Literature Review On Different Skew Angles in Voided Deck Slab of Bridge

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Abstract: Voided slab bridge, which have slabs with strategically placed voids to save weight while retaining structural integrity, are a popular option in modern bridge building. These decks are widely used around the world, particularly in India, because they are efficient and cost-effective. This study focuses on the behavior of simply supported single-span concrete voided slab bridge decks, with a specific emphasis on the impact of skew angles. Bridges have skewed angles to accommodate natural or man-made impediments, complex connections, spatial constraints, or difficult terrains. The skew angle is defined as the angle formed between the perpendicular to the centerline of the bridge and the centerline of the abutment or pier cap. Skew angles can have a considerable impact on the structural performance of bridge decks, influencing stress distribution and overall stability. Given the limits of high-traffic locations where realigning roads to reduce skew is frequently problematic, a large number of bridges are built with variable skew angles. This study looks into the impact of various skew angles on the performance of voided slab bridge decks under IRC loads. The study's goal is to provide insights into the structural behavior of skewed voided slab bridges, which will help to enhance design techniques and build more efficient and resilient bridge constructions.

Index Terms: Voided slab, bridge deck, skew angle, IRC-6 loading, STAAD Pro

I. INTRODUCTION

For river crossings, highways, and other grade changes where skewed geometry is essential due to space limits, skew bridges are frequently used. Skewed RC beam bridges are becoming more and more necessary as complex intersections and space-constrained issues arise in urban and metropolitan areas. Skewed bridges are helpful in certain locations where environmental effect is frequently an issue, as well as due to the topography of things, when route alignment changes do not seem to be practical. Modern highways need to be as straight as possible to handle high speeds and greater traffic safety, which necessitates the building of an increasing number of skewed bridges. The angle formed by a road's center line and a river's center line when there is a river bridge or another obstruction present is known as the skew angle. In comparison to a standard bridge, a skew bridge requires more thought and elegance. Bridge deck analysis and elegance are more difficult when there is skew. Largely skew bridges can significantly affect how the bridge behaves, especially over a range of span lengths. Research publications on the performance of skewed highway bridges are very numerous. Nevertheless, it doesn't seem like there are any thorough guidelines for how skewed highway bridges should operate. Skewed bridges behave in various ways due to a multitude of constraints that affect their behavior. Therefore, there is a compelling need for more investigation to ascertain how skew angle affects beam bridge performance. Many factors, such as man-made or natural obstacles, intricate junctions, limited space, or steep terrain, might result in skew on a bridge.

Features Of Voided Deck Slab Of Bridge

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 slab. Load transfer from a skew slab bridge is complicated problem because there always remains a doubt as to the direction in which the slab will span and the manner in which the load will be transferred to the supports. With increase in skew angle, the stresses in the bridge deck and reactions on the abutment vary significantly from those in straight slab.

Special features of skew deck slab are

- Variation in the direction of maximum bending moment across width, from near parallel to span at edge and orthogonal to abutments in central region.
- Hogging bending moments near obtuse corners.
- Considerable torsion in decks.
- Low reactions and shear forces near obtuse corners.
- High reaction and possibly uplift near acute corners, especially in case of slab with high skew angles.
- The points of maximum deflection nearer obtuse angled corners.

The magnitude of these effects depends on the angle of skew, aspect ratio of the slab and the type of construction of decks and supports. The shape and edge details can also influence the direction of maximum moments, the deck slab span on to abutments, the stiff edge beams acts as a line of support for the slab which effectively spans right to abutments across full width. The skew is so high that the deck is cantilevered off the abutments at the acute corners. The above characteristics are particularly significant in solid and cellular slab decks because their high torsional stiffness tries to resist the twisting of deck. In contrast, the skew is less significant in beam and slab decks.

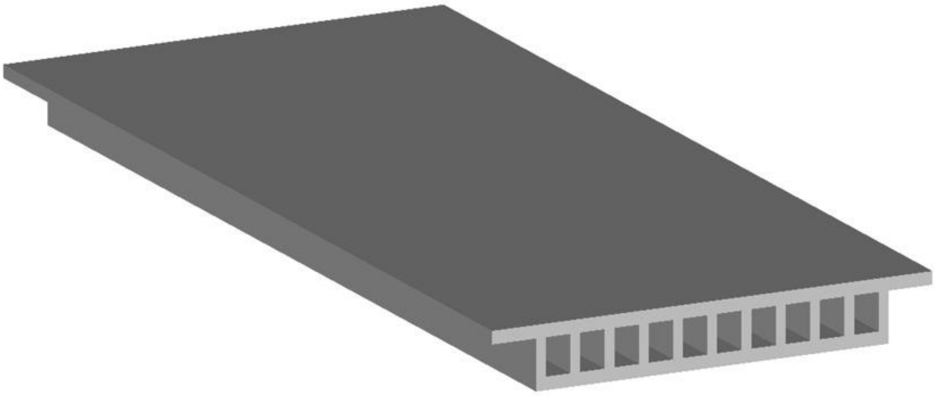

Figure 1. Voided Deck Slab for Bridge

Skew angle and its effects on Voided Deck Slab of Bridge

The skew angle in bridge design significantly influences the structural behavior of voided deck slab bridges. As the skew angle increases, the load path shifts, causing the load to travel more directly towards the supports rather than following the roadway's centerline. This change in load path results in the slab experiencing twisting stresses, as the planes of maximum stress are no longer parallel to the centerline. Consequently, the stress distribution within the slab becomes more complex, which can lead to potential issues like cracking or excessive deformation if not properly accounted for. The support reactions at the obtuse-angled end of the slab become greater than those at the acute-angled end, with increases ranging from 0 to 50% for skew angles between 20° and 50%. This discrepancy requires careful design and reinforcement strategies to ensure stability. Advanced computational modeling is often necessary to accurately predict and accommodate these effects, ensuring the bridge's structural integrity and longevity. Proper understanding of the skew angle's impact is crucial for the successful design and construction of voided deck slab bridges.

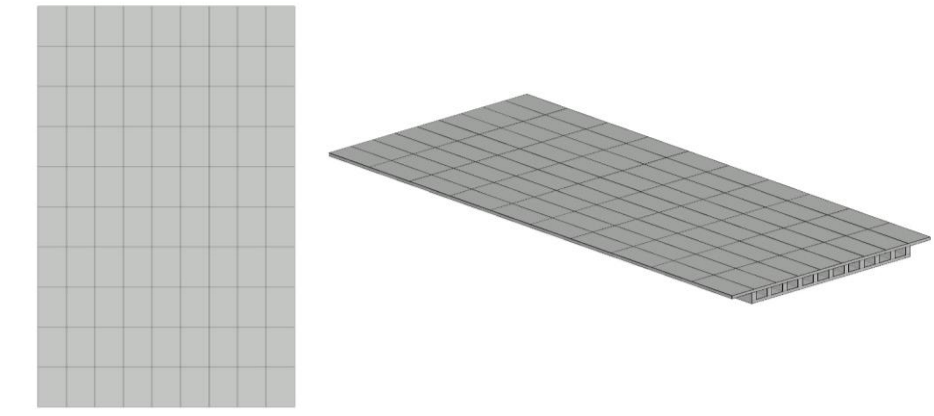

Figure 2. Plan (LHS) and Isometric view (RHS) of voided deck slab in 0° skew

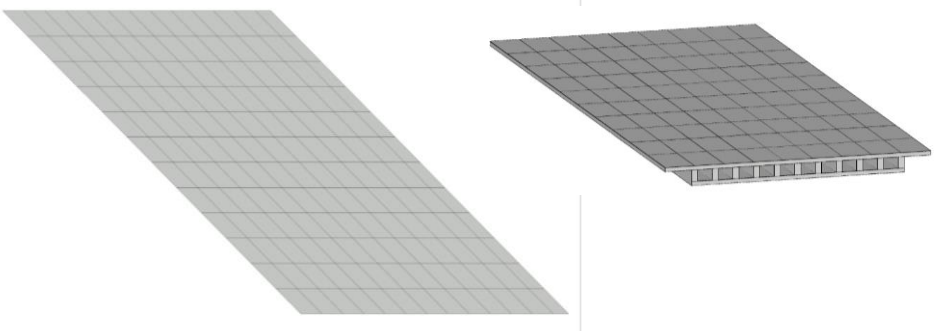

Figure 3. Plan (LHS) and Isometric view (RHS) of voided deck slab in 45° skew

II. Objective And Scope

- To analyze the effect of skew angles on voided deck slab having various spans and loading by dynamic analysis using analysis software (i.e. STAAD Pro / MIDAS / ETABS, etc.)
- To compare the Deflection, Support Reaction, Transverse Moment and Bending Moment for various skew angle of voided deck slab.
- To evaluate the economical and safe skew angle by dynamic analysis.
- Finally, complete content and organizational editing before formatting. Please take note of the following items when proofreading spelling and grammar.

III. Literature Review

This aim is to comprehend and document the state of the art and practice regarding the behavior of skewed highway bridges. Different scholars offered various findings based on skew angle, and the deck of a bridge is briefly covered below.

1. Ibrahim S. I. Harba [1] (2011): This project study examines how skew angle affects the behavior of simply supported R.C. T-beam bridge decks. A three-dimensional finite element analysis was conducted to examine the impact of skew angle on the behavior of simply supported reinforced concrete T-beam bridge decks. The paper suggests performing three-dimensional finite element analysis for skewed T-beam bridge decks, which contradicts the AASHTO standard specifications and the LRFD, which state that bridges with a skew angle of less than or equal 20° are deemed straight (non-skewed)

2. Nipa Chauhan et al. (2016): A comparison of prestressed solid and voided slab is made. SAP 2000 software is used to create models with varying span lengths but the same width. Bending moments and shear forces are calculated for both types of decks. Results indicate that voided slabs are more efficient and convenient than solid slabs for bridge design. Moments from solid to voided slabs drop by 11%, 7%, and 5.5% for 20 m, 30 m, and 40 m spans, respectively.

3. B. Vaignan and Dr. S.R.K Prasad (2014): This study analyzes voided and cellular deck slabs using Midas civil software for spans ranging from 7m to 15m, with intervals of 0.2m. We studied 82 models and compared their beam forces and reactions based on span. The study uses an actual model of a voided slab and analyzes it by shifting the voids to circular and rectangular shapes. Cellular deck slabs offer lower displacements and can handle higher loads compared to voided slabs.

4. Vikash Khatri and P. R. Maiti (2012) used computational methods to analyze a skew bridge. The study modeled a bridge deck with beams and slabs using grillage and finite element methods. This study compares the finite-element and grillage analogy methods for analyzing the impact of grid arrangement on skew angles on equal span reinforced concrete bridges. The maximum deflection, bending, response force, and torsional moments are calculated and compared across both analytical methods. The grid size for this narrow and long bridge is expected to be seven partitions, with a transverse to longitudinal grid ratio.

5. Sindhu B. V, Ashwin K. N[4] (2013):- This study examined the impact of skew angle on single-span reinforced concrete bridges using the finite-element approach. Research is conducted on RC slab bridge decks with and without edge beams to analyze the impact of aspect ratio, skew angle, and load type. The finite-element analysis results for skew angle bridges are compared to straight bridges for dead load, IRC 70R loading, and IRC Class A loading (without and with edge beam). A total of 90 bridge models are analyzed. This study examines how skew angle affects maximum deflection, torsional moment, longitudinal sagging bending moment, and support reaction for 90 bridge deck models.

The FEA findings show that as the skew angle increases, the dead load and live load bending moments and deflections decrease. However, the maximum support responses and torsional moments increase up to 45 degrees before decreasing. Providing edge beams reduces deflection, longitudinal bending moment, and torsional moment.

6. L.A. Abozaid & Ahmed Hassan [5] (2014):-This work compares the results of past experimental revisions to the non-linear finite element analysis of a reinforced concrete slab. The main characteristics examined were the skew angle with steel configurations. The slabs were developed with an elastic stress field and an ultimate design load, as input for the direct design approach. The experimental and theoretical results showed a good agreement. Additionally, a theoretical analysis was conducted on a ribbed bridge with two lanes under traffic loads, following Egyptian code of practice instructions. The analytical studies focused on the skew angle, which ranged from 0° to 45°. Skew angles of 0° and 30° were utilized to investigate the impact of concrete grade on bridge decks. Compressive strength values range from 400 to 900 kg/cm for each skew angle. The skew angle and concrete grade impacted the slab's overall performance.

7. Kamal Kumar Pandey and Savita Maru[6] (2015):- This article highlights the significance of incorporating Ka grillage into bridge deck design assumptions. The bridge deck slab is turned into grillage with varied skew degrees. Determine the most accurate values for bending moments, responses, torsion, shear force, and deflections. The grillage model requires 7.5m roadway width and 10m length spans.

8. Abdel-Hakim Khalil, Tarek Fawzy, Salah Taher, and Ahmed T. Baraghith:- Reinforced Concrete Hollow Core Slabs (HCS) are one of the types of structures employed in bridges throughout the last 30 years. They developed a highly efficient and visually beautiful design for medium and long span bridges (20-30 m). The current need for skew bridge decks stems from large-scale urbanization and construction of complex crossings, as well as a shortage of space in congested locations. Previous studies on HCS did not include the effect of inclination angle on behavior. The current work examines how inclination angle (θs), aspect ratio (λr), and stirrup configurations affect the behavior of HCS. A large-scale experimental program with thirteen specimens was carried out to determine the prominent features of the behavior of reinforced concrete skew hollow core slabs, such as mechanisms of failure, deformational properties, strength parameters, and strain development. The results showed that increasing the skewness reduced the ultimate loads but increased the mid span deflection and toughness.

9. Mallikarjun I.G, Ashwin K.N, Dattatreya J.K., Dr. S.V Dinesh:- The influence of a skew angle on single-span reinforced concrete bridges and PSC bridges is investigated using the finite-element method, and the findings are described in this work. Investigations are conducted on RC slab bridge decks and PSC bridge decks to determine the impact of aspect ratio, skew angle, and load type. The finite-element analysis results for skewed bridges are compared to reference straight bridges under dead load and IRC Class A loading. Additionally, a comparison of the reaction of skewed RCC and PSC slab bridge decks to that of an equivalent right bridge deck is performed. A total of 120 bridge models were examined. The fluctuation of maximum longitudinal bending moment, maximum transverse moment, maximum torsional moment, and maximum longitudinal stresses with skew angle is investigated for all 120 bridge deck models. The FEA results show that dead load and live load longitudinal bending moments decrease with increasing skew angle, whereas maximum transverse moment and maximum torsional moment increase with increasing skew angle, and maximum longitudinal stresses decrease with skew angle up to 30 degrees and then increase. The benefit of pre-stressing is a large reduction in longitudinal bending moment, transverse moment, and longitudinal stress.

10. Alok Singh, Abhishek Kumar, Mohd. Afaque Khan: This study compiles data from several prior investigations on the effect of skew angle on the static behavior of reinforced concrete slab bridge decks and related subjects. The skew angle is defined as the angle between the normal to the centerline of the bridge and the centerline of the abutment or pier cap. Skew bridges have become necessary due to site constraints such as alignment limitations, land acquisition issues, and so on. The direction of greatest bending moment cross width varies from almost parallel to the span at the edge to nearly orthogonal to the abutment in central areas, with hogging moment around the obtuse corner. The most positive and negative reactions are observed in skew bridges that are relatively close together. Maximum shear forces, torsion, and bending moments occur. The longitudinal and transverse bending moments are greatest, and there is a maximum increase in skew angle due to dead load, which ranges between 60% and 70% for all aspect ratios.

11. Brajesh Kumar, Dr. Pankaj Singh, Ravindra Gautam: Circular voids are frequently used into concrete bridge decks to minimize self-weight without significantly compromising flexural rigidity. Incorporating voids into the deck slab provides numerous advantages over a traditional solid concrete slab, including lower total construction costs, reduced material use, and increased structural efficiency. However, the structure's voids confound its examination. In this thesis, a manual analysis of the longitudinal and transverse directions of a voided slab bridge is performed in accordance with industry norms. For transverse analysis, the bridge is idealized with STAAD pro software. The intricate structure is also detailed so that you can understand how the reinforcement is positioned. The design of the bridge superstructure is a task that necessitates extensive experience and knowledge in order to anticipate unanticipated situations that may arise during

the building stage. The longitudinal moments are the regulating moments, and the major bending must not fail in the transverse direction. Transverse analysis treats the entire structure as a single unit, mitigating the stresses caused by individual loadings.

12. Mr. Nihal Dahatonde: Due to advancements and tough situations in bridge construction, voided slabs are becoming more prevalent. It is the most advanced way for increasing productivity while reducing costs and time. Circular voids are frequently used into concrete bridge decks to minimize self-weight without significantly compromising flexural rigidity. However, the voids inside the structure, as well as the analysis of the structure that incorporates voids within the deck slab, provide numerous advantages over a standard solid concrete slab, including lower total construction costs, decreased material use, and increased structural efficiency. However, the structure's voids confound its examination. This thesis presents a manual examination of voided slab bridges in both longitudinal and transverse orientations in accordance with industry requirements. For transverse analysis, the bridge is idealized as a unit and analyzed using STAAD pro software. The intricate structure is also detailed so that you can understand how the reinforcement is positioned.

IV. CONCLUSION

Several studies have been conducted for various skew angles on bridges using Staad Pro, and the findings have been compared for various skew angles and span lengths. When a bridge structure exhibits a varying skew angle, it is required to analyze the bridge for various IRC loading types and load combinations. Many previous investigations have shown that deflection, bending moment, shear force, torsional moment, and support reaction vary with angle of skew.

V. ACKNOWLEDGEMENT

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