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The Influence of Skew Angles on Prestressed Bridges

Chirag Kedare, Roshni John

***Abstract:** Prestressed concrete bridges are crucial in modern infrastructure due to their high durability, low maintenance requirements, and superior load-carrying capacity. However, skew bridges, which feature a non-perpendicular alignment with traffic flow, pose significant challenges in analysis and design. This study presents a comprehensive parametric investigation into the behaviour of prestressed skew bridges to enhance structural understanding and optimize design strategies. Advanced finite element techniques are utilized to analyse the effects of prestressing forces, material properties, and geometric parameters on skew bridges. The study evaluates key structural responses, including bending moments, shear forces, torsional effects, and deflections, under various loading conditions, such as dead loads, moving loads, and prestressing loads, considering relevant IRC load combinations that account for seismic effects. This research analyses fifteen prestressed skew bridge models with varying spans and skew angles between 20° and 50° using MIDAS Civil software. Comparative results highlight the influence of skew angles on structural performance. The findings suggest that increased skewness has a significant impact on torsional behaviour and bending moment distribution. With advancements in computational tools, the precise estimation of structural responses is now possible, providing engineers with a better understanding of the design and analysis of prestressed skew bridges.*

***Keywords**: PSC-Prestressed Concrete, Skew Bridges, Finite Element Analysis, Prestressing Forces, Material Properties, Bending Moments, Shear Forces, Torsional Effects, Displacement, IRC Loading.*

Abbreviations:
BM: Bending Moment
RCC: Reinforced Concrete
PSC: Prestressed Concrete

I. INTRODUCTION

Although skew bridges act very differently from regular bridges, extra consideration must be given to their design. The weight applied to the deck slab is transferred to the supports positioned normally to the deck slab in standard bridges because the deck slab is perpendicular to the supports. On the other hand, load transfer from a skew slab bridge is challenging, as it is never entirely certain.

Which way the slab will span, or how the load will be distributed to the support.

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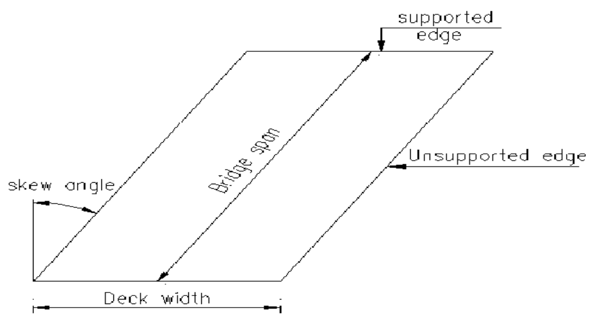
The stiffness will be highest at the shortest span or along the span perpendicular to the faces of the piers or abutments because the slab's thickness remains constant throughout. The rigidity of the numerous channels is thought to determine the amount of load that moves to the support.

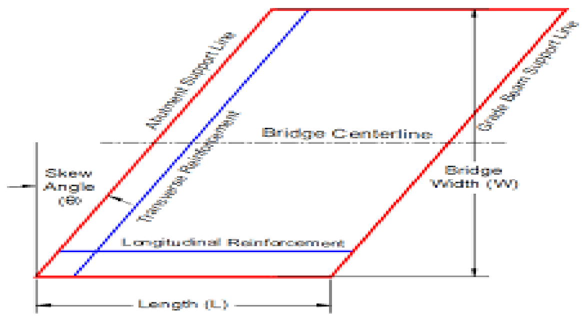
The slab will span longitudinally, which is the shortest distance between the supports, whereas the deck spans in the transverse direction. As a result, a skew slab's plane of maximum stresses is not parallel to the roadway's centre line, and the slab's deflection results in a warped surface.



[Fig.1: Schematic Representation of Skew Angles [11]]

While designing such bridges, the length parallel to the roadway's centerline is employed as the span, because the impact of skew on deck slabs with skew angles up to 20 degrees is not significant. These span lengths were used to calculate the slab's thickness and the reinforcement's positioning parallel to the road's centerline. However, as is typical, the distribution bars are parallel to the supports. The skew effect becomes noticeable when the skew angle ranges from 20 to 50 degrees, and as previously said, the slab tends to span normal to the supports.

In such circumstances, the shortest span is used to determine the thickness of the slab, but the reinforcement calculated using the shortest span is multiplied by Sec20 (0, which is the skew angle). It is positioned parallel to the road, as displayed in Figure a below, with the distribution bars positioned as usual for the supports.



[Fig.2: Placement Alternative of Reinforcement [10]]

When the skew angle is between 20 and 50 degrees, it is also accepted practice to

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place reinforcements perpendicular to the support. The thickness and the reinforcement are established with span normal to the support however since in inserting the reinforcement transverse to the supports, the comer reinforcement within the area ABF or COE (in following figure) do not get any support on one side to rest on, the slab below the footpath (for bridge with footpath) or below the road kerb (for bridge without footpath) shall be provided with extra reinforcement to act as concealed beam. Alternatively, parapet girders, as illustrated in the following figure, may also be provided along the edge of the slab. Such parapet girders are made flush with the bottom of the slab and extended above the slab to the required height to form the solid parapet. This deck requires less steel in the slabs, but parapet girders incur additional costs.

Although the spans are relatively minor, girders should be used for bridges with more than 50 degrees of skew angle. When the bridge's width is limited, the girders can be positioned parallel to the highway, and the thickness of the slab and the reinforcement can be planned with the girder spacing as it spans.

The reinforcement is placed normal to the girders (in the following figure). In wider multi-lane skew crossings with large skew angles, however, using the girders at right angles to the supports is preferable. In such cases, the triangular portions need parapet girders to support one end of the girders. The reinforcement is used normal to the girders, as shown in the above figure. The appropriate style is still applied to each section, with styles re-applied as necessary.

A. Effects of Earthquakes on Bridges

Bridges are critical infrastructure components that play a vital role in transportation networks, enabling the smooth movement of goods and people. However, their structural integrity can be severely challenged by earthquakes, which impose dynamic and often unpredictable forces. During seismic events, bridges experience complex loading conditions, including both horizontal and vertical ground accelerations, which result in bending, shear, and torsion stresses. These effects are further amplified in skewed bridges, which are increasingly used to address geometric constraints such as intersecting roads or rivers.

The response of a bridge to earthquake forces depends on factors such as its geometry, materials, foundation type, seismic zone, and soil conditions. Skewed bridges are particularly vulnerable during earthquakes due to their asymmetric configuration, which can result in uneven force distribution, increased torsional moments, and amplified displacements at the supports. This can lead to potential structural failures, such as bearing displacement, girder unseating, and even complete collapse.

Despite these challenges, prestressed concrete (PSC) box girder bridges, including skewed designs, are widely accepted in modern bridge engineering for their numerous advantages in resisting seismic forces. Prestressing introduces pre-compression into the concrete, which improves its tensile strength, reduces crack propagation, and enhances its load-carrying capacity. The box girder configuration also provides excellent torsional stiffness, making it particularly effective in skewed bridge designs, where torsional forces are more prominent.

[Fig.3: Cracks in Skew Bridges Due to Earthquake [12]]

A Prestressed Concrete (PSC) bridge is generally better than a Reinforced Concrete (RCC) bridge in earthquake-prone areas due to its superior strength, ductility, and resistance to cracking. The prestressing force in PSC bridges reduces tensile stresses, minimizing the formation of cracks that can weaken the structure during seismic events. Additionally, PSC bridges have higher load-carrying capacity and better energy dissipation, allowing them to withstand dynamic earthquake forces more effectively. Their lighter superstructure also reduces inertia forces, thereby enhancing seismic performance compared to conventional reinforced concrete (RCC) bridges.

II. LITERATURE SURVEY

A. Deepak Kumar Singh et.al (2023)

A study was presented in which a single-cell prestressed box girder bridge was subjected to Indian loading conditions to examine its response to the CSI Bridge software. Analysis was carried out on a simply supported bridge with skew angles varying from 0 to 60 degrees and spans of 35, 40, 45, 50, 55, and 60 m, considering the IRC 6:2017, IRC 18:2000, and IRC 21:2000 specifications. The ratios of bending moment, shear force, torsional moments, and vertical deflections are presented as a result of the study. A statistical approach was used to derive equations for the ratios of different spans and span-depth ratios. In conclusion, it's clear that because of the higher span-depth ratio, the skew bridge performs better than a straight bridge, resulting in less bending moment development. It's also observed that prestress load can be reduced by providing skew angles to the bridge [1].

B. Hemant Rawat et.al (2023)

Conducted a study in which a brief introduction regarding the RCC skew bridge & its response against seismic loading is described. Furthermore, various seismic analysis approaches were discussed in the paper, including linear and nonlinear static and dynamic methods. In conclusion, the skew angle has considerable effects on multiple parameters, ultimately promoting the use of skew bridges. Overall, this paper offers a comprehensive understanding of the various techniques employed for seismic analysis of the RCC skew bridge [2].

C. Shivani S. Jadhav et.al (2023)

This paper clearly states that bridges are essential for transportation, but site conditions.

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Often require skewed designs. When roads or rivers do not align at 90 degrees, this study examines how different skew angles affect the behavior of a bridge's deck slab under seismic conditions using ETABS software. Analysing earthquake zones II and V with medium soil, the results show that the longitudinal moment decreases as the skew angle increases. However, shear force and bending moments remain essentially unchanged across both zones. The study highlights that bridges with skew angles of 30° and 50° are more vulnerable, suggesting that skew angles above 50 ° should be avoided in practice [3].

D. S. K. Kulkarni et.al (2021)

The effects on a prestressed concrete bridge consisting of varying skew angles were presented, and the results of the straight bridge and skew bridge for IRC Class AA Tracked loading were also compared. Analysis was done on the CSI Bridge software between a straight and skew bridge to know the results regarding maximum longitudinal stresses, deflection at the obtuse corner, the acute corner, longitudinal bending moment (BM), maximum transverse moment, and maximum torsional moment. It concludes that skew angles are directly proportional to the live load longitudinal bending moment. Also, with increased skew angle, the maximum transverse and torsional moments increased. There was a considerable reduction in longitudinal bending moment, longitudinal stresses, and transverse moment by pre-stressing the bridge [4].

E. Nasir Ali et. al(2020)

Carried out a study on a three lane three span box girder by modelling and analysis on STAAD pro software to know the effect of skew angle under various loads such as dead load, live load, surfacing load, earth pressure, temperature and live load surcharge and their combination on top slab, bottom slab, outer and inner walls using IRC 6:2016 in which skew angles ranges from 0 to 70 degree with an interval of 10 degree, it mainly focuses on parameters such as longitudinal moments, transverse moments, torsional moments, shear forces and displacements. In conclusion, it clearly states that all parameters are increased, as skew angles are increased in all slabs [5].

F. Dhruv Patel et.al (2020)

In this paper, a study was conducted on Reinforced concrete T- beams girder of skew angles ranging from 0 to 60 degrees with an interval of 15 degrees and with different spans like 16m,18m,20m and 24m with two lane carriage way considering various load according to IRC and AASHTO such as dead load, vehicular live load, impact load along with load combination. Staad Pro software and the grillage method were used for analysis. Analysis results primarily focus on parameters such as bending moment, torsional moment, shear force, and deflection of the T-beam girder. It concludes that the skew angle increases as the bending moment and deflection decrease, as per the IRC and AASHTO load combination, in the case of the outer girder and inner girder, where the bending moment and deflection decrease compared to the right bridge. Whereas with increasing skew angle, shear force and torsion moment increase, as per IRC and AASHTO load combination, in the case of the outer girder and inner girder, shear force and torsion moment increased as compared to the right bridge [6].

G. Praveen Naik et.al (2018)

In this paper, a comparative study was done between standard and skew bridges of box girder with skew angles varying from 0 degrees to 60 degrees with an interval of 15 degrees, considering IRC CLASS AA TRACKED loading on two-span deck slabs on parameters such as bending moment, shear forces, and torsional moments. SAP 2000 software was used for the analysis of the above model. In conclusion, it is observed that with the rise in skew angles, shear force increases and decreases under moving load and dead load, respectively. At the same time, torsional moments increased with the surge in skew angle under dead load. It was also observed that with the increase in skew angle, the bending moment also increased under both dead and moving loads for sagging moments. Conversely, for hogging moments under dead loads, there is a reduction in bending moment as the skew angle rises, but with a rise in skew angle under moving loads, the bending moment increases [7].

H. Tanmay Gupta et.al (2018)

In this paper, a study was conducted on the flexural response of simply supported single-cell skew-curved concrete box girder bridges to investigate the effects of curvature and skewness. Curvature angles vary from 0 to 48 degrees with an interval of 12 degrees; similarly, the skew angle ranges from 0 to 50 degrees with an interval of 10 degrees.

Bridge models were created using CSI Bridge, whereas for the gravity load and IRC specified 70R tracked vehicular live load, a finite element analysis was performed. In conclusion, the paper states that in the case of skew-curved bridges, the inner girder (web) response is considered. It is observed that the flexural response of the bridge improves in the presence of skewness in the highly skew bridge. Skewness and curvature are significantly affected due to the maximum longitudinal moment, and the locations of the critical section of the moment are produced by the necessary positioning of the live load [8].

I. Naga Shekhar J P et.al (2016)

Researched to understand the behavior of different skew bridges by finite element analysis, considering Dead load and live load (class A and class 70R) on a bridge span of 25m with varying skew angles 0 to 60 degrees with a 15-degree interval [9]. The project primarily focused on skew effects on the behaviour of bridge girders, considering design parameters such as bending moment, shear force, and torsion. Five models were analysed using the CSI Bridge software, which showed the variation in bending moment, shear force, and torsion for each model, clearly demonstrating that the skew angle is inversely proportional to the bending moment. Additionally, up to a 45-degree skew angle, shear force and torsion increased gradually and then decreased afterwards. Maximum bending moment and torsional moments were reduced by providing abutments at the ends of the girder.

III. AIMS AND OBJECTIVES

A. AIM

The present study aims to investigate the behavior of

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PSC box girder bridges, which are skewed at angles varying from 0 to 60 degrees with an interval of 10 degrees, mainly focusing on parameters such as shear force, bending moment, torsion moment and vertical deflection for different types of spans, IRC loading and number of lanes.

Additionally, the study incorporates the effects of earthquake parameters to analyze the seismic response of prestressed skew bridges.

B. Objectives

- To analyse and study the response of a simply supported multi-cell pre-stressed box-girder that is four cell boxes under the action of Dead, IRC, and Seismic loads.
- To perform analysis on PSC box girder bridges with varying skew angles from 0 to 60 degrees.
- To study the structural responses presented in ratios of bending moment, shear force, torsional moment, and vertical deflection under the effect of earthquake loads.
- To obtain the variation of structural response for bridges under Dead load and moving loads, and Bridges acting under the influence of Dead, Live, and Seismic effects for parameters like skew angle, span-to-depth ratio, Number of lanes, and for different spans like 30m, 45m, 60m.

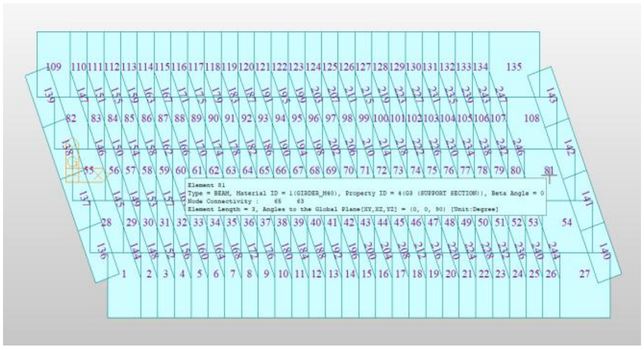
IV. PROBLEM STATEMENT

In the present study, a four-cell prestressed skew bridge is modelled and analyzed in MIDAS CIVIL. Five models have a 30m span with varying skew angles ranging from 20 to 60 degrees. Prestressing tendons are induced in all webs and flanges of girders. For live loads, Class 70R and Class A vehicles are used, as per IRC 6-2017, under seismic conditions.

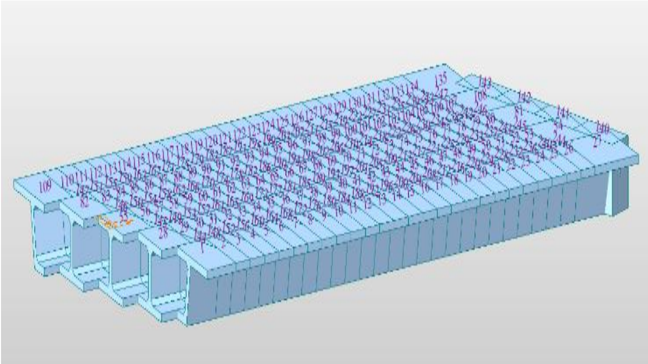
In this study, bridges are considered simply supported bridges. The following are the 20 skew bridges that are modelled and analyzed with four-cell PSC box girders.

A. Analytical Model 1:

- Span = 30 m
- Carriageway = 16 m
- Type of bridge = PSC box girder bridge skewed at 20 degrees.



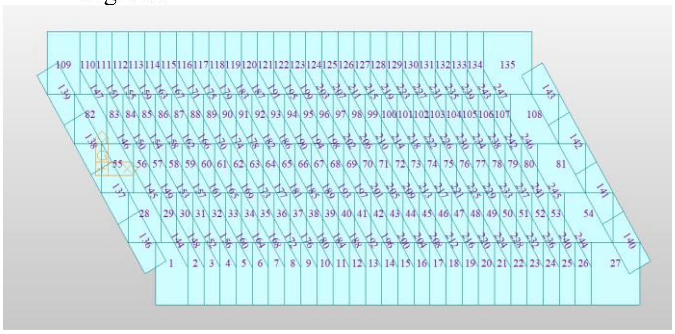
[Fig.4: Plan View of Analytical Model 1]



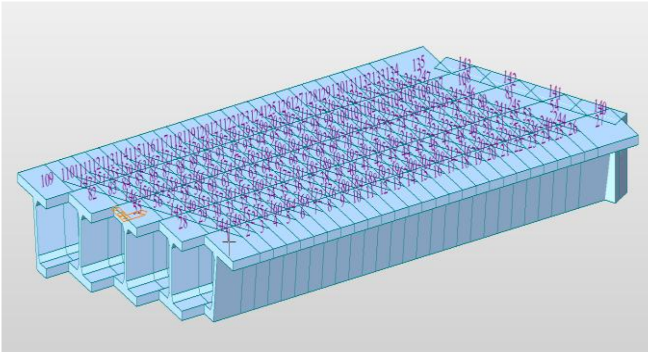
[Fig.5: Isometric View of Analytical Model 1]

B. Analytical Model 2:

- Span = 30 m
- Carriageway = 16 m
- Type of bridge = PSC box girder bridge skewed at 30 degrees.



[Fig.6: Plan View of Analytical Model 2]



[Fig.7: Isometric View of Analytical Model 2]

C. Analytical Model 3:

- Span = 30 m
- Carriageway = 16 m
- Type of bridge = PSC box girder bridge skewed at 40 degrees.

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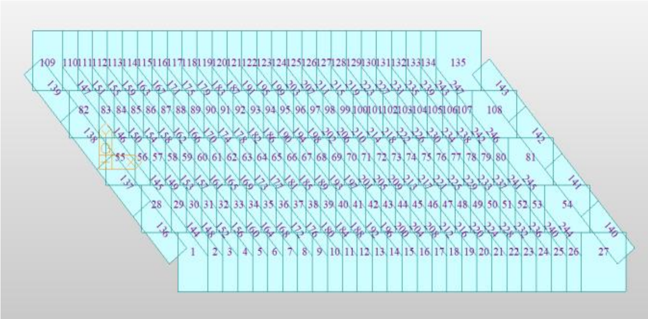
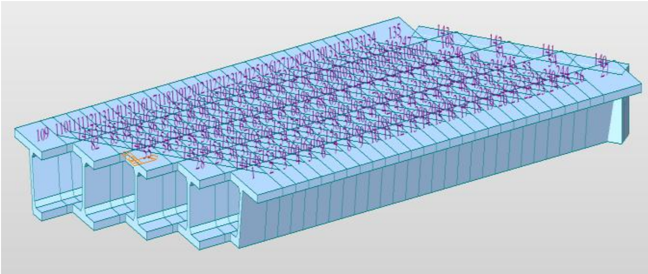


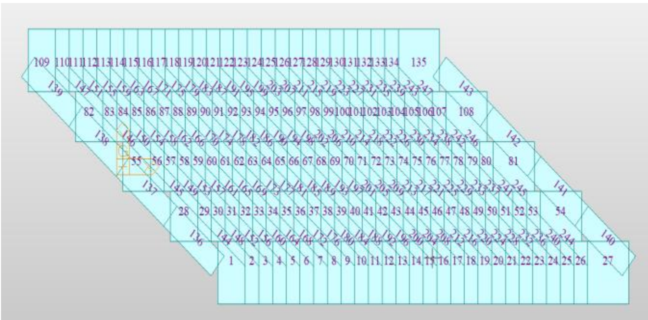
[Fig.8: Plan View of Analytical Model 3]



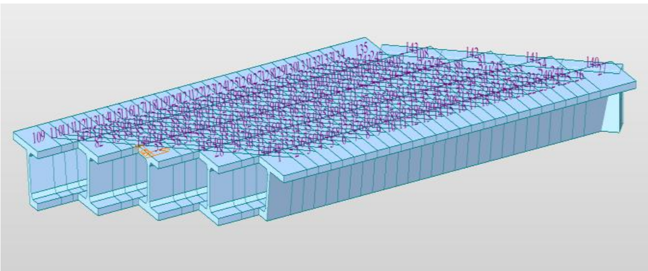
[Fig.9: Isometric View of Analytical Model 3]

D. Analytical Model 4:

- Span = 30 m
- Carriageway = 16 m
- Type of bridge = PSC box girder bridge skewed at 50 degrees.



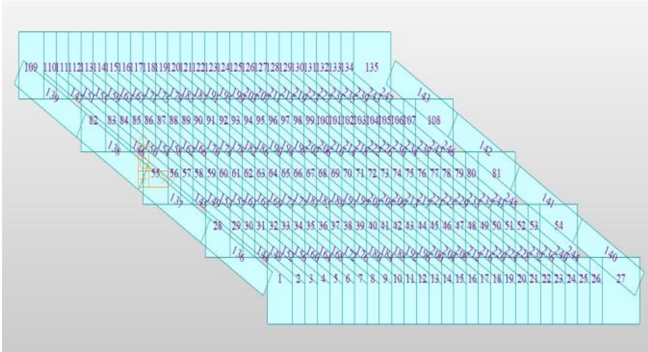
[Fig.10: Plan View of Analytical Model 4]



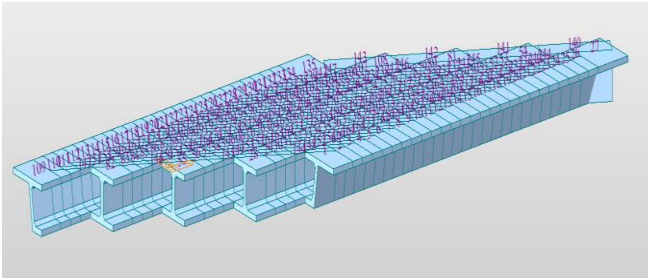
[Fig.11: Isometric View of Analytical Model 4]

E. Analytical Model 5:

- Span = 30 m
- Carriageway = 16 m
- Type of bridge = PSC box girder bridge skewed at 60 degrees.



[Fig.12: Plan View of Analytical Model 5]



[Fig.13: Isometric View of Analytical Model 5]

- The following are the material properties that are used in the model.

F. Concrete Properties

- Grade of concrete – M40 = 40 N/mm²
- Weight density – 25 KN/m3
- Modulus of elasticity - 3.1622e+07 KN/m²
- Poisson's ratio – 0.2
- Thermal coefficient - 6.6667e-06 1/[F]

G. Tendon Properties

- Type of pre-stressing - post-tensioning
- Duct Diameter – 0.1 m
- Pre-stressing Strand diameter = 12.7mm (0.5" strand)
- Number of strands – 19
- Total tendon area - 0.00187549 m²
- Ultimate strength - 1.87e+06 KN/m²
- Yield strength - 1.57e+06 KN/m²
- Curvature friction factor - 0.3
- Wobble friction factor – 0.004 1/m
- Anchorage slip – 0.006 m

H. Steel (Rebar) Properties

- Grade of steel - 550 N/m²
- Modulus of elasticity - 1.9500e+08 KN/m²
- Poisson's ratio - 0.3
- Thermal coefficient - 6.6667e-06 1/[F]
- Weight density – 76.98 KN/m3

V. METHODOLOGY

The study investigates a four-cell PSC box girder bridge skewed at different angles using MIDAS CIVIL software. MIDAS Civil has been used for modelling and analysis.

The following steps need to be followed to achieve our objective.

- A four-cell PSC box Using MIDAS CIVIL software, the girder bridge is skewed at different angles, with

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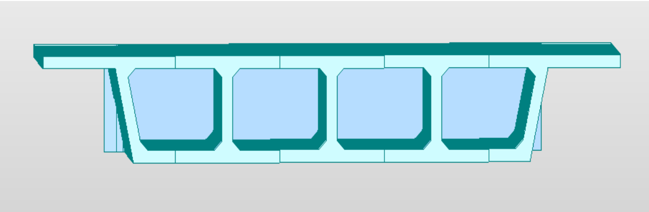
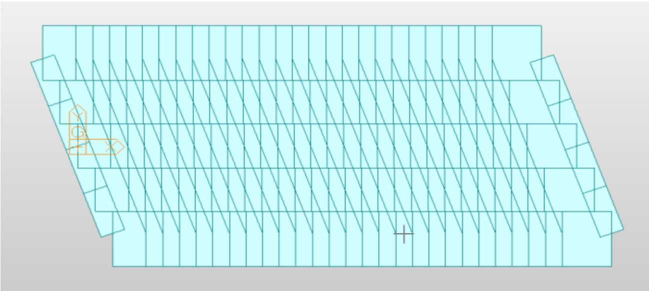
an interval of 10 degrees, varying from 20 to 60 degrees.

- The PSC box girder bridges are analysed for Dead load and live load, that is, moving load, by considering a vehicle of class 70R and class A type.
- The models mentioned above are analysed against two types of loading conditions, DL+LL and DL+LL under Seismic effect as per IRC 114:2018
- Define the cross-section of the PSC skew bridge.



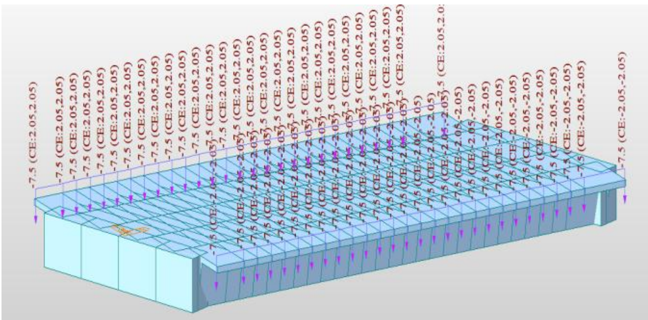
[Fig.14: Cross-Section of Girder]

- Divide the whole 30 m span of the bridge into finite elements that are 1m span.



[Fig.15: Plan of Skew Bridge]

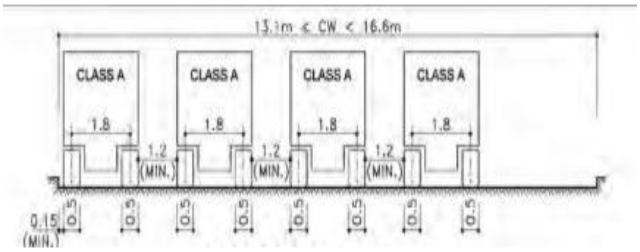
- In bridges, dead loads are generally considered in 2 terms, viz. Dead load of the Structural part of the bridge (DL) and the non-structural part of the bridge, which is generally referred to as superimposed dead loads (SIDL).
- DL means "Gravity loading due to structural parts of the bridge," or permanent gravity forces resulting from structural elements, make up DL. It can be computed as the product of material density and volume. Typically, the analysis software's self-weight option is used to apply self-weight to the analysis model.
- The density of reinforced concrete is taken as 25 KN/m^3
- SIDL is made up of "Gravity loading due to non-structural parts of the bridge," which includes other permanent components like road pavement and parapets, as well as other architectural and non-structural bridge attachments. Although these are long-term items, they may change over the structure's existence. It is computed as a combination of volume and material density, like self-weight.
- Dead load is taken as per IRC 6:2017, which suggests the unit weight of materials used for the construction.
- Crash barrier load is assumed as 7.5 KN/m over edges and middle of girder with eccentricity of 8m from the centre line of the girder.



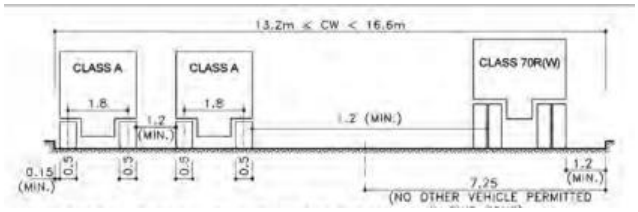
[Fig.16: Crash Barriers Loads Over Girder]

- The bridge's live load consists of moving loads along its entire length, such as cars and pedestrians; however, choosing one or a group of vehicles to build a safe bridge can be challenging.
- To provide safe results against any vehicle moving on the bridge, IRC 6:2017 suggested a few hypothetical vehicles as live loads.
- The vehicle loadings are categorised into the following types:.
- IRC class 70R loading.
- IRC class A loading

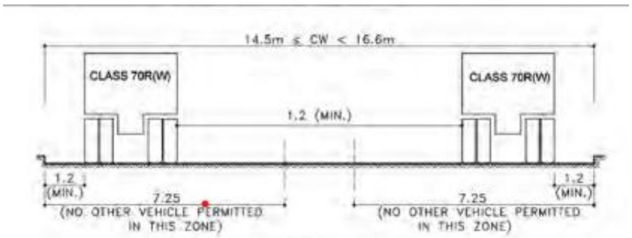
Regarding the carriageway width, which is 16m, the above bridge is designed for four lanes, as per Table 6A of IRC 6:2017, which produces 3 cases considering severe effects.



[Fig.17: CLASS A- 4 LANES]



[Fig.18: CLASS A- 2 LANE + CLASS 70R (W)]



[Fig.19: CLASS 70R (W) – 2 LANES]

- Response Spectrum Analysis (RSA) is a crucial technique in seismic analysis and design of bridges. It helps engineers evaluate their dynamic response to earthquake ground motions. Bridges, being flexible structures with multiple modes of vibration, require careful assessment of their seismic behaviour to ensure safety and functionality.

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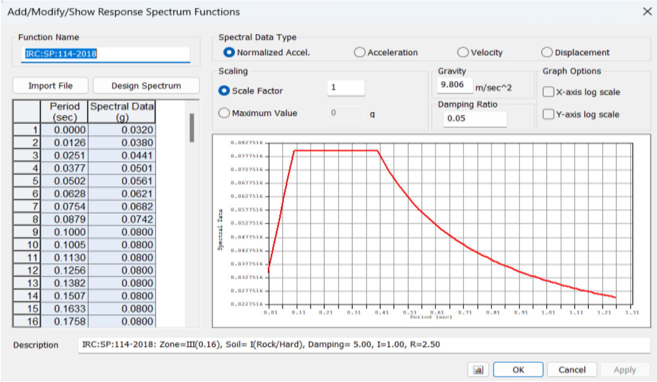
- Define Response Spectrum functions.



[Fig.20: Response Spectrum Functions]

Table-I: Earthquake Load Parameters

Parameters	Value	Reference
Considering the Earthquake zone III		
Zone Factor (Z)	0.16	Table 4.2 of IRC 114:2018
Importance Factor (I)	1	Table 4.3 of IRC 114:2018
Soil Type	1	Rock or Hard soils refer to Table 5.1 of IRC 114:2018
Response reduction factor	2.5	Table 4.1 of IRC 114:2018

Table-II: Support Condition

Bearing type	Elastomeric bearing
Stiffness coefficient for the restraint condition	10^6 to 10^7 KN/m
Stiffness coefficient for release condition	100 to 1000 KN/m

A.Period

The superstructure's vertical period is necessary for analysing vertical seismic action. It must be calculated independently using the formula below.

$$T_v = \frac{2}{\pi} l^2 \sqrt{\frac{m}{EI}}$$

Where,

L= span of bridge in meters.
M= Mass of bridge per unit weight (N-m)
EI= Flexural Rigidity of the superstructure in N-m^2

Table-III: For Models of 30m Span

Parameters	Values
Length of bridge (L)	30m
Cross-sectional Area of Bridge (A)	11.31953m^2
Density of Concrete (D)	25 KN/m^3
Mass of bridge per unit weight (m) = A*D	=11.31953*25 =282.988 KN/m
Flexural Rigidity of the superstructure (EI) E = 3.1622*10^7 KN/m^2 I = 2.974028*10^1 m^4	= E*I =940447134.16 KN.m^2

So, from the above formula of period, for a 30m Span, **Tv** = 0.3142

VI. RESULTS

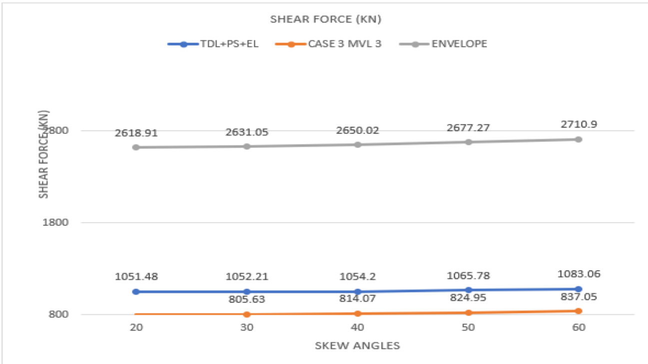
After performing the analysis on a 4-cell Prestressed skew bridge, considering all loadings as per IRC, the parameters such as Shear force, Torsion moment, bending moment, and Displacement are compared for various skew angles, varying from 20 to 60 degrees.

Certain load combinations from Table B-2 of IRC-6 2017 were defined in the model, which were analysed to compare the parameters mentioned above for different skew angles.

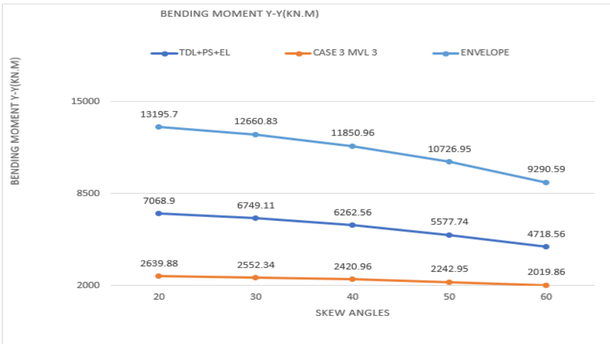
The following are the cases for which the load combination was defined.

[1] Total Dead load + Prestress
[2] Case 1: Moving Case 1[Class A 4 Lanes] + Prestress.
[3] Case 2: Moving Case 2[Class A 2 Lanes + Class 70R 1 lane] + Prestress.
[4] Case 3: Moving Case 3[Class 70R 2 Lanes] + Prestress.
[5] Envelope Case: TOT. DL, LL, PRESTRESS, TDL+LL+PS, MVL 1, MVL 2, MVL 3, [1] DL+LL, [2] DL+LL, [3] DL+LL, [4] DL+LL, [5] DL+LL, [6] DL+LL, [7] DL+LL, [8] DL+LL, [9] DL+LL+EL(CB), [10] DL+LL+EL(CB), [11] DL+LL+EL(CB), [12] DL+LL+EL(CB), TDL+PS(CB), TDL+PS+EL(CB)

A. Following Are the Results Shown in Graphical Format



[Fig.21: Comparison of Shear Force Values for Different Skew Angles]



[Fig.22: Comparison of Bending Moment Y-Y Values for Different Skew Angles]

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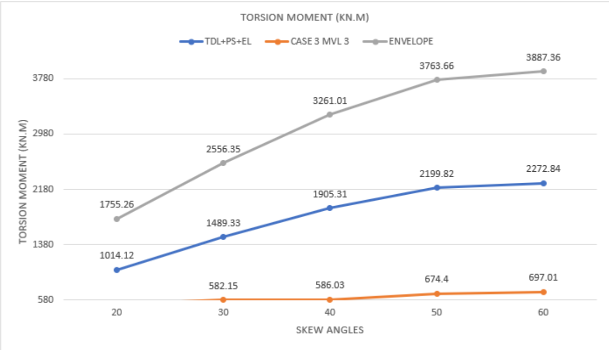
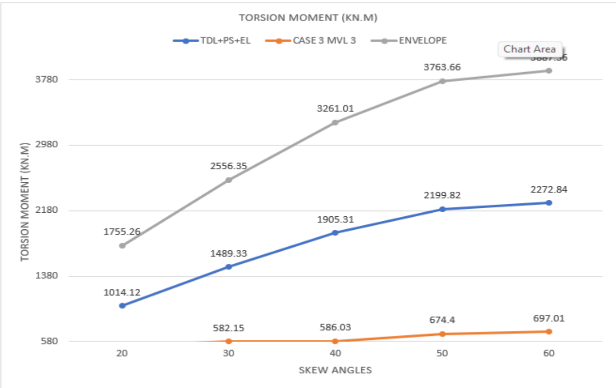
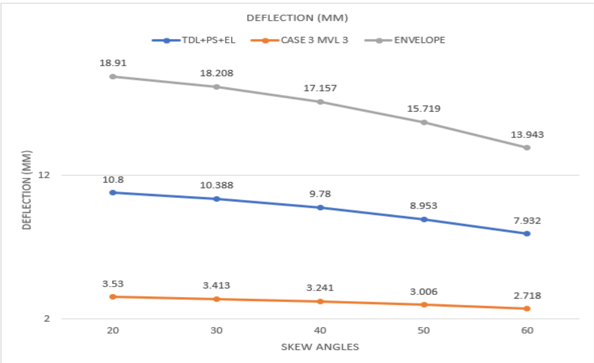


[Fig.23: Comparison of Bending Moment Z-Z Values for Different Skew Angles]



[Fig.24: Comparison of Torsional Moments Values for Different Skew Angles]



[Fig.25: Comparison of Deletion Values for Different Skew Angles]

VII. CONCLUSION

In the present study, an attempt is made to investigate the variations in forces and moments induced in prestressed bridges skewed at different angles, to examine the relationship between prestressing forces, material properties, and geometric parameters in skewed bridges. Various load conditions were considered, like dead loads, moving loads, and prestressing loads along with the certain load combinations as per IRC loading to observe structural parameters such as bending moments, shear forces, torsional effects, and deflection to obtain overall stability and safety of prestressed skew bridges under the impact of seismic conditions.

The following are the conclusions obtained based on the analysis of the prestressed skew bridge:

A. The results mentioned above are primarily observed regarding three cases: Total dead load + Stress, moving load Case 3, which governs out of 3 MVL Cases, and Envelope.
B. The Shear force in the bridge increased gradually as the skew angle increased. It increased by 3.51% to 60° from 30°.
C. The Bending moment Y-Y decreased as the skew angle increased, and a reduction of 29.59% was observed.
D. The Bending moment Z-Z gradually increased from 20°to 60° by 9.70% as the skew angle increased.
E. The significant impact was seen in torsional moments, as it is increased by almost 121.47% from 20° skew to 60° skew. This is mainly due to increased eccentricity in the transverse direction, as the supports are not aligned in the same line.
F. In the case of deflection, its value kept on decreasing as the skew angle increased; a considerable reduction of 26.26% was observed.

FUTURE SCOPE

A. In the present study, a comparative analysis is carried out on five models of a four-cell prestressed skew bridge with skew angles from 20 to 60 degrees for a 30m span only under seismic conditions. Further studies can be carried out for different spans as well, like 45m and 60m, so there can be a comparative analysis that concludes which span is optimal for skew bridges.
B. In this study, all models were compared on parameters like shear force, bending moment, torsional moments, and deflection for 30m spans only. The study could be extended by including various other parameters, such as the modal participation factor and nodal forces for each earthquake load case.

DECLARATION STATEMENT

After aggregating input from all authors, I must verify the accuracy of the following information as the article's author.

- **Conflicts of Interest/ Competing Interests:** Based on my understanding, this article has no conflicts of interest.
- **Funding Support:** This article has not been sponsored or funded by any organization or agency. The independence of this research is a crucial factor in affirming its impartiality, as it was conducted without any external influence.
- **Ethical Approval and Consent to Participate:** The data provided in this article is exempt from the requirement for ethical approval or participant consent.
- **Data Access Statement and Material Availability:** The adequate resources of this article are publicly accessible.
- **Author's Contributions:** The authorship of this article is contributed equally to all participating individuals.

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