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Design and Analysis of Grade Separator

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Abstract - *This present work focuses on the application of the finite element method to analyze skew slab bridges found in grade separators. The analysis employs various elements, including brick elements and shell elements, and utilizes the SAP 2000 software package for finite element formulation. The modeling approach presented in this study is adaptable for a wide range of skew angles and aspect ratios in slab bridges.*

To comprehensively assess the behavior of these structures, the analysis incorporates different types of I.R.C. loadings, such as Class AA Tracked and Class A, along with considering various live load positions. This approach enables the determination of maximum stress levels within the slab.

Through a detailed analysis and parametric study, valuable insights for analyzing skew bridges have been obtained. The primary parameters under consideration include the skew angle, span length, and bridge width. The conclusions of this study offer practical guidelines for the efficient analysis of skew slab bridges, making the results particularly valuable for design engineers engaged in the analysis of such structures.

Key Words: Grade separators, Concrete

1. INTRODUCTION

Grade separators, also known as flyovers, overpasses, or interchange bridges, are prominent features in modern urban landscapes. These structures serve a crucial role in transportation infrastructure by effectively separating conflicting traffic flows, thereby enhancing traffic flow, reducing congestion, and improving road safety. Throughout this comprehensive exploration of grade separators, we will delve into their history, design, engineering, environmental impacts, societal implications, and future trends, shedding light on their multifaceted significance in contemporary society.

A grade separator, also known as a flyover, overpass, or interchange bridge, is a type of transportation infrastructure designed to separate conflicting traffic flows or modes of transportation at different elevations. It is essentially a bridge-like structure that allows vehicles or pedestrians to pass over or under another roadway or railway line without any at-grade intersections or crossings. Grade separators are employed to improve traffic flow, enhance road safety, and reduce congestion in areas where multiple roads, railways, or pedestrian pathways intersect.

The evolution of transportation infrastructure has been marked by numerous innovations aimed at improving the efficiency, safety, and overall functionality of our roadways and railways. One such innovation that has played a significant role in this evolution is the skew grade separator, also known as a skewed bridge or skewed intersection. These specialized structures are designed to accommodate intersections and railway crossings at oblique or non-orthogonal angles, a feature that distinguishes them from traditional perpendicular crossings. This essay delves into the history, significance, design principles, benefits, and notable examples of skew grade separators to understand their profound impact on modern transportation infrastructure.

1.1. Grade separators come in various forms, including:

Overpasses: These structures elevate one road or railway over another, allowing traffic on the upper level to bypass the lower level.

Underpasses: In contrast to overpasses, underpasses allow traffic on the lower level to pass beneath the upper level. They are often used in situations where space constraints or aesthetics are considerations.

Interchanges: These complex grade separator systems involve multiple ramps, lanes, and connectors to facilitate the efficient movement of vehicles between intersecting roads or highways.

Objectives of present work

- To survey about skew bridges in grade separator
- To survey why skew bridges are more useful in grade separator
- To investigate load calculations of different angles of skew bridges.
- To study why now a day’s grade separator is essential part of road construction.

Case Studies

To better understand the practical application and impact of grade separators, let's examine a few notable case studies from around the world.

1. Spaghetti Junction, Birmingham, United Kingdom

Spaghetti Junction in Birmingham, UK, is an iconic grade-separated interchange that connects several major motorways. Its complex web of ramps and bridges allows for the efficient flow of traffic in a heavily congested urban area. The interchange has significantly improved traffic conditions in the region and serves as a testament to the effectiveness of grade separators in managing traffic in busy urban environments.

2. Marine Drive Flyover, Mumbai, India

The Marine Drive Flyover in Mumbai is a vital grade separator that has eased traffic congestion along the city's famous Marine Drive waterfront. This elevated structure not only enhances traffic flow but also provides unobstructed views of the Arabian Sea, preserving the scenic beauty of the area. It demonstrates how grade separators can balance the functional needs of transportation with aesthetic considerations.

3. Tom Moreland Interchange (Spaghetti Junction), Atlanta, USA

The Tom Moreland Interchange, known locally as "Spaghetti Junction," is a massive grade-separated interchange in Atlanta, Georgia. It connects several major highways and is renowned for its intricate design. Despite its complexity, this grade separator has significantly improved traffic conditions in the region, showcasing the ability of such structures to address the demands of a sprawling urban area.

4. M. Previous Research of SKEW angles in G.S.

Over the last thirty years, the finite element analysis method has gained significant popularity as an efficient and effective technique for assessing box-girder bridges, skew bridges in grade separator. Numerous researchers have undertaken studies on skew bridges using the finite element method during this period.

2. LITERATURE REVIEW

Mallikarjun, I. G et al. [2015], has studied about Influence of skew angle on static Behaviour of RCC and PSC Slab Bridge Decks in this literature and he concluded that as the skew angle increases the shear force also increase, and it goes upto 25% to 30%.

Sindhu, B. V et al. [2013]. Has studies about the effect of Skew Angle on the Static behaviour of Reinforced Concrete Slab Bridge and the test results demonstrated that shear force increases.

Abozaid, L. A et al. (2014) has studied about Nonlinear Behaviour of a Skew Slab Bridge under Traffic Loads by the method of fem.

Dhar, A., Mazumder et al. [2013], has researched on the Effect of Skew Angle on Longitudinal Girder and Deck Slab of an IRC Skew Bridge by the method of Finite Element Analysis.

Vikash Khatri, and P. R. Maiti, [2012] studied about Analysis of skew bridges using Computational Methods.
Arindham Dhar, et al. , have studied about Effect Of Skew Angle On Longitudinal Girder (Support Shear, Moment, Torsion) And Deck Slab Of An Irc Skew Bridge by using FEM method.

In the years 1985 and 1986, Balendra and Shanmugam conducted research that delved into the analysis of the natural vibration behavior of multi-cell structures characterized by straight configurations, featuring both solid web sections and web sections containing openings.

In 1992, Kashif introduced a finite-element methodology for evaluating the dynamic behavior of multiple box-girder bridges supported in a simply supported manner, taking into account the interaction between the bridge and moving vehicles.

Let's consider one example for the calculation of the load of following details:

Table - 1

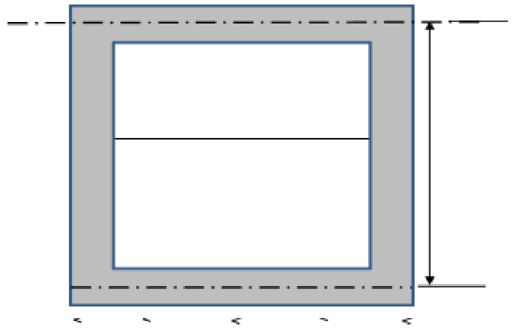
Thickness of Top Slab (at middle) =	1.000 m
Thickness of Top Slab at Joint=	1.200 m
Thickness of Side wall =	1.000 m
Thickness of Bottom slab =	1.000 m
Clear span =	14.650 m
Maximum Clear height of box =	5.497 m
Centre to centre distance of Side wall=	15.871 m
Maximum Centre to centre height of wall =	6.497 m

3.BASIC DESIGN DATA

The project aimed to investigate how the skew angle affects the design of a composite superstructure for a bridge. We created six different models, each representing a bridge with spans of 0m, 3.565m, 7.130m, 10.695m, 14.260m and 14.500m. These models were analyzed at skew angles of 0°, 10°, 20°, 30°, 35, 40°, and 50°.

Table - 2

Size of Box Culvert =	12 m x 4.712 m
No. of cells :	1 Nos.
Skew angle :	35 °
Thickness of Wearing Coat =	0.065 m
Total Width of Culvert=	14.500 m
Width of Crash Barrier=	0.500 m
Carriage way Width=	13.500 m
Length of Side wall = Seismic zone of the LVUP location:	17.70 m



Using Finite Element Analysis (FEA), we obtained and presented the results in terms of key structural response parameters, including longitudinal bending moment, shear force, and torsional moment. These parameters were evaluated under the influence of both dead load and applied live load.

The findings illustrate how the behavior of the structure varies as the skew angle changes.

Table – 3. Shear Force Data

Skew angles in degrees	**Dead load**	**Class A loading**	**Class 70R loading**
0	1623.049	312.950	257.298
10	1623.122	314.195	245.105
20	1623.251	315.270	235.397
30	1623.499	295.251	219.308
35	1624.369	292.256	219.644
40	1624.211	289.211	220.160
50	1625.456	234.281	199.695

The maximum shear force caused by the dead load is nearly the same for all the skewed bridges. Under Class A loading conditions, the highest shear force occurs in the bridge with a 20-degree skew angle, and as the skew angle increases beyond 20 degrees, the shear force gradually decreases. Similarly, under Class 70R loading, the shear force also decreases as the skew angle increases.

Table – 4. Bending Moment

Skew angles in degrees	**Dead load**	**Class A Loading**	**Class 70R Loading**
0	11619.072	7480.221	5329.218
10	11591.985	7440.039	5568.971
20	11484.607	7394.080	5794.512
30	11241.328	7267.009	5837.364
35	11008.119	7092.0005	5837.6265
40	10776.002	6917.642	5838.189
50	9964.326	6187.022	5458.291

The highest bending moment caused by the dead load is observed in the bridge with a skew angle of 0 degrees. As the skew angle increases, the bending moment decreases. Similarly, under Class A loading conditions, the greatest bending moment is seen in the bridge with a 0-degree skew angle. However, for Class 70R loading, the maximum bending moment occurs in the bridge with a 30-degree skew angle.

Table – 5. Torsion Moment

Skew angles in degrees	**Dead load**	**Class A loading**	**Class 70R loading**
0	0.000	0.000	3279.009
10	94.661	430.229	3187.001
20	218.712	704.602	3040.201
30	385.669	776.181	2834.589
35	489.767	747.4435	2693.579
40	589.869	718.718	2558.554
50	809.217	726.361	2193.433

At a 0-degree skew angle in the bridge, there is no torsion induced by the dead load and Class A loading. As the skew angle increases, torsion also increases for both dead load and Class A loading scenarios. However, when it comes to Class 70R loading, the highest torsion is observed at a 0-degree skew angle, and as the skew angle increases, the torsion progressively diminishes.

4. RESULT AND DISCUSSION

Based on the analysis results of the various bridges with different skew angles, several conclusions can be drawn:

Bending Moment Trends:

(1) The bending moment due to dead load decreases uniformly as the skew angle increases by about 14%.

(2) Under IRC Class A loading and Class 70R loading, the bending moment also decreases with increasing skew angles, showing reductions of approximately 17% and 25%, respectively.

Shear Force Trends:

(1) The shear force due to dead load experiences a negligible increase of about 0.2% as the skew angle increases.

(2) For live load cases, the shear force varies significantly with skew angle:

(3) Under Class A loading, there is an approximately 25% increase in shear force.

(4) Under Class 70R loading, there is an approximately 22% decrease in shear force.

Torsion Effects:

(1) Torsion behaves differently based on loading conditions:

(2) Under Class A loading, torsion increases by about 68% with an increase in skew angle.

(3) Under Class 70R loading, torsion decreases by approximately 33% with increasing skew angles.

These conclusions provide valuable insights into how skew angles impact the structural response of composite superstructure bridges under various loading conditions

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