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STUDY OF BRIDGE SUPERSTRUCTURE USING FINITE ELEMENT METHOD

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Abstract
The widespread use of the digital computer has brought about a revolution in structural analysis techniques, which has generally been advantageous to engineers. However, this has made it difficult for engineers to make decisions when choosing the best approach to a problem. The need to construct bridges across wide rivers with alluvial and secure beds, deep gorges, open seas, and grade separators on urban highways necessitates the resolution of numerous engineering issues. Bridges are essential links in the communication system. Over the past two decades, bridge analysis and design have undergone significant transformations worldwide. Some of the reasons for these developments include an increase in the demand for intricate roadway alignments and advancements in computer technology for bridge analysis and design[1,2,3]. Typically the scaffolds are developed straight for effortlessness of development and plan, however once in a while the site condition for span is to such an extent that having straight bridge is beyond the realm of possibilities. In such a case, the skew or curve bridge must be built. The analysis of a straight bridge is relatively simple, whereas the analysis of a skew or curve bridge is somewhat challenging. Computer programs that incorporate a variety of analysis techniques, such as finite element analysis, are used in the process of skew or curve bridge analysis [4,5].

Introduction

In any nation, a bridge is an essential communication link. A bridge helps the area grow and opens up previously inaccessible areas. Every year, a large[6] number of bridges are built. Engineers are finding it increasingly difficult to develop novel structural forms and suitable materials due to the variety of locations. Equally quickly, the use of computer methods has accelerated the development of analysis methods. Curved bridge decks are being used a lot because of the limited space and the way the traffic system skew is aligned[7,8]. Skew, curved, and continuous spans are becoming increasingly difficult due to the availability of microcomputers. In the past, the development of design methods required a significant amount of theoretical and experimental research. Today, a number of design techniques have been refined to the point where they are usable. With an understanding of physical behavior, designers can now examine intricate decks without resorting to intricate mathematical concepts[9].

The concept of conceptually breaking down a whole into its constituent parts in order to gain insight into the whole is implied by the word analysis. The analysis is typically referred to as force analysis in the field of structural engineering; a procedure by which the distribution of force effects or responses, like deflections and bending moments, in various[10,11] parts of the structure is determined. Strength analysis, which refers to the process of determining the strength of a structure as a whole or its components, is another less common term in structural engineering.

Bridge Classification

A bridge's function, construction material, type of superstructure, plan geometry, support conditions, and span all play a role in determining its classification.Because this section primarily focused on the analysis of highway bridge decks, [12] the primary factors that govern and influence the selection of analytical techniques are only identified.These are:

1. Deck type or construction type
2. Plan geometry or form and
3. Support conditions

Purpose of Study

The purpose of this work is to investigate how various parameters—such as loading conditions and load position, skew angle, sectorial angle, aspect ratio, and curved slab angle—affect the behavior of skew slab, skew girder, and curved slab bridges[13,14]. As immediate scientific arrangements strategies are not accessible to examine slant and bended chunk span, limited component examination strategy utilizing SAP 2000 programming is utilized to concentrate on something similar. The primary objective of studying the skew slab bridge is to investigate both the maximum bending moment and deflection on the skew slab bridge and how the skew angle affects various quantities like shear force and torsional moment variation at the bridge's corner locations. The purpose of analyzing a curved slab bridge is to investigate the influence of aspect ratio and sectorial angle on a variety of parameters, including span moment, torsional moment, and deflection. With the goal of determining how skew angle affects longitudinal girder parameters like deflection, shear force, [15]and bending moment, girder type bridges are studied. The results of various available analytical solutions are compared to those of the finite element method. Comparing the results of the grillage analogy method and those of the finite element analysis is another objective of the study of skew girder bridges.

Experimental Work

Finite Element Modeling ofBridge Superstructure

Elements and Objects

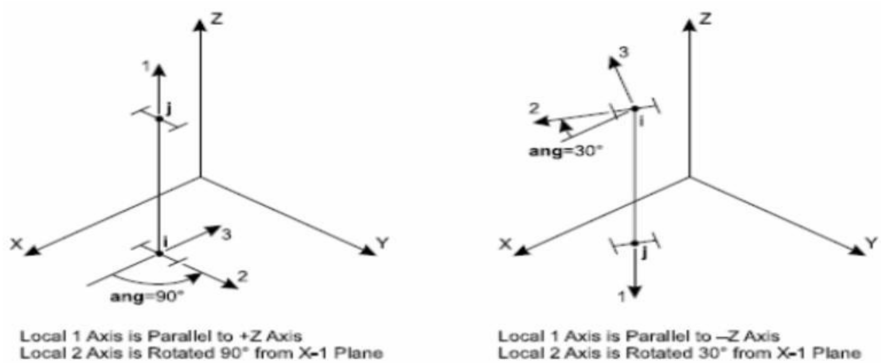
In a SAP2000 model, objects are used to represent the actual structural members. To completely define the model of the physical member, one can use the graphical user interface to "draw" the object's geometry, then "assign" properties and loads to the object. There are a variety of objects to choose from, arranged by geometrical dimension[16].

Objects: These can be explicitly added to model supports or other localized behavior, and they are automatically generated at the corners or ends of all other types of objects below.

Link objects: with one joint used to simulate the behavior of special support elements like isolators, dampers, gaps, and multi linear springs, among others.

Cable and frame objects: used to model braces, trusses, cable members, columns, beams, and other connecting (two-joint) link objects: used [17,18]to simulate the behavior of special members like isolators, dampers, gaps, and multi linear springs, among others. Connecting link objects, in contrast to frames and cables, can have no length at all.

Area objects: used to model two-dimensional solids (plane stress, plane strain, and axisymmetric solids), as well as thin-walled members like floors and walls.



Solid things:used to model solids in three dimensions.

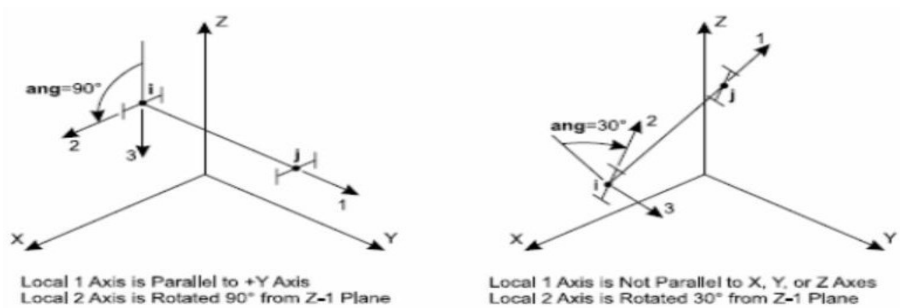


Fig.1 The Frame Element Coordinate Angle With Respect to Default Orientation

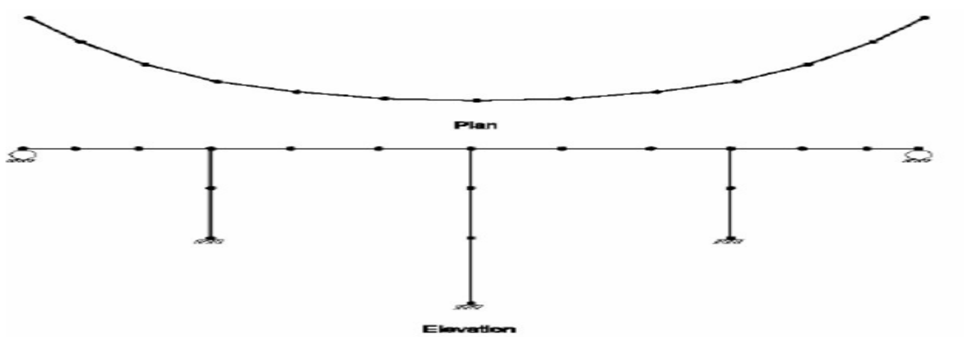
A straight line that connects two points is how a Frame element is modeled. Depending on the user's specifications, curved objects can be divided into multiple straight objects in the graphical user interface. For interpreting output and defining section properties and loads, each element has its own local coordinate system. Self-weight, multiple concentrated loads, and multiple distributed loads can all be used to load each Frame element. At its two connected joints, the Frame element activates all six degrees of freedom.

Analysis of Bridge

In order to calculate influence lines for traffic lanes on bridge structures and examine these structures for the response caused by vehicle live loads, bridge analysis can be carried out. The response of bridge structures to the weight of vehicle live loads can be assessed using bridge analysis. The maximum and minimum displacements and forces resulting from multiple-lane loads on complex structures like highway[19,20] interchanges can be determined with a lot of power and flexibility. The response envelopes can be calculated by combining the effects of vehicle live loads with those of static and dynamic loads. Frame elements represent the superstructure, substructure, and other relevant parts of the bridge that will be analyzed. Vehicle live loads can have an effect on displacements, reactions, spring forces, and internal forces of the frame elements. It is possible to use other element types, including NL Link, Shell, Plane, and Solid, which all contribute to the structure's stiffness but are not analyzed for the effect of vehicle load. On the superstructure, there are lanes that show where the live loads can move. Complex traffic patterns can be considered even if these lanes are not parallel or of the same length.

Modeling of Bridge Superstructure using Frame Elements

In straightforward situations, define a "two-dimensional" model with piers and supports represented by vertical elements and the superstructure and roadway represented by longitudinal elements. These Frame elements need not all be in the same plane in order to be used in curved bridge structures. Fig. The frame element-based curve bridge model is demonstrated in 3.3. The bents and other features could also be modeled with elements oriented in the third, transverse



direction. The internal forces and moments of the frame elements will be reported in the Bridge Analysis results, which can then be used to design the actual sections. Only those elements that are specifically requested will have their moving-load response calculated.

Fig..2-Frame Element as a Bridge Superstructure

Straight Slab Bridge

In order to model a slab bridge, the values of the material properties and element properties must be entered, as shown in the modeling of a straight and skew bridge slab bridge illustration. Take the length of the bridge as 10 meters, the width as 5 meters, and the thickness of the slab as 1 meter. The concrete's density is 25 kN/m3, the poission ratio is 0.2, and the material property of the deck slab is assumed to be 25000000 kN/m2. Additionally, use the 10 kN/m2 UDL for a single load case.

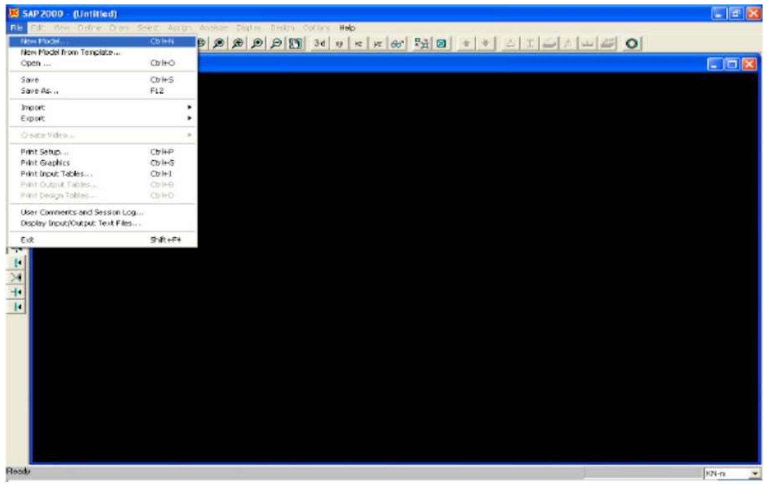


Fig.3 Starting with SAP2000

Now, to mesh frame elements, select the frame element, click the edit menu, and then select Divide Frames with the pointer. A dialogue box titled Divide Selected Frames will appear, as shown in Fig. 3.38. Four frame elements must be separated from selected frame elements; Therefore, enter Divide into 4 and select "1" in the dialogue box, then select "OK." The bridge will be analyzed after the frame elements are divided into four equal parts. A similar process will be followed for the other frame elements.

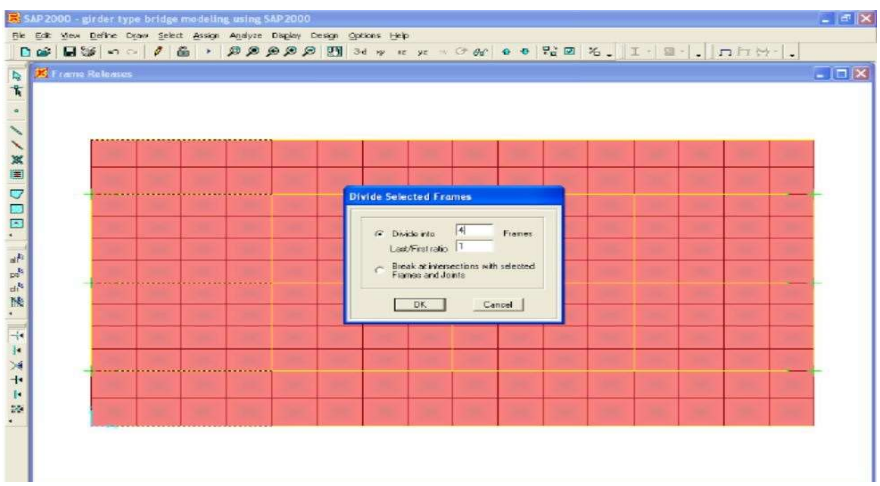


Fig. 4 Meshing of Frame Element

Summary

The SAP2000 software for bridge and building structure analysis is a very effective finite element program. SAP2000 is software that is easy to use. This software uses the shell element to model the deck slab and the frame element to model the girder. The quadrilateral shell element serves as a deck slab when modeling a curve slab bridge in the cylindrical coordinate system. Shell element mashups are simple. For the simple support end of a girder, assign frame release is used to perform partial release of moments.

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Finite Element Modeling & Analysis of Skew Slab Bridge

4.1 Behavior and The Characteristics of Skew Slabs

A rectangular slab bridge deck typically exhibits longitudinal and transverse flexure orthogonality. The most important times are also in the direction of traffic and in the normal traffic direction. The slab primarily bends along the line connecting the obtuse angled corners in skew slabs, where the force flows through the strip of area connecting the obtuse angled corners. The ratio of the skew span to the width of the deck (aspect ratio) determines the width of the primary bending strip. The areas on either side of the strip only transfer the load as a cantilever to the strip rather than directly to the supports. As a result, the skew slab experiences twisting moments. The significance of this pivotal moment cannot be overstated. The principal moment direction also changes as a result, and this is a function of the skew angle. Skew has a significant impact on the deck's behavior as well as important design stresses.

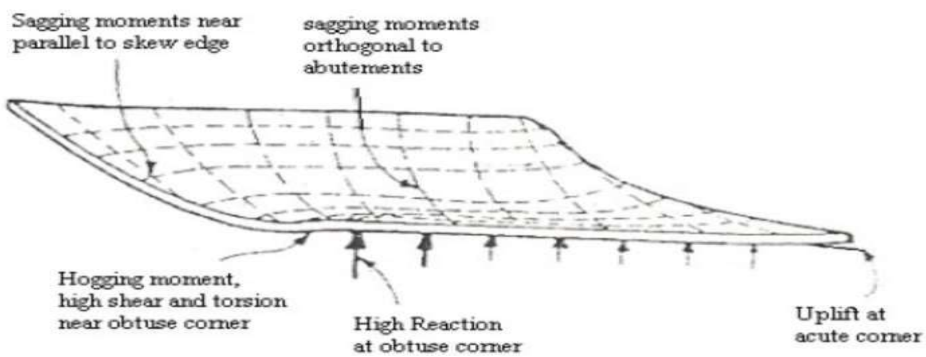

Fig.5 Characteristics of a Skew Slab Deck

Shear force distribution on straight and skew bridge

The shear force distribution at the four corners of the skew slab bridge varies with the skew angle. The shear force variation of a straight slab bridge at 510 meshing and 4080 meshing is depicted in Figs. 4.4 and 4.5, respectively. The shear force variation for a 20° skew slab bridge at 510 meshing and 4080 meshing is depicted in Figs. 4.6 and 4.7. Shear force is measured in kN per unit length.

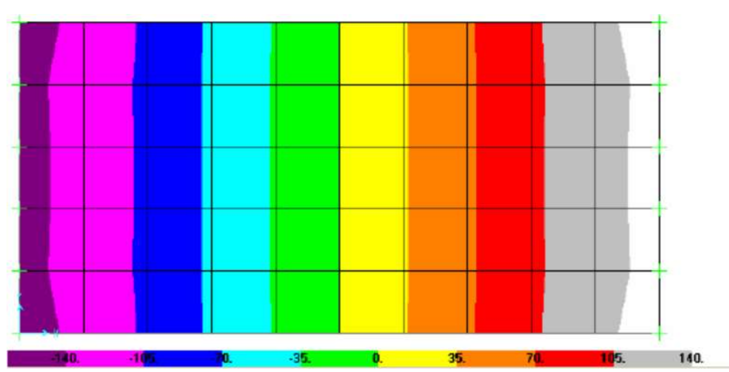

Fig.6 Shear force variation on straight bridge at 5 x 10 meshing

Result comparison

The straight slab bridge is idealized as a beam component for the purpose of comparing the outcome. The SAP result is contrasted with the result of just supporting beam elements like shear force and bending moment.

The bending moment and shear force are measured in kN-m/m. According to simple beam theory, the shear force is 175 kN/m, and the bending moment is 437.5 kN-m/m. Corner 1 is an obtuse corner, and Corner 2 is an acute corner.

Table 1 Result of shear force and bending moment for straight bridge by SAP2000

Sr. No.	Meshing	Shear force	Bending moment
1	5×10	150.99	445.27
2	10×20	158.61	445.44
3	20×40	162.15	445.48
4	40×40	163.78	445.49

Table 2 Shear force comparison in kN/m

Sr. No	Skew angle	Acute corner				Obtuse corner			
		Meshing				Meshing			
		5×10	10×20	20×40	40×80	5×10	10×20	20×40	40×80
1	0	150.99	158.61	162.15	163.78	150.99	158.61	162.15	163.78
2	5	133.55	133.12	128.59	122.18	173.89	195.34	218.31	249.98
3	10	118.93	112.89	104.37	96.14	205.96	252.46	319.19	433.24
4	15	105.40	94.54	82.93	73.07	252.13	342.87	497.75	796.48
5	20	91.99	76.70	62.29	50.37	318.72	483.81	800.09	1460.68

Result comparison

Straight bridge results and beam theory results are contrasted. Results for maximum deflection, maximum shear force, maximum bending moment, and maximum skew angle are compared. Deflection is measured in mm, shear force is measured in kN/m, bending moment and torsional moment are measured in kN-m/m. Corner 2 = 3, and Corner 1 = 4 (acute corner) (obtuse corner).

SAP2000 calculates shear force as 135.80 kN/m and

Bending moment as 404.21 kN-m/m

Shear force = 145 kN/m,

Bending moment = 324.5 kN-m/m in a straightforward beam theory.

Table 3 Result Comparison

Skew angle	Shear force		Torsional moment		Bending moment	Deflection
	Acute corner	Obtuse corner	Acute corner	Obtuse corner		
0	135.80	135.80	38.60	38.60	404.21	1.98
5	99.87	193.62	21.30	62.81	403.85	1.99
10	74.33	292.81	9.99	94.59	402.71	2.01
15	54.63	464.38	3.35	133.66	401.03	2.06
20	39.22	753.74	-0.04	179.06	399.25	2.13

Conclusion

The purpose of this investigation is to examine how various parameters affect the behavior of the bridge by performing a finite element analysis of a variety of bridge superstructure configurations. Slab bridges and girder bridges are the two types of bridges that are taken into consideration for this study. Skew and curved slab bridge are the two types of configurations that can be used in slab bridge. The skew configuration of the bridge is chosen for the girder type of bridge. The SAP2000 software is used for the analysis. The various issues that were investigated are outlined below.

The skew slab bridge has a span of 10 meters, a width of 5 meters, and a slab thickness of 1 meter. Both the straight bridge and the skew bridge are modeled for the slab bridge. The skew angle can be anywhere from 0° to 20°. The uniform load case and the vehicle load case are the two load scenarios that are being considered. The load intensity in the uniform load case is 10 kN/m2. The bridge is loaded with a class-AA tracked and wheeled vehicle in the vehicle load case. In the case of a class-AA tracked vehicle, two positions are taken into consideration: near the support and in the middle of the span. The bridge that is subjected to wheeled vehicles of class AA is located halfway across the span

The following conclusions are derived from the completed work.

1. As the skew angle increases, the obtuse angled corner of a skew slab bridge experiences a significant increase in both torsional moment and shear force. As the skew angle rises, low shear forces are thrown toward the corners with acute angles.

2. low torsional moment or the possibility of uplift at the corners of the acute angle as the skew angle grows.

3. The mid-span deflection in skew slab bridges goes up as the skew angle goes up.

4. When compared to bridges with higher aspect ratios, those with a lower aspect ratio are more likely to exhibit deflection, span moment, and torsional moment.

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