Bolts: Cracked, incomplete or missing mortar or grout under base plates	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No
RSU foundation: Any movement or damage in the foundation	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No

Equipment	PTZ	VIDS	VMS	ATCC	VSDS	MET	ECB
RSU Foundation: Nut Bolts and Washer in place	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No
RSU Cabinet: Any corrosion sign on the RSU Cabinet	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No
RSU Cabinet: Water Ingress in the cabinet	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No
RSU: Clean up the dust using blower	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No
Check input and output voltages of all power supply	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No
RSU door limit switch and relay working properly	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No
Solar Panel Clean	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No
VMS: The surface of the display is uniform and clean	Not Applicable	Not Applicable	Yes/No	Not Applicable	Not Applicable	Not Applicable	Not Applicable
VMS: The lock, handle, positioning pin, door lock, etc. are not damaged, no oxidation	Not Applicable	Not Applicable	Yes/No	Not Applicable	Not Applicable	Not Applicable	Not Applicable
VSDS: Is the display surface clean	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Yes/No	Not Applicable	Not Applicable
VSDS: Verify the display is working properly	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Yes/No	Not Applicable	Not Applicable
VSDS: Is the LPU clean and free from dust	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Yes/No	Not Applicable	Not Applicable
VSDS: Check for accuracy for 30 minutes/30-40 vehicles. Is the VASD accurate?	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Yes/No	Not Applicable	Not Applicable
MET: All sensors working properly	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Yes/No	
MET: Clean all sensors and LPU	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Yes/No	

Equipment	PTZ	VIDS	VMS	ATCC	VSDS	MET	ECB
ECB: Battery Voltage Check	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Yes/No
ECB: Master/Slave Clean and check working properly	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Yes/No

(c) ATMS Maintenance Checklist:

Device Type	Weekly	Monthly	Yearly
PTZ	Is the camera lens focused and adjusted correctly?	Is image transmission clear and distortion-free?	Any corrosion sign on mounts and clamp of camera
	Is the road stretch visible in the camera?	Ensure lightening arrestor is present and functional	Tighten the clamp and camera
	Is the camera lens free from dust, stains, water droplets and smudges?	Inspect and clean the camera lens for dust or smudges.	Camera properly cleaned
	Are all camera functions like zoom, tilt and pan working correctly?	Check for any damage to the camera housing	Lightening arrestor tightened
	Check for Network status and ping the camera to check the delay	Check all power and network cables for wear and tear	Lightening arrestor earthing cable connection
	Verify that the traffic data is being collected and displayed accurately.	Perform a system-wide check for camera alignment	Check for power and network cable connections (Replace if required)
	Verify that all camera connections (power, network) are secure	Verify camera lens is free of obstructions (dust, water)	Camera properly cleaned
	Inspect camera's physical condition for damage or misalignment.	Check network status and ping the camera to check the delay	Replace any worn-out or damaged parts
	Test for any error messages or alerts in the system logs.		Perform full camera and system calibration
	Monitor live system feeds for accuracy in real-time data.		Ensure that the camera is functioning within the correct parameters (FPS, resolution)
VIDS	Is the camera lens focused and adjusted correctly?	Is image transmission clear and distortion-free?	Any corrosion sign on mounts and clamp of camera
	Is the road stretch visible in the camera?	Inspect lightening arrestor for corrosion or damage	Inspect camera housing for any physical damage or signs of wear
	Is the camera lens free from dust, stains, water droplets and smudges?	Check alignment of VIDS grid and adjust if needed	Camera properly cleaned

Device Type	Weekly	Monthly	Yearly
	VIDS Grid alignment is proper	Check for proper functioning of the detection system (incident detection)	Lightening arrestor tightened
	Check for Network status and ping the camera to check the delay	Verify camera lens is clean and free from obstructions (dust, stains)	Lightening arrestor earthing cable connection
	Verify that VIDS is detecting incidents accurately	Check for any system errors or alerts in logs	Check for power and network cable connections (Replace if required)
	Ensure proper calibration of VIDS system	Perform routine system checks for stability and error-free operation	Tighten and secure all clamps, mounts, and connections
	Monitor the system for false alarms or missed incidents		Check and replace any worn-out or damaged cables or connectors
	Check all power, network, and data cables for integrity		Ensure VIDS detection accuracy by simulating traffic incidents
	Check camera FPS and resolution settings		Perform a full system calibration and test for accuracy
			Test the system for overall performance and responsiveness
ATCC	Is the camera lens focused and adjusted correctly?	Is image transmission clear and distortion-free?	Any corrosion sign on mounts and clamp of camera
	Is the road stretch visible in the camera?	Inspect lightening arrestor for proper functioning	Check the condition of the camera housing and any external components
	Is the camera lens free from dust, stains and smudges?	Check for proper functioning of the system's detection algorithms	Clean camera lens and housing properly
	Grid alignment is proper	Check for proper calibration and accuracy of traffic data	Verify proper earthing and grounding of lightening arrestor
	Inspect system for accurate traffic counting and classification	Inspect camera for any physical damage (lens, casing, etc.)	Ensure all external connections (power, network) are intact and secure
	Check for ATCC Camera FPS and resolutions	Inspect network connections and verify stable communication	Perform a complete camera and system calibration
	Monitor for any false readings or missed classifications	Check camera lens and housing for dust, water, or debris	Test and calibrate the detection algorithms for correct vehicle classification

Device Type	Weekly	Monthly	Yearly
	Check all power, network, and data cables for integrity	Verify the synchronization of the system with NTP time	Replace any worn-out cables, connectors, or other components
	Check for Network status and ping the camera to check the delay	Verify that the system's overall operation is consistent and reliable	Clean and maintain internal system components, such as servers and switches
	Test for any system alerts or error messages in the logs		Check for power and network cable connections (Replace if required)
	Ensure the camera lens is free from dust, stains, water droplets, or smudges		
VASD	Is the camera lens focused and adjusted correctly?	Inspect for any physical damage to the VASD components (camera, radar, display)	Radar: Verify that the mounting bolts for the Radar unit is in good condition and free of corrosion
	Is the road stretch (effective area) visible in the camera?	VASD: Verify the display is working properly.	Display: Clean the display
	Is the camera lens free from dust, stains and smudges?	Is the LPU clean and free from dust	All mountings and clamps are free from rust
	Verify the captured images are in focus with a speed stamp	Check for Accuracy for 30 minutes/30-40 vehicles. Is the VASD accurate?	Tighten all mountings and clamps of camera display and radar
	Check for Network status and ping the camera to check the delay	Check radar functionality and mounting bolts for corrosion	Inspect the condition of cables, making sure they are free of exposed wires or wear
	Check radar functionality	Is image transmission clear and distortion-free?	No signs of rust or corrosion on the gantry (welds, joints etc.)
	Monitor captured data for accuracy	Ensure the display is working properly and visible	Check radar functionality and mounting bolts for corrosion
	Clean the camera lens and housing if required	Ensure that the LPU (Local Processing Unit) is clean and free from dust	Clean and calibrate radar for accuracy
	Check LPU for proper functioning	Test the radar for accurate speed detection	Ensure the VASD system is synchronized with NTP time
		Check the VASD system for proper synchronization with the overall traffic system	Clean and maintain internal components (servers, switches, cables)

Device Type	Weekly	Monthly	Yearly
		Test the radar for stability and no false detections	Are the cables in good condition and free of exposed wires.
VMS	Check if VMS is displaying the correct messages	The Surface of VMS is uniform and clean.	The surface of the VMS is uniform and clean.
	Check for Network status and ping the device to check the delay.	The lock, handle, positioning pin, door lock, etc. are not damaged, no oxidation.	The surface of the VMS unit is free from scratches, oxidation, damage, and deformation.
	Inspect the brightness and visibility of the message displayed	Inspect all physical parts of the VMS such as the casing, hinges, and seals	The lock, handle, positioning pin, door lock, etc. are not damaged, no oxidation; the function meets the requirements.
	Inspect for any warning lights or system alerts in the VMS system	Check for any corrosion on the VMS unit or its housing	The mounting hole of the box has no sliding teeth, paint, oxidation
	Inspect and test the display system for pixel clarity and responsiveness	Check for proper grounding of the VMS unit	The lock module, power supply, fan, and other screws are not loose, no leakage phenomenon; the terminal screw is not loose
		Inspect cables for signs of wear and tear	Warning, the grounding mark is correctly pasted, no missing stickers
		Check the lock module, power supply, and other screws for tightness	No signs of rust or corrosion on the gantry (welds, joints etc.)
			The cabinet power cord and data cable are connected without any defects.
MET	Weather data and format are proper	All Sensors working properly?	Corrosion on joints
	Check for Network status and ping the device to check the delay.	Clean all sensors and LPU.	Foundation damaged
ATMS Server	Checking server log files		
	Assessing hard disk space		

Device Type	Weekly	Monthly	Yearly
	Reading server logs for security alerts or evidence of computer hacking attempts		
	Updating critical service packs and software updates		
	Clean the dust		
	Verify all connections		
NVR	Clean the dust		
	Disk space management		
	Software updates		
	Verify all connections		
Video Wall	Clean the dust		
	Software updates		
	Verify all connections		
	All screen clear of any pixel issue		
Workstations	Clean the dust		
	Software updates		
	Verify all connections		
	Assessing hard disk space		
Network Switch	Clean the dust		
	Verify all connections		
	Check all cable marking		
ATCC Server	Checking server log files		
	Assessing hard disk space		
	Reading server logs for security alerts or evidence of computer hacking attempts		
	Updating critical service packs and software updates		
	Clean the dust		
	Verfiy all connections		
VIDS Server	Checking server log files		
	Assessing hard disk space		
	Reading server logs for security alerts or evidence of computer hacking attempts		

Device Type	Weekly	Monthly	Yearly
	Updating critical service packs and software updates		
	Clean the dust		
	Verify all connections		
Cables and wire		Are the cables in good condition and free of exposed wires	
		Are all cables connected correctly?	
		Is the Ping status ok for all equipment at this chainage	
Structure and Foundation		Structure: Any impact damage, signs of buckling or leaning?	
		Corrosion to components, particularly at welds and connections to the gantry beam, base plates/gussets	
		Warping or bending in the base plate?	
		Condition of coatings/paintwork	
		Footings: Movement or settlement of the footing	
		Anchor Bolts: Failed or missing holding down bolts	
		Achor Bolts: Washers missing or insufficiently covering the hole	
		Anchor Bolts: Nuts missing, not fully tightened or unevenly seated	
		Anchor Bolts: Corrosion to steel components	

Device Type	Weekly	Monthly	Yearly
		Anchor Bolts: Cracked, incomplete or missing mortar or grout under base plates	
RSU		RSU foundation: Any movement or damage in the foundation	
		RSU Foundation: Nut Bolts and Washer in place	
		RSU Cabinet: Any corrosion sign on the RSU Cabinet	
		RSU Cabinet: Water Ingress in the cabinet	
		RSU: Clean up the dust using blower.	
		RSU: Any missing equipment (UPS, Batteries, Moxa switch, SMPS etc.)	
		Check input and output voltages of all power supply	
		RSU door limit switch and relay working properly	

PART-7 WORK ZONE TRAFFIC MANAGEMENT PLAN AND SAFETY DURING MAINTENANCE ACTIVITIES

7.1 Health Safety and Environmental Policy

Each contractor must prepare a written policy statement addressing the environment, safety, and health of construction/building workers, and submit it for approval by the competent authority, in accordance with safety standards. The policy should reflect the contractor's intention and commitment to ensuring the well-being of workers, and it should be considered when making decisions related to plant, machinery, equipment, materials, and the placement of workers on site.

The contractor is required to revise the policy as often as necessary to maintain its relevance and effectiveness. A copy of the policy must be prominently displayed at conspicuous locations on the construction site, in both English and the local language, as well as in the language understood by the majority of the construction workers.

7.2 Scope of safety

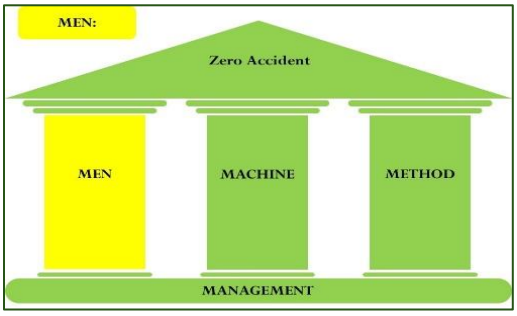
This document outlines the minimum Health, Safety, and Environmental (HSE) requirements for work to be performed by Contractors or Service Providers at the SITE.

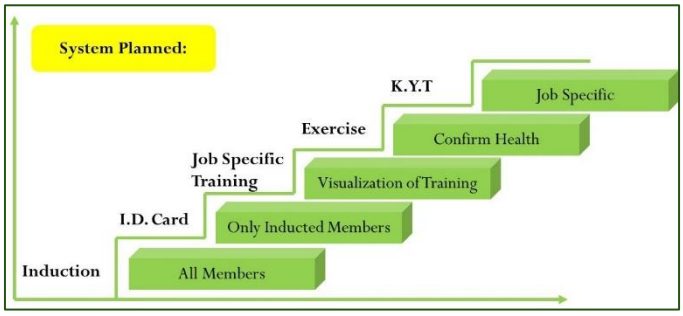
The requirements specified in this document are intended to protect both SITE and Contractor personnel from hazards associated with the work, as well as to prevent accidental damage to property or the environment.

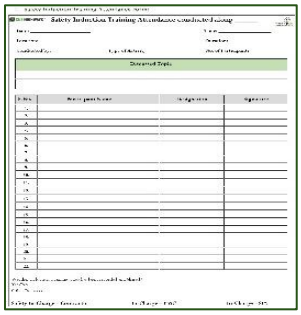
Contractors are required to comply with all applicable statutory regulations related to health, safety, environment, construction, and contractual work.

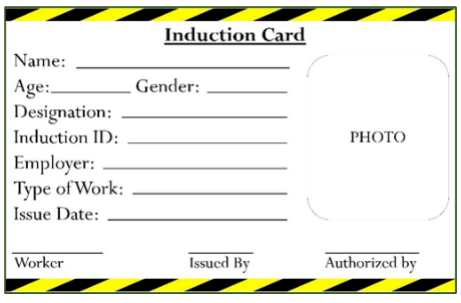
7.3 4 M CONCEPT (SYSTEM)

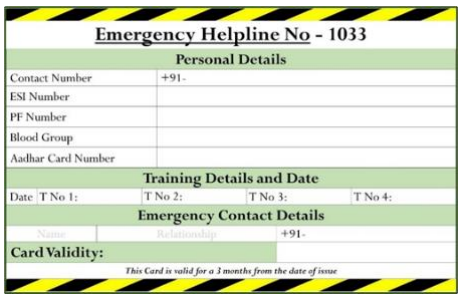
I. Men:

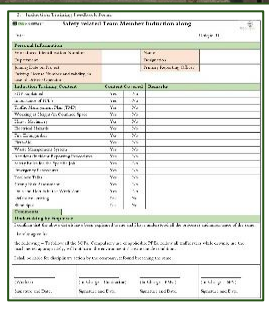


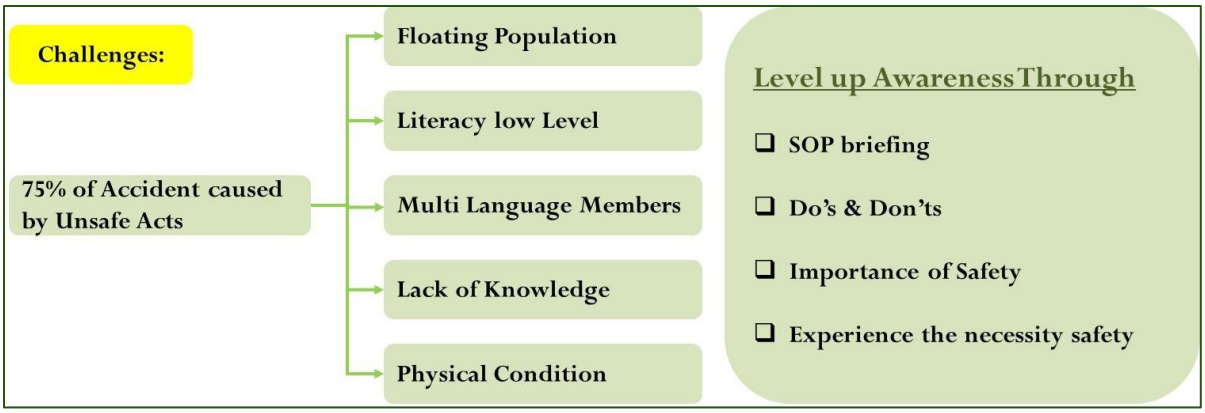




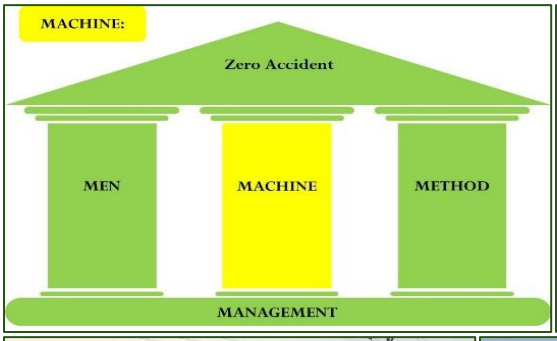


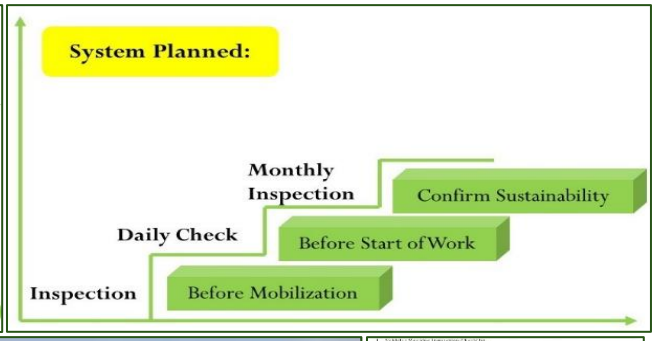


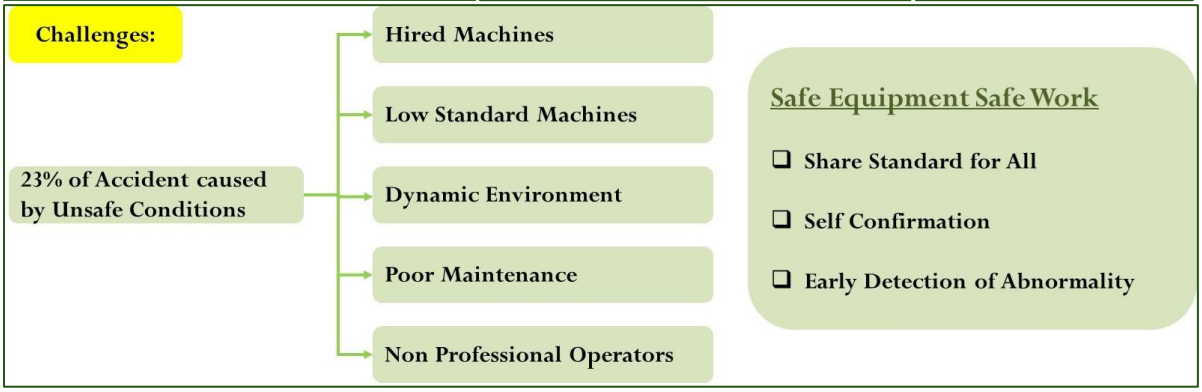




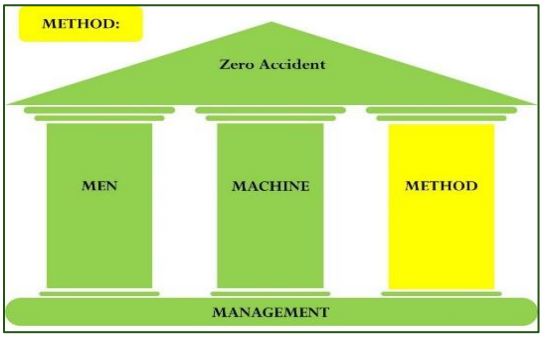
II. Machine:

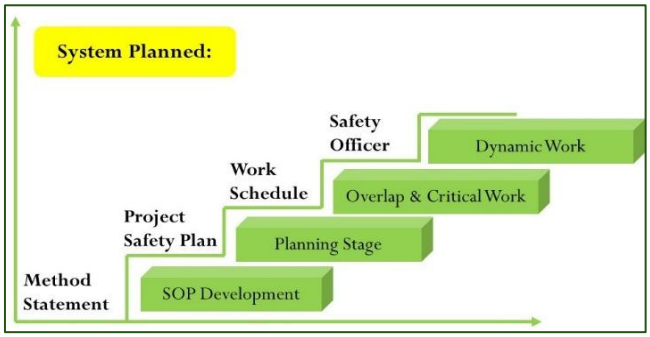


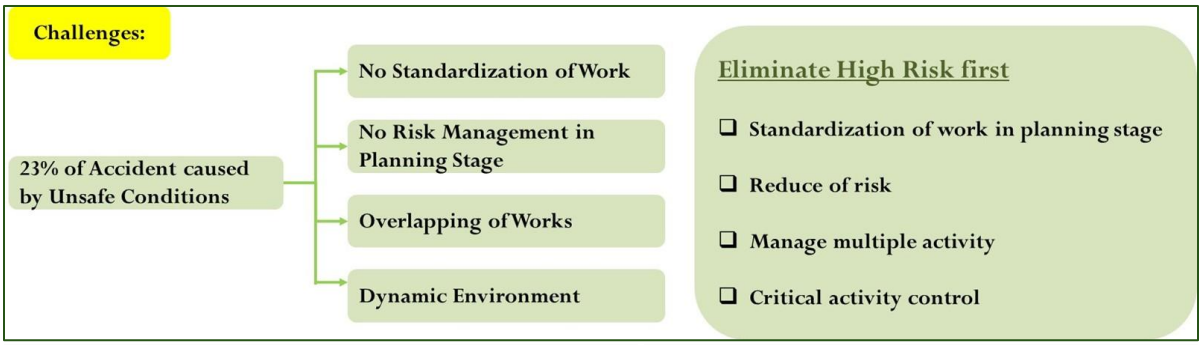


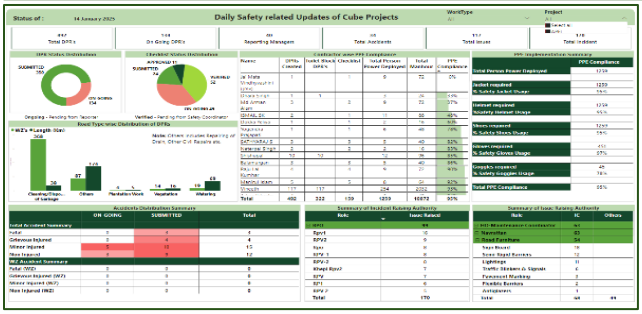


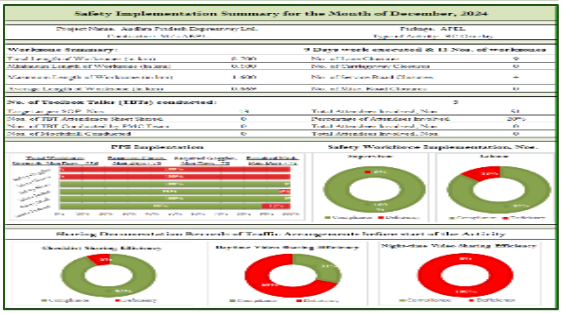
III. Method:



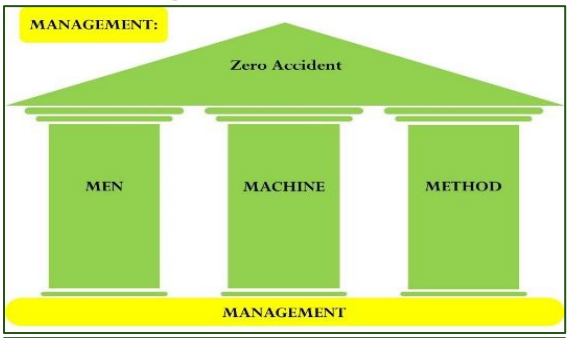


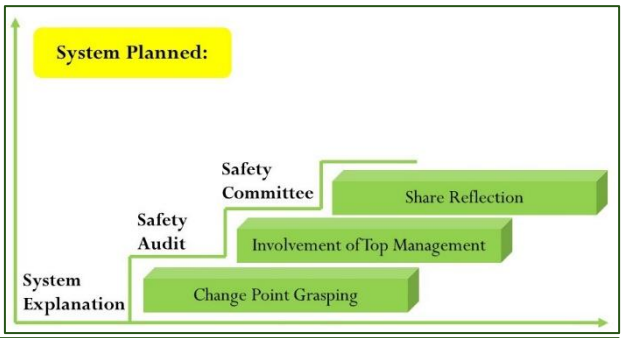


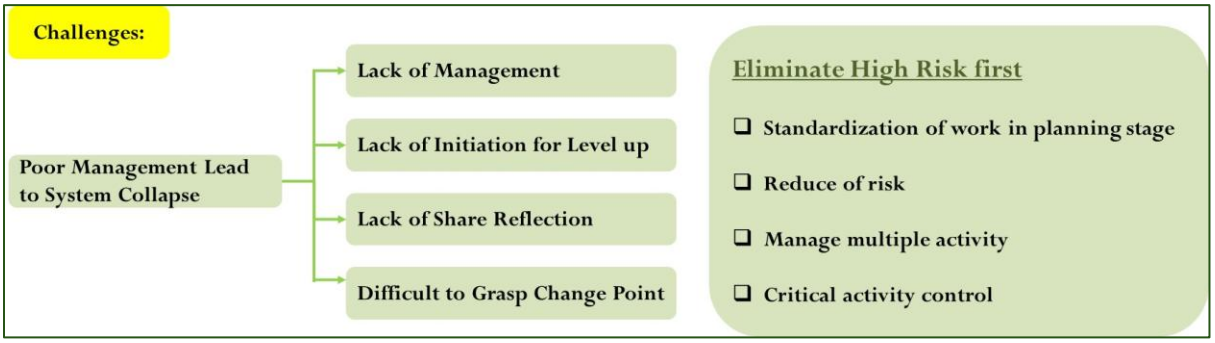




IV. Management:







7.4 Safety During Maintenance Operations

Implementing safety measures is crucial to protect both the maintenance crew and road users from potential hazards. Proper safety protocols minimize the risk of accidents during maintenance operations.

I. Work Zone Safety Management

- All maintenance activities shall be carried out in accordance with the work zone safety protocols prescribed in IRC:SP:55 and referenced standards.

- Clearly define and barricade the maintenance area using approved barricading materials to restrict unauthorized entry and maintain separation between traffic and work zones.
- Ensure adequate signage, warning boards, and cones are in place to alert road users well in advance of the maintenance activity.
- Shadow vehicles equipped with retro-reflective signage and flashing beacons must be deployed upstream of the work area to absorb impact in case of vehicular intrusion.

II. Provision of Safety Equipment

- All maintenance personnel must be provided with and shall wear mandatory Personal Protective Equipment (PPE), which includes but is not limited to:
    - Safety helmets
    - High-visibility vests/jackets
    - Safety gloves
    - Protective eyewear (if applicable)
    - Safety boots with steel toe caps
- Additional safety accessories such as harnesses, fall arrest systems, or ear protection shall be used as per the specific nature of the work.

III. Training and Awareness Programs

- Conduct pre-job safety briefings (Toolbox Talks) prior to the commencement of each maintenance activity.
- Regularly organize structured safety training sessions for all crew members covering:
    - Proper use and maintenance of PPE
    - Identification of work zone hazards
    - Emergency response procedures
    - Communication and signalling methods within the work zone
- Maintain a record of participation in all safety training programs for audit and compliance purposes.

IV. Continuous Safety Enforcement and Monitoring

- Appoint a dedicated Safety Officer or designate a responsible supervisor to oversee the implementation of safety protocols on-site.
- Conduct periodic safety audits and inspections during the maintenance operation to verify compliance and rectify any lapses immediately.
- Reinforce safety awareness through visual aids, checklists, and signage within the maintenance zone.
- Report all near-misses, unsafe conditions, or incidents to the site management and record them in the safety log for future learning and preventive action.

7.5 Safety & Health Expectations / Requirements

I. Basic Safety Expectations / Requirements

- The Contractor shall assume full and independent responsibility for the safety and health of its employees while working at the site. The Contractor must also comply with all applicable laws, Indian standards, and requirements related to safety and health.
- The Contractor shall not expose site employees to any unsafe acts or conditions that could reasonably be predicted as hazardous or unsafe, or that would violate statutory provisions and site safety procedures.
- Contractors are required to conduct documented self-inspections of their work operations, facilities, and equipment at least once per day on construction projects. Written records of all safety and health inspections must be maintained and submitted to the site on a daily basis, along with findings and closure reports.
- Contractors must attend a project-specific or job orientation meeting organized by the site Project Coordinator. This meeting will familiarize the contractor with site-specific safety and health requirements.
- The Contractor's employees assigned to work at the site are required to attend an HSE orientation before the start of work. During this session, environment, safety, and health requirements and rules

will be discussed. The orientation will be coordinated by the site Project Coordinator and conducted by the HSE Team.

- If a Contractor hires subcontractors, the hiring Contractor will be responsible for communicating all requirements outlined in this document to the subcontractor.
- Contractors must inform the site Project Coordinator as soon as possible, and within 24 hours, of any accidents that occur at the site involving contractor operations. Contractors are expected to participate in any site-led investigations related to such accidents.
- Contractors must ensure, to the satisfaction of the site, that their employees assigned to the site are physically fit and able to safely perform their designated tasks.

7.6 Work at Height

I. Fall Protection Requirements

To ensure safety during high-risk work at height, the following steps must be followed:

1. **Integrate Fall Protection into the Safety Program** - Make fall protection a core part of your workplace Safety and Health Management System.
2. **Identify & Evaluate Hazards** - Assess the site and pinpoint fall hazards *before* allowing work to begin.
3. **Eliminate Hazards Where Possible** - Use engineering controls or design modifications to remove fall risks.
4. **Train Workers** - Educate employees on how to recognize fall hazards and properly use protective systems.
5. **Use Appropriate Equipment** - Ensure workers use:
    - Scaffolds
    - Elevated Working Platforms (with guardrails)
    - Ladders
    - Approved safety harnesses (preferably with double lanyards)
    - Safety nets or fall arrest systems as necessary
6. **Inspect Equipment Regularly** - Check all fall protection gear before and after each use to ensure it's in good condition.

II. Personal Fall Protection Systems

1. Full Body Harness & Fall Arrest Systems

Mandatory for any worker operating 6 feet (1.8 meters) or more above ground.

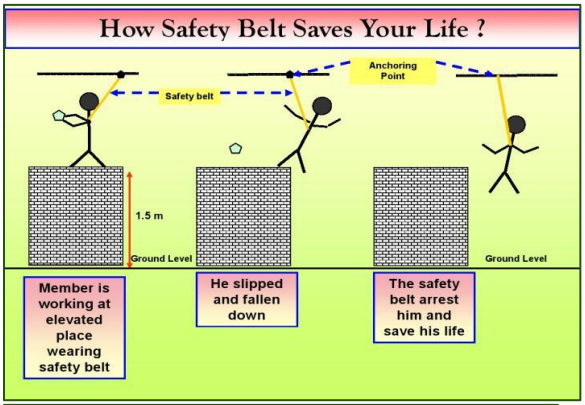
Key Requirements:

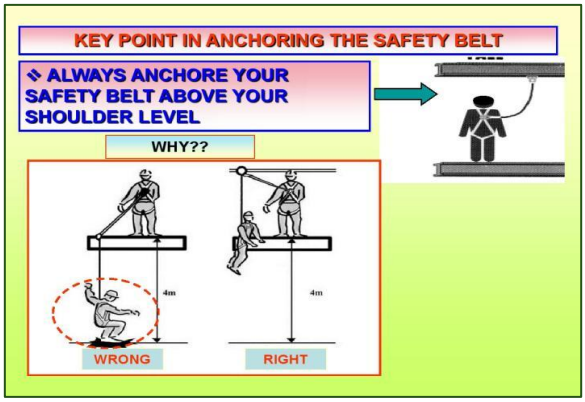
- **Anchorage Points**
    - Must be independent of any platform-supporting anchorage.
    - Must support at least 5,000 lbs (22.2 kN) per attached person.
- **Lanyards & Lifelines**
    - Must also have a minimum breaking strength of 5,000 lbs (22.2 kN).
- **System Components**
    - Full-body harness
    - Anchorage
    - Lifeline
    - Deceleration devices

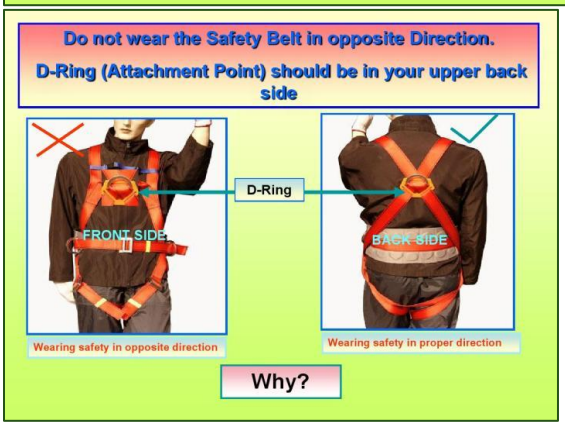
➢ **Performance Criteria for Fall Arrest Systems**

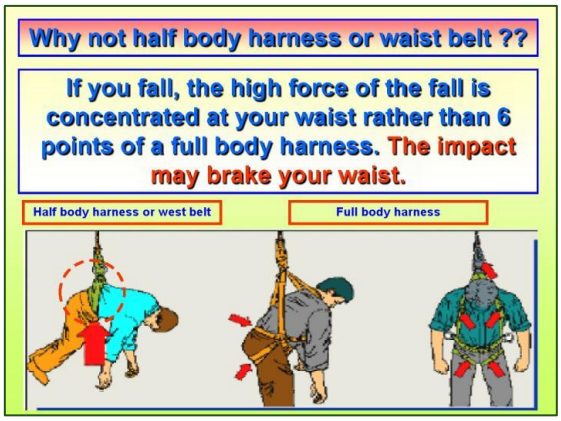
If a **personal fall arrest system** is used, ensure:

Criterion	Requirement
Max arresting force	≤ 900 lbs (4 kN) with safety belt, ≤ 1,800 lbs (8 kN) with body harness
Free fall distance	≤ 6 feet (1.8 m)
Deceleration distance	≤ 3.5 feet (1.07 m)
System strength	Must withstand **twice** the potential impact energy of an employee's free fall from a distance of 6 feet the permitted free fall distance (whichever is less)









III. Scaffolds:

(a) Minimum Safety Requirements:

To ensure worker safety when using scaffolding systems, the following minimum safety requirements must be strictly followed:

1. Erection by Skilled Workers Only

- Only trained and skilled personnel may erect scaffolding.
- All scaffold erection activities must be carried out under the direct supervision of a competent person.

2. Restricted Access During Erection

- The scaffold erection area must be barricaded to prevent unauthorized access.
- 'Do Not Use' caution signage must be clearly displayed on scaffolds that are incomplete, under construction, or found faulty.

3. Post-Erection Safety Check

- Upon completing the scaffold erection, a competent person must inspect the scaffold using a formal checklist to verify:
  - Structural integrity
  - Stability
- Only after certification of safety can personnel be permitted to use the scaffold.

4. Daily Inspections

- A competent person must inspect the scaffold daily before work begins.
- Inspections must be documented in a specified format.

5. Guardrail Systems are Mandatory

- All scaffolds and working platforms must be equipped with a guardrail system.
- Scaffolds without a proper working platform or guardrails are strictly prohibited.

7.7 Electrical Management & Hazard Control

(a) General Precautions

- Electricity is essential for operating machinery, lighting, and tools on road maintenance sites. Proper handling is crucial to prevent accidents.
- Follow the Lockout-Tagout (LOTO) procedure as per site-specific guidelines to prevent electrical hazards.

(b) Electrical Equipment and Installations

- Use distribution boards equipped with MCB (Miniature Circuit Breaker), ELCB (Earth Leakage Circuit Breaker), or RCCB (Residual Current Circuit Breaker).
- Ensure temporary electrical setups have ELCBs and that all portable tools are double-insulated and protected by an ELCB (30mA rating or lower) and MCB.

(c) Qualified Personnel

- Only trained electricians should handle electrical installations, repairs, and maintenance. They must use insulated tools and wear appropriate Personal Protective Equipment (PPE).

(d) Temporary Wiring

- Temporary wiring for lighting and power must comply with Indian Electricity Rules and be approved by the **Site Project Coordinator**.
- Use armoured or metal-sheathed cables to prevent damage.

(e) Special Locations

- In damp or confined areas (e.g., culverts or manholes), use portable lighting at a maximum of 24 volts or protected by ELCB and MCB.

(f) Underground Power Lines

- Before excavation or other ground-disturbing activities, confirm the location of underground power lines. Use insulated tools, gloves, and footwear if working near live lines.

(g) Weather Protection

- Ensure all electrical equipment is shielded from rain using weatherproof covers.

(h) Compliance

- Adhere to National Indian Electrical Codes for all installations. Enclose all current-carrying parts properly and ensure correct earthing.

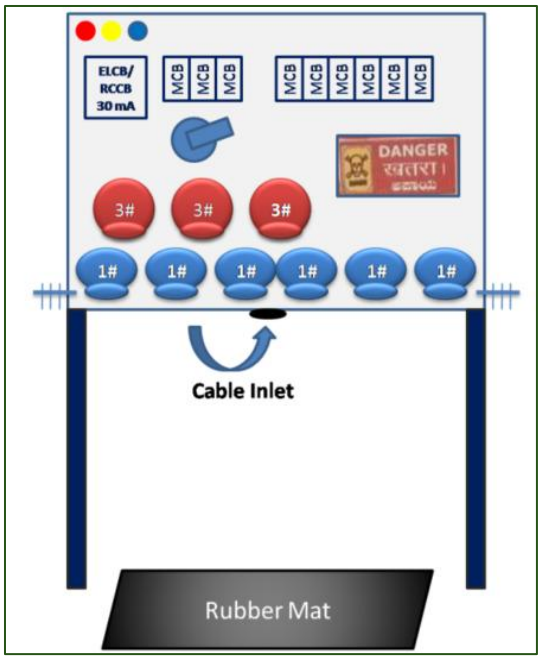
IV. Illumination of Work Areas

(a) Adequate Lighting

- Provide sufficient illumination in all work zones, including passageways, stairways, and ramps, to ensure visibility and worker safety.
- Use lighting that minimizes shadow and glare, particularly during night operations or work at heights, to reduce the risk of falls.

(b) Clearance from Overhead Lines

- Maintain minimum clearances when working near or under electrical lines:
  - 11 KV to 33 KV: 3 meters
  - 66 KV to 130 KV: 6 meters
  - Above 230 KV: 9 meters



(c) Fundamentals of Electrical Hazards

- **More than 3 mA:** Painful shock
- **More than 10 mA:** Muscle contraction ("no-let-go" danger)
- **More than 30 mA:** Lung paralysis (usually temporary)
- **More than 50 mA:** Possible ventricular fibrillation (heart dysfunction, usually fatal)
- **100 mA to 4 Amps:** Certain ventricular fibrillation (fatal)
- **Over 4 Amps:** Heart paralysis and severe burns (usually caused by voltages greater than 600 volts)

(d) Overhead Protection

- Every contractor must ensure that overhead protection is installed along the periphery of any building under construction that will be 15 meters or more in height upon completion.
- Safety nets or other appropriate means of overhead protection should be provided.
- The contractor must ensure that any areas exposed to the risk of falling materials, articles, or objects are roped off, cordoned off, or suitably guarded to prevent inadvertent entry by individuals other than authorized building workers.

8.1 Maintenance Module in NHAI ONE Application

The app for NHAI contractors and AI/IE to report and resolve maintenance-related issues on the highways Launched in September 2022 as TATPAR, which has now been integrated into NHAI ONE Application. The App Available on Android and iOS.

Roles and rights of users in the NHAI ONE application:

AE/IE	**Conduct joint inspections**
	Add quick defects
	Check ATR filled by contractor and verify defects
	Approve/reject EoT requests

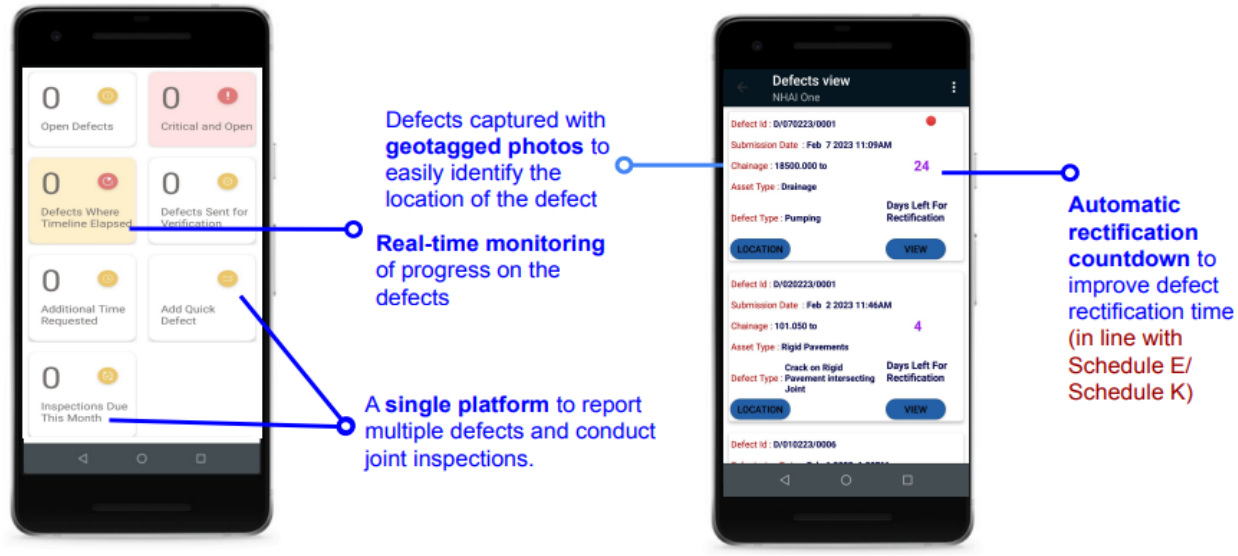
Contractor	**Conduct joint inspections**
	Track and rectify defects; submit ATR
	Request EOT when necessary

The objectives of developing the application include:

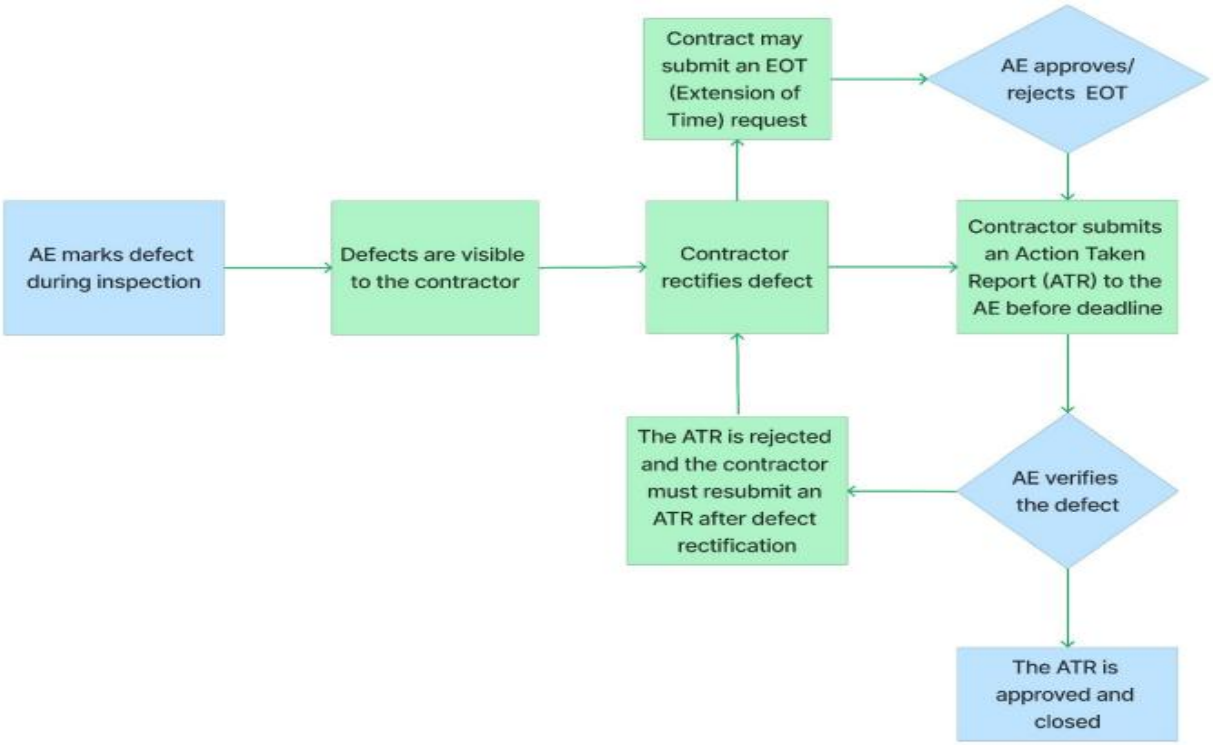
1. Regular Monitoring: All defects are notified by the Supervision Consultants on the App which can be viewed and acted upon by the Contractor Login.

2. Timeline adherence as per contract: The defect rectification timelines as per relevant provisions of the contract agreement
3. Transparency: An open and reliable platform for management to gain better insights into O&M of highway assets.
4. Optimal Decision Making: Using this robust data to enhance decision making resulting in better outcomes and cost optimisation.

Key features



Walkthrough of the defect rectification Process on the NHAI ONE Application



AE marks the defect

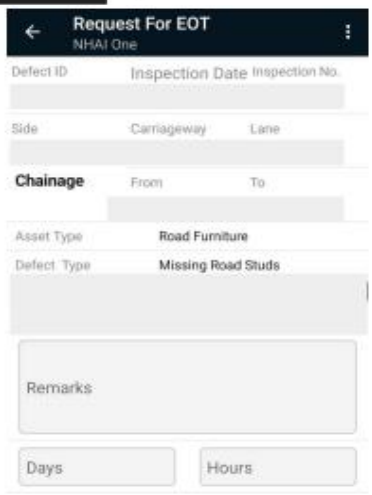
Defects are visible to the contractor on the dashboard

Contractor rectifies the defect and updates on the app with a picture before the deadline

AE verifies the defect and closes it

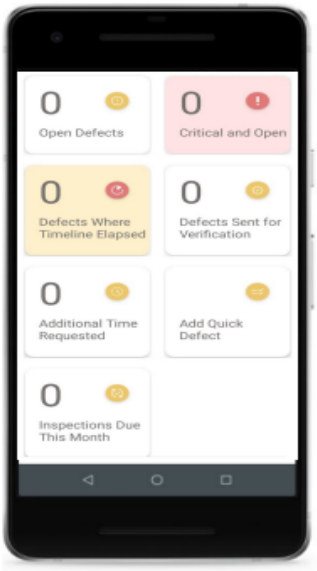
AE marks the defect

Defects are visible to the contractor on the dashboard



Contractor can also submit an EOT (time extension request) and the AE can approve or reject the request

Tracking of Defects



Open Defect – All defects which are pending to be resolved will show in this tile.
Critical and Open – This category shows defects marked as "Critical" by AE.
Defect Where Timeline Elapsed - This category shows those defects whose timeline is overdue.
Defect Sent for Verification - This category shows defects rectified by contractor and sent to the AE for verification.

Additional Time Requested - This category shows those defects which are requested for additional time by contractor.
Overdue Additional Time - This category shows those defects which are requested for additional time by still not rectified under approved timeline .
Inspection Due - All pending inspections shows in this tab which are conducted by AE (Joint Inspection).
Add Quick Defect - AEs and contractors both can add a quick defect n in this tile.

8.2 Bridge Inventory and Condition Rating System (BICRS)

8.2.1 SOP for use of BICRS

Uploading Data through NHAI ONE App

A. Inventory Data:

(i) Below Screen will appear as user login into the NHAI ONE Application.

(ii) Click on “Asset Details” as mentioned below:

(iii) After clicking in Asset Details, below screen will appear where user needs to select the UPC for which they need to make structure inventory:

(iv) After selecting the UPC, the details of past Registered structure will appear. User can check details of these structures or can add new structures details using “Add a Structure” button as mentioned below.

(v) The below screen will appear after clicking on Add a Structure, User needs to click in ‘Click to fetch the location as the start of the location in increasing way’. Fill the required details as mentioned below and click on ‘Submit’ button.

(vi) After clicking on Submit button the below screen will appear, user can check the details that are filled above and make changes if required. If no changes are required then user can click on ‘Save’ button as mentioned below.

(vii) After clicking on Save button below pop-up will appear. Click on ‘CLOSE’ option as it shows that your data is saved successfully.

Note: Once inventory data gets updated on NHAI ONE application, it will get auto reflected on Data Lake.

B. Inspection Data:
(i) To rate any structure the user need to click on ‘Rate Asset’ as mentioned below.

(ii) After clicking on Rate Asset, the below screen will appear where user needs to select the ‘UPC’ from the dropdown.

(iii) After selecting the UPC, inventory details of selected UPC will appear as mentioned below. Select View Details if you want to check the inventory details of that structure. If not then click on ‘CLICK TO RATE’ to rate the structure as marked below in screenshot.

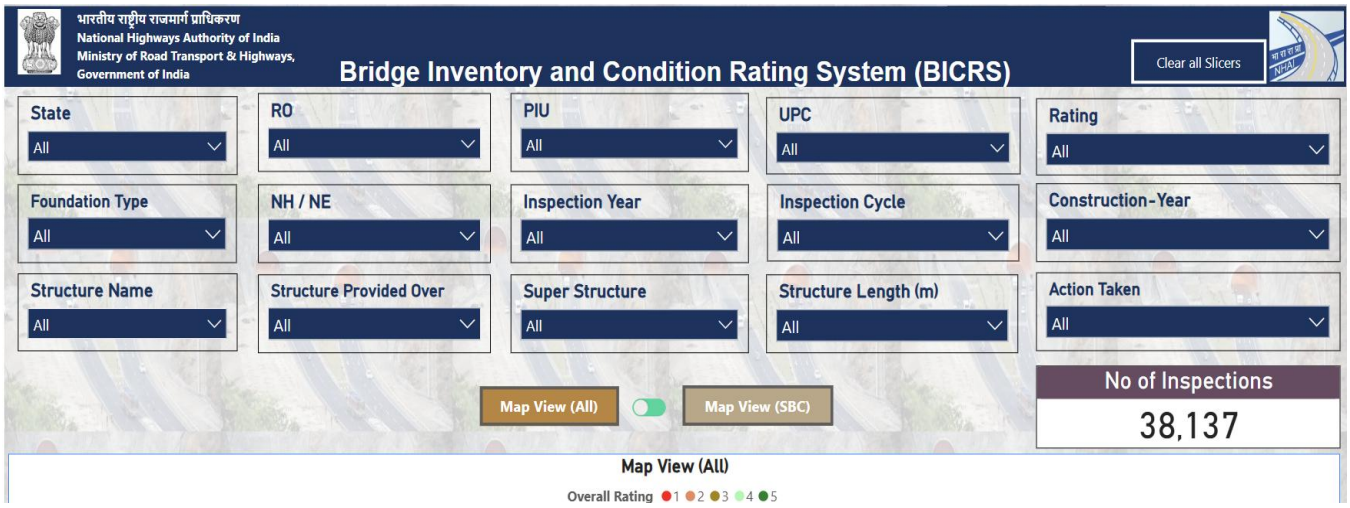
(iv) Rate the structure as per different criteria that is defined in the dropdown. After providing rating to all aspects, user need to click on ‘Submit’ button as mentioned below.

DataLake:

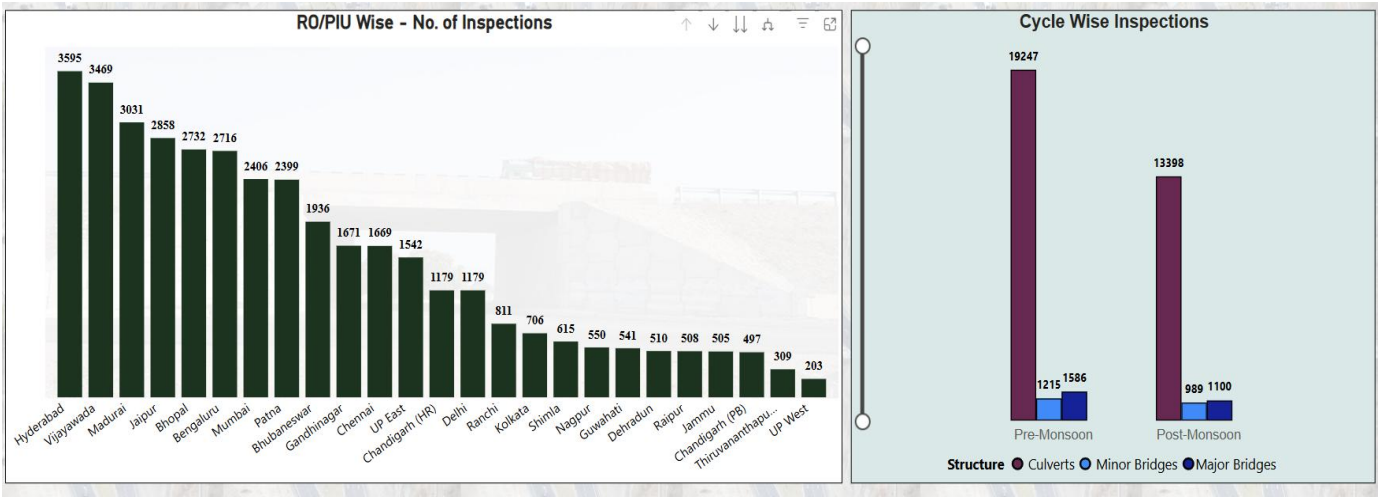
Inspection

5)

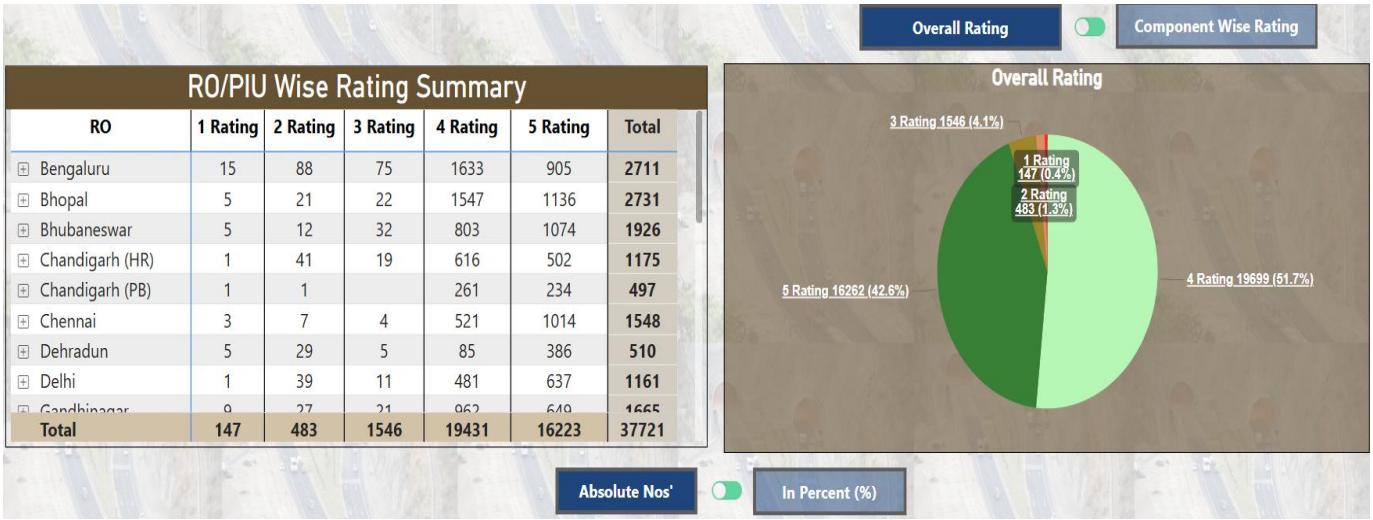
Dashboards for Monitoring



RO Wise Data and Cycle Wise Data



RO/PIU/Rating Summary



Component Wise distribution of rating and Project wise inspection details

Component Wise Distribution

Component Name	Rating-1	Rating-2	Rating-3	Rating-4	Rating-5	Rating-6	Rating-7	Total
Approach Slab	41	168	564	8790	23527	4321	234	**37557**
Bearing & Expansion Joint	18	69	348	7443	17964	11453	438	**37572**
Bed Block	19	89	135	4850	16298	15076	1119	**37533**
Crash Barrier / Railing / Parapet	28	71	127	6395	24040	6201	847	**37633**
Drainage Pipes / Spouts	39	103	631	13007	17223	6125	618	**37624**
Flooring	27	50	573	6939	24374	464	5405	**37720**
Masonry / Concrete	23	43	72	3383	11318	20729	1964	**37492**
RE Wall	16	139	292	10994	9563	16192	445	**37531**
Road Surface	35	63	167	5806	26955	3924	713	**37634**
Super Structure	17	126	134	9578	27027	565	146	**37564**
Training Prowork	31	94	208	3670	6065	27232	334	**37589**

Project Wise Number of Inspections

RO	PIU	UPC	Project Name	Structure Name	Construction Year	Over all Rating	No. of Inspections
Bengaluru	Bagalkot	N/08007/02001/KA	4 laning of Bijapur-Hungund Section of NH-13 from km 102.00 to km 202.00	Pedestrians Subway	2010	4	1
Bengaluru	Bagalkot	N/08007/02001/KA	4 laning of Bijapur-Hungund Section of NH-13 from km 102.00 to km 202.00	Pedestrians Subway	2010	5	3
Bengaluru	Bagalkot	N/08007/02001/KA	4 laning of Bijapur-Hungund Section of NH-13 from km 102.00 to km 202.00	PUP	2010	4	1
Bengaluru	Bagalkot	N/08007/02001/KA	4 laning of Bijapur-Hungund Section of NH-13 from km 102.00 to km 202.00	PUP	2010	5	7

RO Wise Rating Summary of Components

Rating-1 | Rating-2 | Rating-3 | Rating-4 | Rating-5 | Rating-6 | Rating-7

RO/PIU Wise Rating Summary across Components

RO	Approach Slab	Bearing & Expansion Joint	Bed Block	Crash Barrier / Railing / Parapet	Drainage Pipes / Spouts	Flooring	Masonry / Concrete	RE Wall	Road Surface	Super Structure	Training Prowork
⊞ Bengaluru	RO Bengaluru	2712	2704	2715	2716	2716	2716	2706	2716	2713	2715
⊞ Bhopal	2725	2728	2729	2731	2732	2732	2730	2723	2730	2722	2732
⊞ Bhubaneswar	1934	1936	1935	1936	1936	1936	1936	1935	1936	1935	1936
⊞ Chandigarh (HR)	1167	1169	1176	1176	1176	1179	1178	1169	1178	1164	1177
⊞ Chandigarh (PB)	494	495	497	496	497	497	497	497	497	496	497
⊞ Chennai	1665	1668	1668	1669	1667	1669	1666	1663	1669	1663	1666
⊞ Dehradun	503	506	503	508	509	510	509	500	509	502	510
⊞ Delhi	1176	1175	1175	1169	1170	1178	1177	1164	1177	1171	1179
Total	**37972**	**37988**	**37948**	**38049**	**38040**	**38136**	**37908**	**37946**	**38050**	**37978**	**38005**