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Efficient Bridge Management System: A Comprehensive Approach for Sustainability of Bridge

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KEYWORDS

Bridge, Bridge Management System, General Inventory & Condition Assessment.

ABSTRACT:

Introduction: In order to facilitate the movement of people and products, bridges are important parts of a country's infrastructure. For these assets to remain functioning and safe over time, sustainable maintenance and management are essential. The assessment, maintenance, and repair of bridges are all optimized thorough Bridge Management System (BMS).

Objectives: Assessing the bridge type then performing the general inventory and condition assessment of bridge.

Methods: Assessing the bridge type according to IRC Code Books. Then performing the general inventory of bridge components which is done through measurements and noting the components numbers and types. In the final stage noting the condition of each component of bridge and making the remarks accordingly.

Results: For the long-term management of bridge infrastructure, an effective bridge management system is required. BMS enables governments and organizations to make decisions, prioritize maintenance efforts, and increase the lifespan of crucial bridges by applying data-driven methodologies, ultimately resulting in safer and more dependable transportation networks with a lower environmental effect.

Conclusions: BMS has features that improve decision-making procedures for bridge maintenance and repair. Key components of this system include Condition Assessment, Risk Assessment, Maintenance Planning.

1. Introduction

A Bridge Management System (BMS) is a method for organizing the planning, monitoring, assessing, maintaining, and rehabilitating of bridge.

As per the Indian Railways Institute of Civil Engineering for the Indian Railways' engineers, the book "Bridge Inspection and Maintenance" served as a useful manual. The comprehensive information about maintaining different types of railroad bridges is provided in this book. The suggestions made by several groups that oversee bridge standards as well as the suggestions about LWR were also appropriately included.

While this was going on, IRICEN was able to gather a sizable number of real-world images of various bridge parts and activities related to their construction and maintenance. Numerous topics, including the mobile bridge inspection unit, the role of construction engineers in bridge maintenance, painting steel bridges, bearing inspection and maintenance, new NDT techniques, maintenance of composite girders, and many others, have been revised and updated with the most recent data[2].

Ensuring the efficiency and durability of these essential infrastructure components is key. In this paper, I'll give a general overview of the components of Bridges and the critical Distresses in these components which is going to help in Condition Assessment or Bridge Rating [4][5]. An outline of the main features and advantages of Bridge Management System:

- Importance of Bridges:

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Any transportation system would be incomplete without bridges, which allow for the swift passage of people and cargo over rivers, valleys, and other barriers. They are vulnerable to a variety of operating and environmental conditions, which over time may cause wear and damage. For public safety and economic growth, bridge reliability must be maintained [7].

- Purpose of a Bridge Management System:

A bridge management system is made to make it easier for engineers to access bridges. Its principal objective is to give decision-makers the resources and information they need to make well-informed decisions about bridge maintenance, repair, and replacement. By doing this, it maximizes resource allocation and prolongs the useful life of bridges [7].

- Key Components of a BMS:

A typical Bridge Management System consists of several key components:

a. Data collection and inventory: Compiling comprehensive data on each bridge, including its design, age, condition, and traffic load.

b. Condition Assessment: Bridge structural integrity and safety are evaluated through routine inspections and assessments of the bridges' condition. Defect detection and maintenance needs prioritization are part of this process[6][7].

c. Efficiency modelling: Using gathered data to forecast future bridge performance based on various situations and scenarios.

d. Assessment of risk: Analysing the possible hazards connected to each bridge, such as the repercussions of failure.

e. Maintenance and Rehabilitation Strategies: Cost-effective maintenance and rehabilitation solutions for bridges are being developed to increase their lifespan.

- Benefits of a BMS:

A bridge management system's implementation has the following advantages:

a. Improved Safety: Timely maintenance and routine inspections lower the possibility of bridge failures, improving public safety [2][3].

b. Cost-Savings: Engineers may extend the lifespan of bridges and prevent pricey repairs or replacements by giving maintenance and rehabilitation activities top priority [1][3][7].

c. Enhanced Resource Allocation: By concentrating on urgent requirements and tackling the most vulnerable bridges first, BMS assists engineers in allocating resources effectively.

d. Improved Asset Longevity: Bridges can be used for decades to transport people and goods thanks to proper upkeep and restoration.

e. Data-Driven Decision-Making: BMS offers data and insights that help engineers make well-informed choices that provide better results.

f. Safety and Transparency: It improves accountability and transparency in bridge management while assisting agencies in meeting their regulatory responsibilities.

Aim of the Study

Assessing a bridge according to its distresses involves evaluating various signs of deterioration, damage, or wear and tear to determine the bridge's condition and safety. Bridge distresses can be categorized into several types, including structural distresses, functional distresses, and aesthetic distresses.

2. Objectives

The initial work is to categorise the bridge type. After categorising the bridge, the next work is about noting the general inventory. The general inventory includes the bridge length, number of spans, type of superstructure, road name or location of bridge.

Then need to assess the different components of bridge and categorising each component according to its risk factor. To assess each component of bridge and noting the distress in each and finalizing the condition of bridge by assessing all the components and its distress [2].

The main objective is always to assure the security of all bridge users, including vehicles, pedestrians, and cycling.

This will help in the management of bridge assets, including their age, maintenance history, and physical state and will make long-term planning for bridge maintenance, repair, and replacement easier. To

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providing a clear understanding of the condition and maintenance needs of each bridge there should be a regular monitoring of bridges to access the performance over time [3].

3. Theoretical Background

Delegation of Bridge

Our infrastructure is not complete without bridges, and they are essential to many facets of society. The significance of bridges is demonstrated by the following major points:

Figure 1: Front view of a Bridge

Figure 2: Side view of a Bridge

Connectivity: Bridges facilitate the flow of people, products, and services by linking communities and regions together. They facilitate movement and transportation by crossing natural barriers like rivers, valleys, and canyons [4].

Economic Development: Bridges facilitate the effective flow of commodities and services, which is essential for economic development. They make it simpler for enterprises to reach markets and customers by lowering transportation expenses and trip times [4].

Tourism: Beautiful bridges themselves can attract travellers. They provide amazing views and frequently serve as landmarks, bringing in tourists and boosting the local economy.

Cultural and Historical Significance: Many bridges are important historically and culturally. They might be works of art in architecture or maintain historical tales. Such bridge maintenance and repair are crucial for protecting cultural heritage.

A Range of Bridges

Bridges are classified in 3 categories according to its length-

1. Small (= < 30 m)
2. Minor (= < 60 m)
3. Major (> 60 m)

Classification of Bridge according to Types-

1. Solid Slab Bridge
2. Girder Bridge
3. Arch Bridge
4. Suspension Bridge
5. Cable Stayed Bridge
6. Truss Bridge
7. Cantilever Bridge
8. Viaduct
9. Box Cell Bridge
10. Bailey Bridge

Figure 3: Solid Slab Bridge (SH 66 – Bhopal)

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Figure 4: Girder Bridge (SH 63_3 – Bhopal)

Figure 5: Steel Girder (SH 63_1 – Sagar)

Figure 6: Arch Bridge (SH 60 – Bhopal)

Figure 7: Canakkale Bridge Turkey (@google)

Figure 8: Cable Stayed Bridge (Kota @google)

Figure 9: Truss Bridge (Sahpura @google)

Figure 10: Cantilever Bridge (@google)

Figure 11: Viaduct (@google)

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Figure 12: Single Cell Box Bridge (SH 63 – Sagar)

Figure 13: Multi Cell Box Bridge (SH 63 – Sagar)

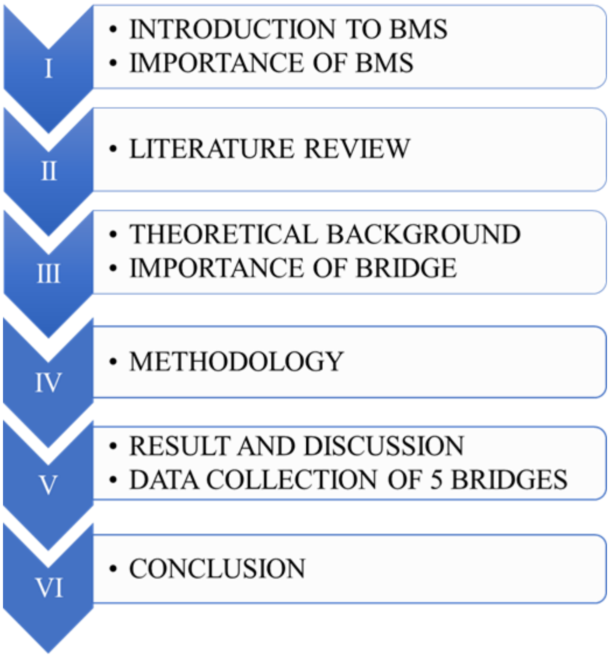
Figure 14: Bailey Bridge (@google)

The above-mentioned bridges with photographs are the types of bridges in which some of them are taken from google and others surveyed by me.

4. Methodology

The word "methodology" in the context of a thesis or research paper refers to the systematic approach or framework that a researcher employs to carry out their study, collect data, and analyse information.

Bridge Management System (BMS) deals with complete inventory and condition details of the bridge. The bridge condition is being determined accordingly by the condition state of each component and overall rating is being provide by seeing the severity of distress in bridge components and always keeping in mind the safety of public who is using this bridge.



The above-mentioned methodology is going to be followed in this paper. I am going to compare 5 bridges with its inventory details and condition states and going to compare the difference in results. All these bridges are surveyed with complete data and photographs of each component of the bridge with its distress is going to be illustrated.

5. Result and Discussion

Here I am going to illustrate the 5 bridges which I have surveyed and data collected accordingly. All these bridges fall under State Highway Roads of Madhya Pradesh under MPRDC. The bridges fall under Narmadapuram Division with Road Name SH 67_3.

All these 5 Bridges are mentioned with its location i.e., longitude and latitude and Inventory and Condition State with all important Photographs.

Bridge Components

The safe passage of vehicles, pedestrians, and other types of transportation is supported by the complex structures known as bridges, which are made up of numerous parts that all operate together. Bridges aid in boosting network efficiency, decreasing collision domains, and raising performance. The following are some typical bridge

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components, though these might vary based on the type of bridge and its design:

Figure 15: Primary Bridge Components

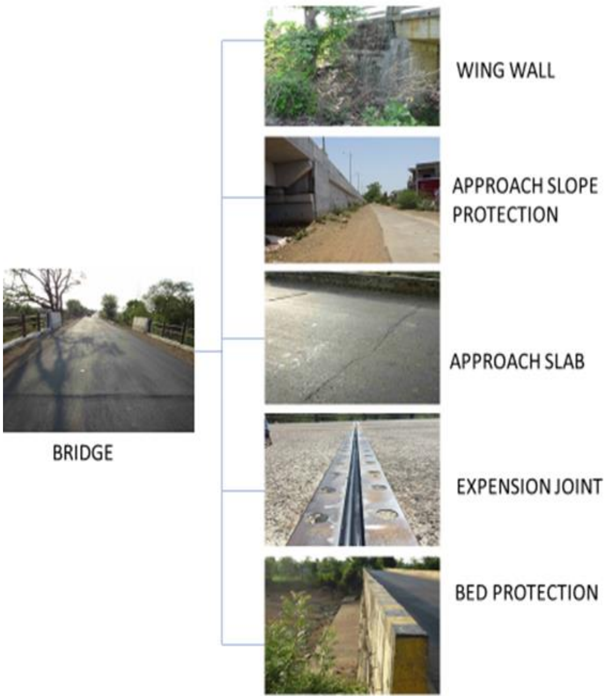

Figure 16: Secondary Bridge Components

These are some of the primary & secondary (as displayed in Fig. 15 & 16) components of a typical bridge. The design and composition of these components can vary significantly depending on the type of bridge (e.g., beam, arch, suspension, cable-stayed) and its intended use. Engineers carefully consider various factors, including environmental conditions, traffic loads, and location, when designing and constructing bridges to ensure their safety and functionality.

The Tertiary Elements

Drainage systems: Water collection on the bridge deck can be avoided with proper drainage. To keep water from getting on the bridge structure, drainage systems including gutters, scuppers, and downspouts are used.

Lighting and Signage: Lighting is essential for maintaining visibility on the bridge, particularly at night. Users of bridges are given direction and safety information through signage, such as traffic signs and lane markings.

Architectural features and aesthetics: This may be added to the bridge, depending on where it is located and what it is intended to do, to improve its appearance and mix in with the surroundings.

Box Cell Bridge

A box cell bridge is a form of bridge structure that consists of a square or rectangular tunnel or culvert made of concrete or steel that is used to carry materials, such as water, underneath a road or other transportation infrastructure. Box culvert bridges are commonly used in both urban and rural settings to facilitate transportation and manage water flow.

Here are some key features and characteristics of box culvert bridges:

Design: As opposed to circular culverts, which are spherical, box bridges are often rectangular or square in design.

Materials: They are made of steel or reinforced concrete, which makes them strong and able to endure enormous weights and extreme environmental conditions.

Applications: Box cell bridges have many uses, such as stormwater and drainage conduits, pedestrian walkways, and traffic and railroad crossings.

Size: Box culverts come in various sizes, depending on the specific needs of the project.

Installation: Box culverts are typically precast off-site and then transported and installed on-site. They are designed to be sturdy and capable of supporting the loads placed upon them (as seen in Fig. 17 & 18).

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Box cell bridges are a crucial part of contemporary infrastructure since they address both drainage and transportation issues. They are an essential component of civil engineering projects since they are made to be durable and long-lasting.

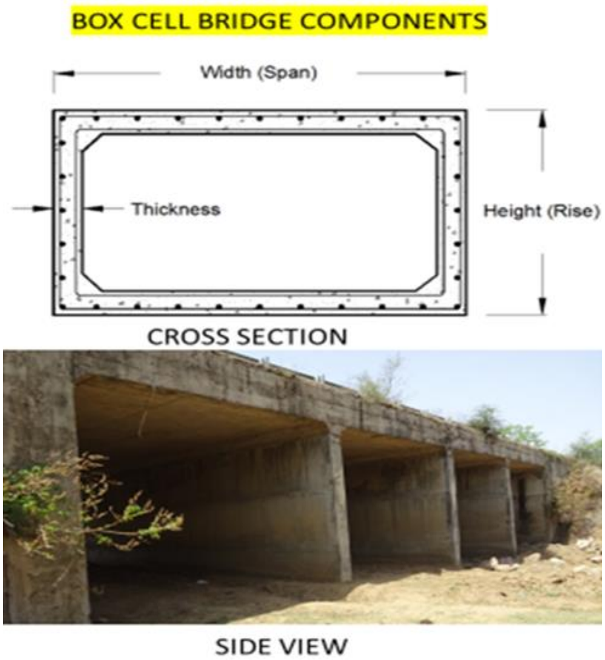

Figure 17: Cross Section and Side View

Figure 18: Box Cell Bridge Components

Major Distress in Bridge

Impact Damage: Impact damage is the damage or destruction a sudden force or collision causes to a material, structure, or object.

Spalling: Spalling is a term used to describe the breaking or chipping of material, typically concrete or masonry, into small fragments or flakes. It occurs when the surface of the material undergoes damage and begins to break apart.

Exposed Rebars: Reinforcing steel bars used in reinforced concrete constructions that are visible on the concrete's surface are referred to as exposed rebars.

Cracks: Cracking often refers to the formation of tiny breaks or splits in a bridge's structural elements. The safety and structural integrity of the bridge may be seriously impacted by these cracks, which can develop for a number of reasons.

Voids/Honeycombing: Refer to empty spaces or gaps within the concrete structure of a bridge. These voids can occur when there is insufficient consolidation or compaction of the concrete during the pouring and curing process.

Abrasion: Erosion caused by the abrasive impact of external forces or natural pressures on the bridge's structural elements, such as its foundation, piers, abutments, or even the bridge deck.

Scaling: Scaling often refers to a process where the surface of a bridge, particularly the materials used in its construction, deteriorates over time due to various environmental conditions and factors and develops cracks, flakes, or other types of damage.

Deflection: The degree of bending or deformation experienced by a bridge's structure under different loads, including the weight of passing cars and people as well as changes in wind and weather.

Bulging: A bridge structural problem where a portion of the structure, such as a support pillar or a segment of the deck, extends or swells beyond its intended or original shape.

Scouring: The erosion of soil around a bridge foundation (piers and abutments) is known as scouring.

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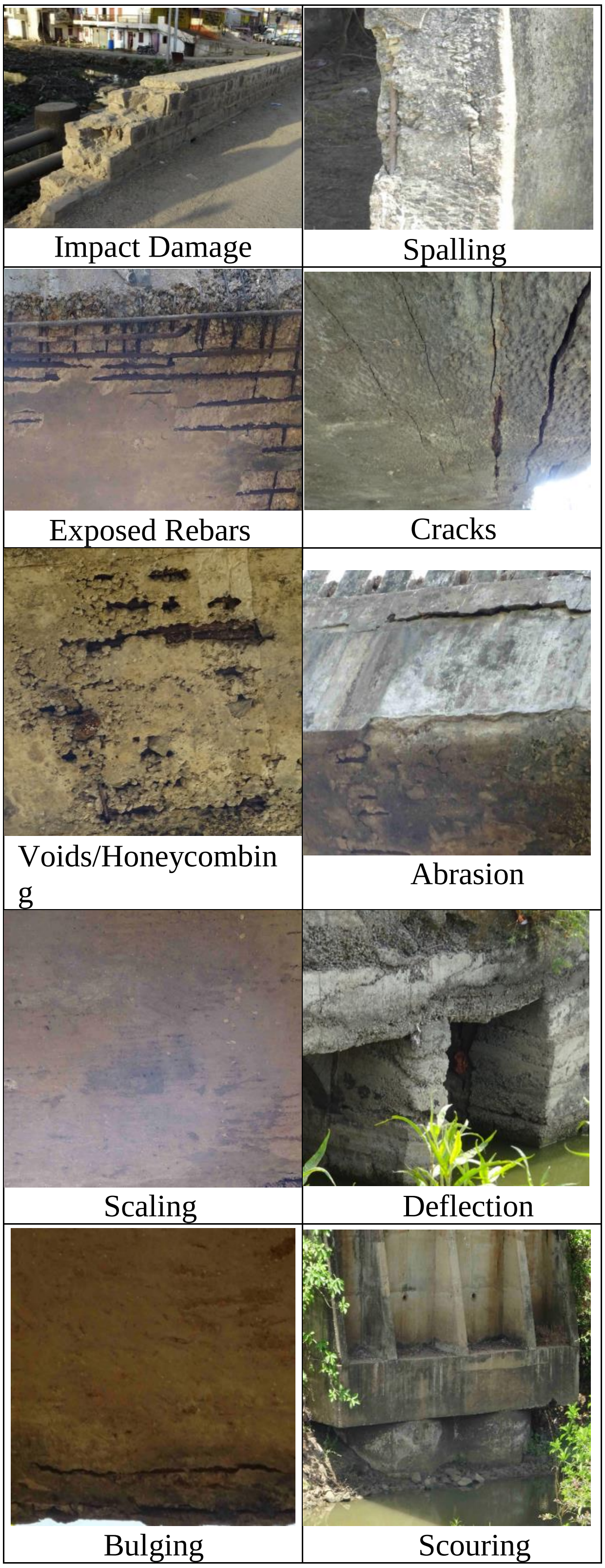

Figure 19: Major Distresses in Bridge

Bridge Details

Bridge No.: 01

Division: Narmadapuram

Road No.: SH 67_3

Road Name: Shahpur - Timarni

Latitude: 22.709033

Longitude: 78.210294

Types of Bridge: Solid Slab

No. of Spans: 1

Bridge Length: 6.5 m

Details of Distress: Significant spalling, Bulging and the exposure of reinforcement have been noticed on the underside of the bridge's deck slab. Masonry deterioration has also been observed in the substructure. Impact Damage in Handrails (as mentioned in table 1).

Figure 20: Front View

Figure 21: Side View

Figure 22: Bulging in Deck

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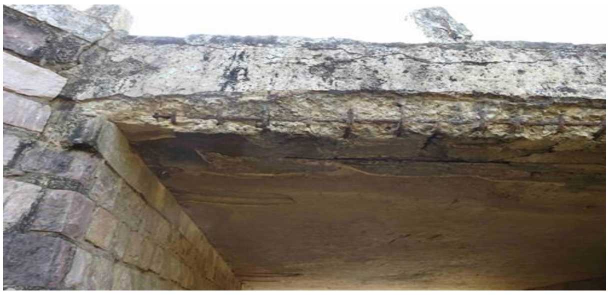

Figure 23: Exposed Rebars in Deck

Figure 24: Crack in Deck

Figure 25: Crack in Abutment Cap

Figure 26: Impact Damage on Handrails

Bridge No.: 02

Division: Narmadapuram

Road No.: SH 67_3

Road Name: Shahpur - Timarni

Latitude: 22.697788

Longitude: 78.166318

Types of Bridge: Solid Slab

No. of Spans: 4

Bridge Length: 36 m

Details of Distress: Severe spalling, Scaling and the exposure of steel and rusting have been noticed on bridge's deck slab. Masonry deterioration and vegetation growth has been observed in the substructure. Spalling and Cracks in Handrails has been observed (as mentioned in table 2).

Figure 27: Front View

Figure 28: Side View

Figure 29: Scaling in Deck

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Figure 30: Exposed Rebars in Deck


Figure 31: Spalling in Deck and Pier Cap


Figure 32: Vegetation Growth in Substructure


Figure 33: Crack in Handrails

Bridge No.: 03

Division: Narmadapuram

Road No.: SH 67_3

Road Name: Shahpur - Timarni

Latitude: 22.708064

Longitude: 77.826413

Types of Bridge: Box Cell

No. of Cells: 2

Bridge Length: 7 m

Details of Distress: Rebars in the deck, web, and bottom slab are exposed and rusted. Web has enormous cracks. There has been noticeable spalling all around the cell. Bulging has been seen at the Deck corner. There are exposed rebars and spalling all across the cell (as mentioned in table 3).


Figure 34: Front View


Figure 35: Side View

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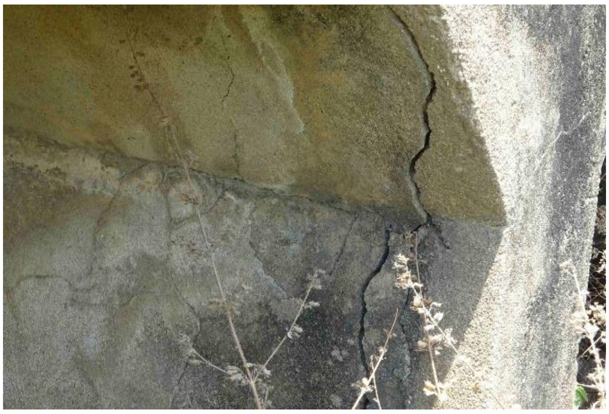

Figure 36: Crack in Web

Figure 37: Exposed Rebars in Deck

Figure 38: Exposed Rebars in Bottom Slab

Figure 39: Spalling & Exposed Rebars in Web

Figure 40: Exposed Rebars in Web

Bridge No.: 04

Division: Narmadapuram

Road No.: SH 67_3

Road Name: Shahpur - Timarni

Latitude: 22.691457

Longitude: 78.132862

Types of Bridge: Box Cell

No. of Cells: 11

Bridge Length: 45 m

Details of Distress: Spalling and exposed rebar have been found throughout the cells. The bridge's components are all severely damaged. Significant distress is being carried by the webs and haunches. Growth of the vegetation has also been seen (as mentioned in table 4).

Figure 41: Side View

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Figure 42: Spalling & Exposed Rebars in **Web**

Figure 43: Spalling & Exposed Rebars in Web

Figure 44: Exposed Rebars in Deck

Figure 45: Exposed Rebars in Bottom Slab

Figure 46: Spalling & Exposed Rebars in Web

Figure 47: Vegetation Growth in Web

Bridge No.: 05

Division: Narmadapuram

Road No.: SH 67_3

Road Name: Shahpur - Timarni

Latitude: 22.710082

Longitude: 77.850791

Types of Bridge: Arch

No. of Spans: 2

Bridge Length: 6.20 m

Details of Distress: There has been noticeable vegetation growth all over the bridge. There has been brick spalling. With Split and Spall, mortar breakdown has been seen. Both Spans have seen a crack in the centre of the Arch Deck. Bricks under bed protection have been observed to weather and crumble mortar (mentioned in table 5 below).

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Figure 48: Front View


Figure 49: Side View & Vegetation Growth


Figure 50: Spalling of Bricks in Deck


Figure 51: Crack in the Centre of Deck


Figure 52: Mortar Break down in Substructure


Figure 53: Split Spall in Wing Wall


Figure 54: Weathering in Bed Protection

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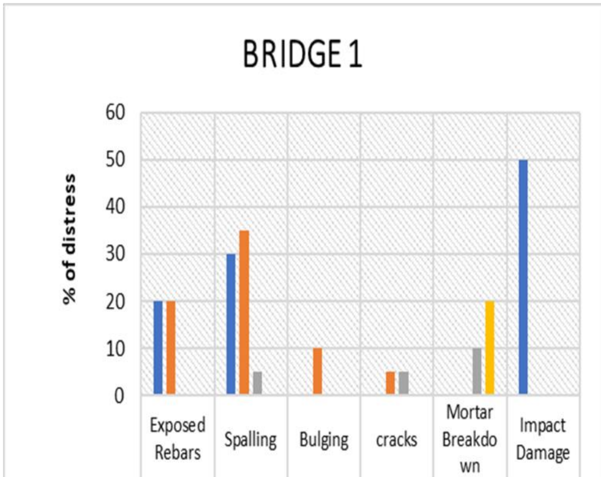
Comparing All the Components By Their Distress

In the chart below each component of bridge is mentioned with the percentage of distress. The chart for all 5 bridges is mentioned to compare the type of distress in each component of the bridges. And to observe the severity of distress in the bridge and its components.

Table 1: Distress % distribution of Bridge 1

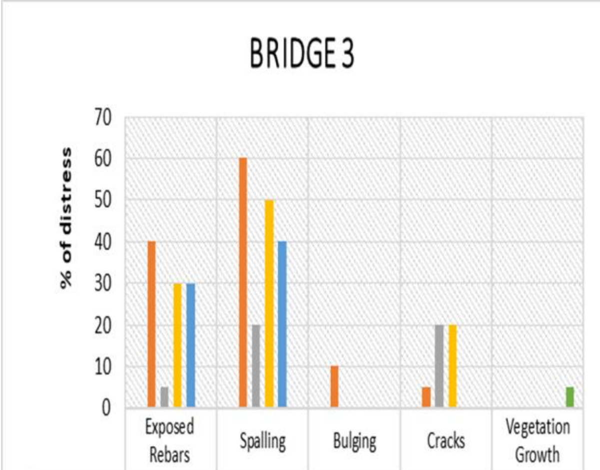


	Exposed Rebars	Spalling	Bulging	cracks	Mortar Breakdown	Impact Damage
Handrails	20	30	0	0	0	50
Deck	20	35	10	5	0	0
Abutments	0	5	0	5	10	0
Wing Walls	0	0	0	0	20	0

Table 2: Distress % distribution of Bridge 2

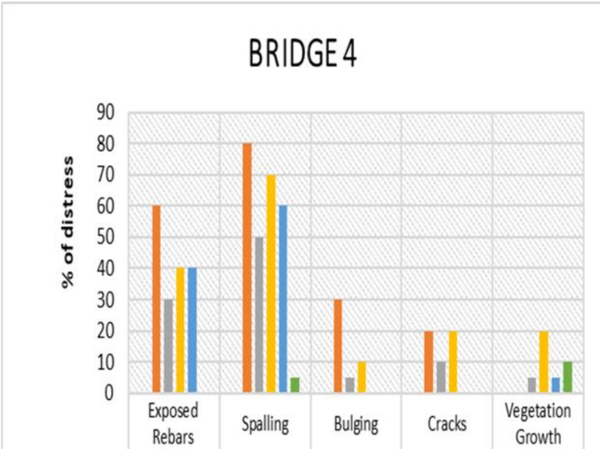
	Exposed Rebars	Spalling	Scaling	Bulging	cracks	Mortar Breakdown	Vegetation Growth
Handrails	30	40	0	0	10	0	0
Deck	50	70	50	20	0	0	0
Abutments	0	5	0	0	5	0	0
Piers	0	0	0	0	0	10	0
Wing Walls	0	0	0	0	0	5	10

Table 3: Distress % distribution of Bridge 3



	Exposed Rebars	Spalling	Bulging	Cracks	Vegetation Growth
Guard Rails	0	0	0	0	0
Deck	40	60	10	5	0
Haunch	5	20	0	20	0
Web	30	50	0	20	0
Bottom Slab	30	40	0	0	0
Wing Walls	0	0	0	0	5

Table 4: Distress % distribution of Bridge 4



	Exposed Rebars	Spalling	Bulging	Cracks	Vegetation Growth
Handrails	0	0	0	0	0
Deck	60	80	30	20	0
Haunch	30	50	5	10	5
Web	40	70	10	20	20
Bottom Slab	40	60	0	0	5
Wing Walls	0	5	0	0	10

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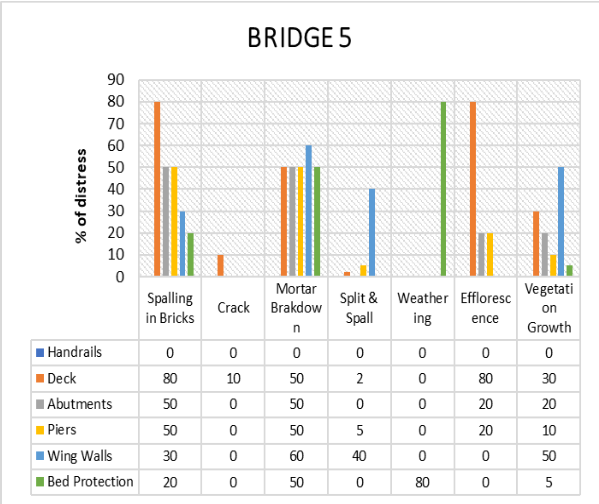
Table 5: Distress % distribution of Bridge 5



	Spalling in Bricks	Crack	Mortar Brakdown	Split & Spall	Weathering	Efflorescence	Vegetation Growth
Handrails	0	0	0	0	0	0	0
Deck	80	10	50	2	0	80	30
Abutments	50	0	50	0	0	20	20
Piers	50	0	50	5	0	20	10
Wing Walls	30	0	60	40	0	0	50
Bed Protection	20	0	50	0	80	0	5

5. Conclusion

A crucial tool for assuring the security, dependability, and economical management of bridge assets in a transportation network is a bridge management system. BMS enables organizations to make well-informed decisions that increase public safety and the sustainability of infrastructure by gathering data, evaluating conditions, and prioritizing maintenance operations. BMS will become more and more important in the management of contemporary transportation infrastructure as technology advances.

Regular bridge evaluations should be carried out in compliance with regional standards and laws. According on the results, suitable maintenance, repair, or rehabilitation actions should be planned and carried out to take care of the detected problems and maintain the bridge's safety and functionality. To ensure accurate and complete evaluations, it is crucial to employ qualified bridge engineers and inspectors in these examinations.

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