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ANALYSIS AND DAMAGE ASSESSMENT OF SKEW BRIDGES (SUPERSTRUCTURE)

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ABSTRACT

Bridges are very special type of structures. They are characterized by their simplicity in geometry and loading conditions. The reinforced concrete bridges usually carried uniformly distributed dead load, vehicular live load to its surface and transfers same to the support by flexure, shear and torsion. Newly designed bridges are often skew. This is due to space constraints in congested urban areas. It can be also needed due to geographical constraints such as mountainous terrains. However force flow in skew bridges is much more complicated than straight bridges. Many recent bridges are often skewed due to space and alignment constraints in most urban areas. The use of skew bridge allows a designer to choose the best solution in roadway alignments. **Staad Pro** and **CSI Bridge**, software's are used to Design and Analysis of skew bridges. These bridges has been affected by external factors such as weather and temperature. Substructure and foundation of the skew bridges are also affected by Velocity and Discharge of water flow. Our Project is Using **Staad Pro,** software to Analyzing the Skew structure and Using **Staad Pro** and **ETABS** and **Leap Bridge** software to Checking crack widths, distress and other Damages are Assesse.

Skew bridge design involves angling the bridge deck relative to its supports, creating complex load paths (torsion, shear) needing special analysis, often using software like STAAD Pro, with design focusing on reinforcing obtuse corners, managing creep effects (tension/lifting), and orienting girders/reinforcement, especially for angles >20-25°, to handle

these unique forces for efficiency and safety,

Key Design Considerations

- **Angle Dependence:**
  For small skews (<15-20°), it's simpler, but larger angles (over 20-25°) require treating the bridge as spanning perpendicular to supports, not parallel.
- **Load Distribution:**
  Skew introduces torsion and uneven loading; obtuse corners take more load, requiring extra reinforcement (e.g., U-bars, reinforcement normal to girders).
- **Creep Effect:**
  The deck's tendency to "creep" causes tension along the longer diagonal and lifting at acute corners, necessitating specific reinforcement to prevent cracking, notes an article from

  Structural Behavior:

  Unlike straight bridges, skew bridges experience significant twisting and bending, making finite element analysis (FEA) more suitable than simpler methods,.

  Design Approaches & Solutions

- **Reinforcement:**
  Place extra steel at acute corners (top & bottom) and normal to girders at obtuse ends; sometimes parapet girders are used, says the Scribd document.
- **Bearing Placement:**
  Fixed bearings or dowel bars might be used to prevent creep-induced movement, notes an article from Your Article Library.
- **Girder Orientation:**
  For large skews, cross girders might be arranged perpendicular to main girders, potentially fanning out at ends to trimmer beams.
- **Software:**
  Use powerful structural analysis software (like midas Civil or STAAD Pro) to model complex forces and stresses accurately.

  Benefits of Skew

- Integrates better with landscape/flow.
- Minimizes bridge length and span for specific crossings.
- Aligns piers parallel to traffic/water flow, reducing obstruction.

  Challenges

Complex analysis and detailing, Higher costs for formwork and bearings, and Potential for track twist on railways.

GENERAL

INTRODUCTION

Skewed bridges are commonly used to cross roadways, waterways, or railways that are not perpendicular to the bridge at the intersection. Skewed Bridges are characterized by their skew angle, defined as the angle between a line normal to the centreline of the bridge and the centreline of the support. The majority of bridge decks that are constructed now days are often some skewed or curved. Tight geometry is often placed on highway structures due to right of way restrictions in congested urban areas. If a road alignment crosses a river or any other obstruction at an inclination different from 90°, a skew crossing may be necessary.

The adoption of high skew angle bridges results in stresses which are significantly different than in right-angle bridges. In right-angled bridges, the load is transferred straight towards the support in the direction of the span but in skew bridges, load is transferred by a complex interaction of loads and moments. The complex geometry and highly skew angle also lead to the development of significant torsional moments in the deck slab with a decrease in longitudinal moment and increase in transverse moment. It results in concentration of reaction forces and negative moments at the obtuse corners and low reactions and a possibility of uplift reaction forces at the acute corners. These special characteristics of skew bridges make their analysis and design more complicated than right bridges

SCOPE OF WORK

Skew bridges are common at highways, the analysis and design of skew bridges are much more complicated than those for a right bridge. There are no detailed guidelines addressing the performance of skewed highway bridges. Therefore, there is a need for more research to study the effect of skew angle on the performance of highway bridges. And Monitoring also highly required at Construction stage, compared to right angle bridges, Because Damages are heavily acquired at Skew bridges.

SKEW BRIDGES

Skewed bridges are one of the most economical and satisfying construction in such conditions. In addition skew bridges are common at highway interchange, river crossing and other extreme grade changes where skew geometry is necessary due to space limitations.

In fair meaning, the plan of bridge may appear like parallelogram in plan view. This condition occurs when bridge alignment is not exact perpendicular or making some angle to crossing. The term angle of skew or skew angle is generally applied to the difference between alignments of an intermediate or end support and a line square to the longitudinal axis of the bridge above. Thus, on straight bridge, the skew angle at all supports would normally be the same and the term skew angle can be applied to the bridge as a whole. The simple form of bridge is right deck but demand of skew bridge is increasing due to various factors.

Figure 1: a) Skew Slab Crossing, b) Square Slab Crossing

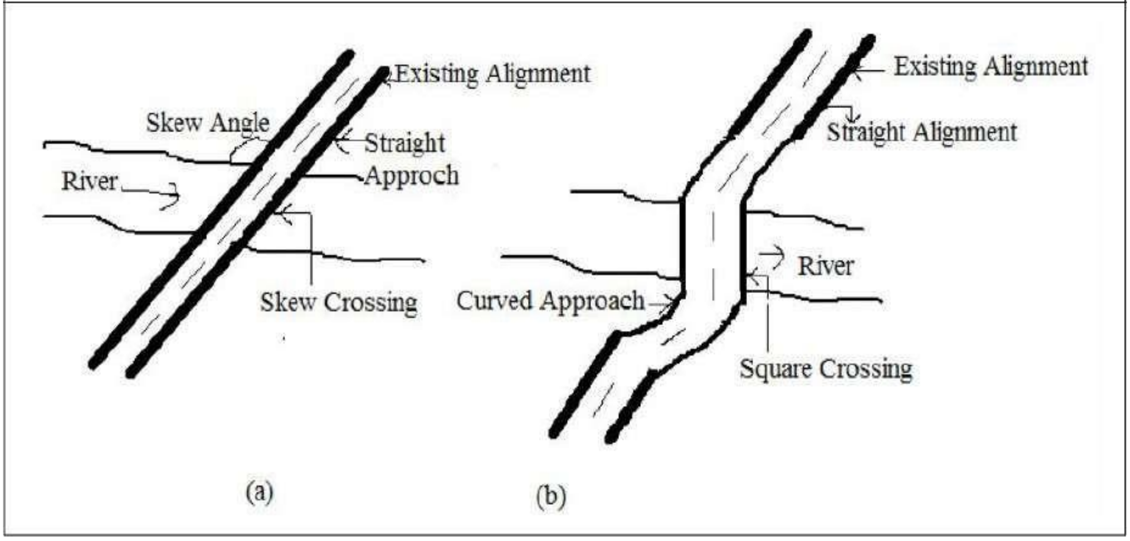


Fig. 1.1 Skew Bridge

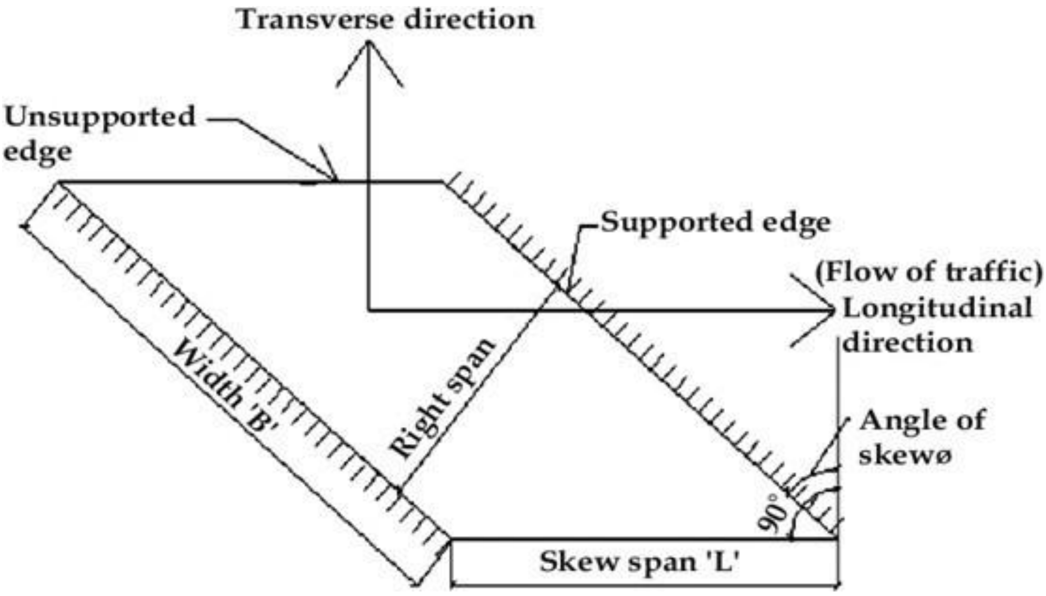


Fig. 1.2 Skewe angle

OBJECTIVE OF THE WORK

The objective of this work is Analysis and Damage assessment of bridge with skew angle. In Highways providing right angle bridges at skew crossing, we have to increase the span length more than actual stream width. Providing Skew bridges is Economic.

Consider a Skew angle and width of Structure

1. Skew angle- 25^0
2. Square width of bridge - 16.0m
3. Skew width of bridge - 17.7m

GENERAL

CHAPTER 2 LITERATURE REVIEW

Skewed bridges are necessary to cross roadways or waterways with an angle other than 90 degrees. They are often characterized by the skewed angle, defined as the angle between the normal to the bridge centerline and the support (abutment or pier) centerline. Section 2.1 briefly presents the state of art and practice related to skewed bridges. Almost all of these researchers have employed numerical and experimental analysis to analyze the skewed bridges and did regression analysis to find the effect of parameters on the behavior of skewed bridges.

In addition to the numerical and experimental approaches, an analytical approach is developed in this research. The analytical solution for skewed bridges is derived based on the analytical solution for skewed thick plates. Section 2.2 shows the existing research which has been devoted to analyze skewed thick plates. Currently there exists only numerical method such as FEA and boundary element analysis to analyze skewed thick plates and significant difference between these numerical research were reported. For example, deflection values at the center of a skewed plate derived by one research is twice as that of another research. Analytical (series) solution developed in this research is expected to make a breakthrough in solving this problem.

The literature on analyzing the skew bridges with skew angle and what are the Damages acquired in those bridges. There are several literatures are available for Analyzing and Damage Assessing of Skew bridge and among that some of the literatures are as follows.

REVIEW OF LITERATURE

Vikash Khatri, Anshuman Khar, P. K. Singh, P. R. Maitiin their research work conducted grillage analysis method for analysis of bridges. A total of nine different grid sizes (4 divisions to 12 divisions) are made using grillage analogy and have been studied on skew angles 30°, 45° and 60° to determine the most effective grid size. In their study is observed that finite element method (FEM) and Grillage method results are not similar for every grid size. They can be different for each grid size depending on various parameters. It is also observed from the analysis that mostly seven divisions on gridding is appropriate i.e., ratio of transverse grid lines to longitudinal grid lines is 1.8-

2.0. Also variation of grid sizes analysis results predicts that, variation in reaction value is same in FEM and Grillage method but variation of bending and torsion moment in FEM is lower than grillage results. So, FEM may be preferred for analysis of skew bridges.

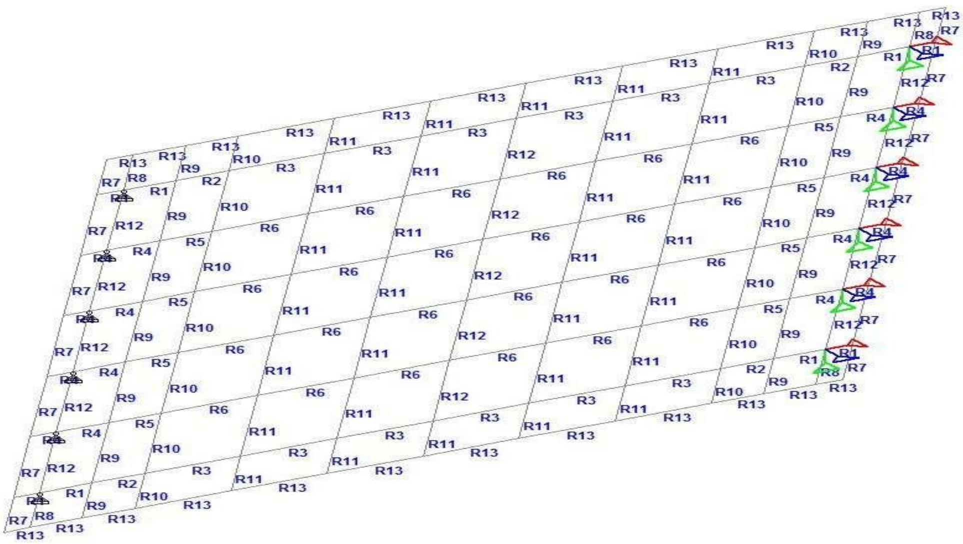


Fig.2.1 - Stadd Analysis of Skew Bridge (Superstructure).

CHAPTER 3 METHODOLOGY

LITERATURE REVIEW

Study about Skew Bridges

Studying Staad Pro

Studying IRC codes for Bridge Design

Choose the locations of Bridge

Fixing the span of the bridge

Analysis with Dead load & various SIDL combination

Analysis with Various Live

Design of Skew bridge

load combination

Analyzing the Cracks and Distress in the Skew bridge

Analyzing Crack width & Deflection of Bridges

RESULTS AND DISCUSSIONS

CONSCLUSION

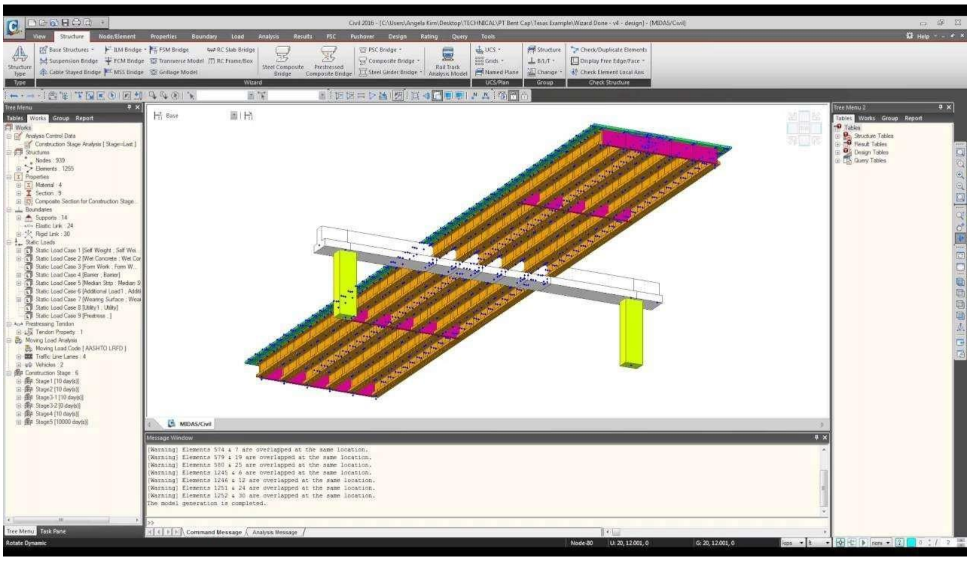


Figure 3.1 Methodology - flow chart

ABOUT CSI BRIDGE

CSI Bridge is a design solution that uses terms that are familiar to bridge engineers such as layout lines, lanes, bents, spans, bearings, hinges, etc. CSI Bridge is a logo designing software that offers you 3D design options.

Modelling, analysis and design of bridge structures have been integrated into CSI Bridge to create the ultimate in computerized engineering tools. The ease with which all of these tasks can be accomplished makes CSI Bridge the most versatile and productive software program available on the market today.

Using **CSI Bridge**, engineers can easily define complex bridge geometries, boundary conditions and load cases. The bridge models are defined parametrically, using terms that are familiar to bridge engineers such as layout lines, spans, bearings, abutments, bents, hinges and post-tensioning. The software creates spine, shell or solid object models that update automatically as the bridge definition parameters are changed.

4.1CODE BOOKS

IRC code books to be mainly referred to Study and Designing of the bridges.

Following code books to be used to Design of bridge

1. IRC 5-2015
2. IRC 6-2016
3. IRC 13-2004
4. IRC 78-2014

IRC 5-2015 - Standard Specifications and Code of practice for road Bridges.

It will use to mainly study about the **General Features of Bridge Design.** This code deals with general features of design of road bridges including immediate approaches and the recommendations of this code shall apply to all types of bridges

IRC 6-2016 - Standard Specifications and Code of practice for road Bridges.

It will use to mainly study about the **Loads and Load Combinations** for Bridges. The Design and construction of road bridges require an extensive and through knowledge of the science and technique involved and should be entrusted only to specially qualified engineers with adequate Practical experience in bridge engineering and capable of ensuring careful execution of work.

IRC 6-2016 - Guidelines for the Design of small bridges and culverts.

A large no. of small bridges and culverts form part of most of our highways. With the massive road development plans which our country has taken up, It is necessary to look for standardization of such structures so as to reduce the time spent on project preparation.

IRC 78-2014 - Standard Specifications and Code of practice for road Bridges.

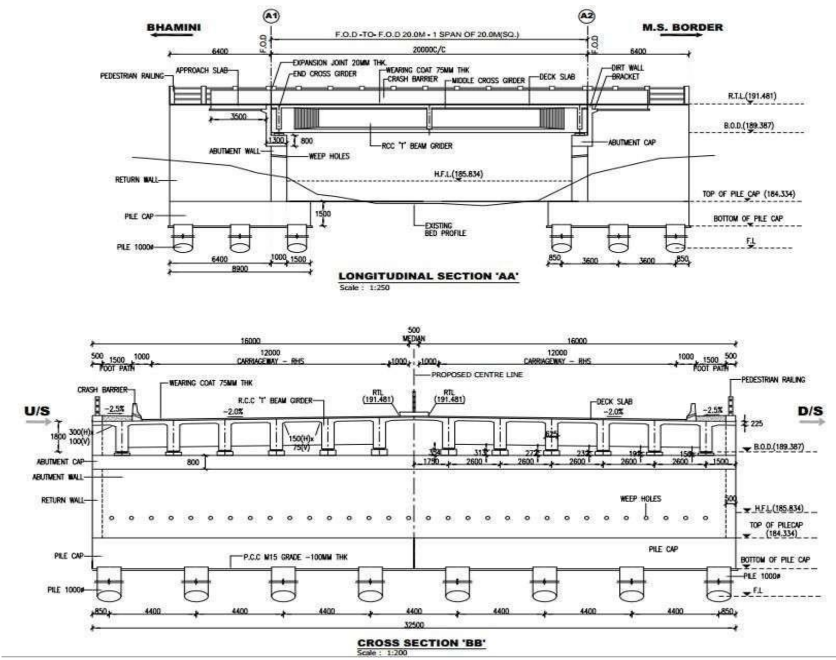
It will use to mainly study about the **Foundations and Substructure** of the Bridges. This code deals with the design and construction of foundations and substructure for road bridges. The provisions of this code are meant to serve as a guide to both the design and construction engineers, but mere compliance with the provisions stipulated herein will not relieve them in any of their responsibility for the stability and soundness of the structure designed and erected.

5.1 Components of bridges

1. Abutment
2. Approach
3. Approach slab
4. Bearing
5. Camber
6. Crash barrier
7. Dirt wall
8. Kerb
9. Wing wall
10. Return wall

CHAPTER 5 STUDY OF SKEW BRIDGE

11. Expansion joint
12. Pier
13. Pier cap
14. Abutment cap



About Skew Bridges

Many highway bridges are skewed and their behavior and corresponding design analysis need to be furthered to fully accomplish design objectives. This project has used an approach of physical-test-aided and detailed finite element analysis to better understand the behavior of typical skewed highway bridges in Michigan and to thereby develop design guidelines and tools to better assist in routine design of these structures.

The behaviour of skew bridges differs widely from that of normal bridges and therefore, the design of skew bridges needs special attention. In normal bridges, the deck slab is perpendicular to the supports and as such the load placed on the deck slab is transferred to the supports which are placed normal to the slab.

It is believed that the load travels to the support in proportion to the rigidity of the various paths and since the thickness of the slab is the same everywhere, the rigidity will be maximum along shortest span i.e. along the span normal to the faces of the piers or abutments.

CHAPTER 6 CONCLUSIONS

- Torsional moment plays a major role for both equivalent bending moment and equivalent shear force observed during the analysis and design for varying skew angle both for the dead load and live load. As the skew angle increases, torsion moment increases. Thus, this increases the value of Mt which directly affect the value of Equivalent Bending and Equivalent Shear.
- From the graphical observation for live load, bending moment decreases for all three girders, moment due to torsion for girder-G2 increases whereas moment due to torsion for girder-G1 and G3 decreases. Thus, due to net effect, equivalent design bending moment increases gradually as we increase the skew angle from 0 to 60^o but the considerable effect is due to torsional moment.
- For the combination of dead load and live load, it is observed that, bending moment, moment due to torsion, and equivalent design bending moment increases gradually as we increase the skew angle from 0 to 60^o and the considerable effect is due to torsional moment generated both for dead load and live load.
- From the graph, it is also observed for dead load that, there is a considerable decrease in normal shear force for girder G2 whereas increase in normal shear force for girder G1 and G3. Shear due to torsion for dead load increases for all three girders as skew angle increases. Thus, equivalent shear force also increases for all three girders as skew angle

increases.

- The net effect due to dead load and live load shows that, shear force decreases for girders G1 and G2 whereas shear force increases for girders G3as the skew angle increases from 00 to 60^0.

CHAPTER 7 FUTURE SCOPE

The future scope of skew bridge damage assessment is rapidly evolving towards more accurate, data-driven, and automated methods due to the high vulnerability of skewed structures to seismic activity, complex load distributions, and differential deterioration. Future efforts are moving away from traditional, simplified, linear analyses toward high-fidelity modeling, structural health monitoring (SHM), and specialized retrofitting strategies.

Key areas for future research and industrial application include:

15. Advanced Analytical and Modeling Techniques

- **3D Nonlinear Finite Element Analysis (FEA):** Future studies are focusing on 3D, non-linear models that capture the complex interaction of coupled translational and torsional motions, which simplified 2D models fail to address.
- **Performance-Based Seismic Design (PBSD):** Development of probabilistic tools like M- PARS (Multi-Phase Probabilistic Assessment of Response to Seismic Excitations) to compute damage probabilities under complex seismic scenarios.
- **Sequential Earthquake Analysis:** Assessing the cumulative damage of skew bridges subjected to mainshock-aftershock sequences.

16. Technological Innovations in Monitoring and Inspection

- **Point Cloud-Based Assessments:** Utilizing laser scanning and 3D modeling to monitor long- term deformation, specifically targeting the concentration of stresses at acute corners.
- **Real-time Structural Health Monitoring (SHM):** Integrating sensors to monitor critical components like bearings and abutments in real-time, providing early warnings for damage.

17. Advanced Retrofitting and Design Strategies

- **CFRP (Carbon Fiber Reinforced Polymer) Application:** Increased use of CFRP for strengthening bridge piers, particularly for taller, high-skew piers.

- **Sacrificial Shear Key Design:** Designing shear keys as sacrificial elements to prevent unseating and protect piers during high-intensity earthquakes.
- **Optimized Post-Tensioning:** Refining the use of transverse post-tensioning rods parallel to skewed abutments to mitigate damage.

18. Research on Deterioration and Environmental Factors

- **Skew Angle-Deterioration Correlation:** Further research into the relationship between increasing skew angles and faster deterioration rates (with angles >45° showing the highest rates), to better inform maintenance schedules.
- **Soil-Structure Interaction (SSI):** Incorporating complex foundation behaviors into damage assessments, as skew bridges are sensitive to uneven foundation settlement.

19. Standardized Guidelines and Codes

- **Development of Specialized Codes:** There is a recognized need for detailed, standardized guidelines that specifically address the unique performance challenges of skewed highway bridges, which are not adequately covered by existing, general bridge codes.

  Future Key Focus Areas
- **Impact Dynamics:** Understanding the oblique pounding of deck segments, which triggers unique rotation mechanisms.
- **Automation:** Using Artificial Intelligence (AI) to interpret inspection data and predict the remaining life of skewed bridges.

CHAPTER 8

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