Finite Element Analysis of Skew Girder Type Bridge

Nilang D. Leua[a], Vatsal V. Yagnik[a] and Paresh V. Patel[b]

[a]Nirma University, Ahmedabad
[b]Institute of Technology, Nirma University, Ahmedabad

Abstract—**Bridges form vital links in the communication system. Normally the bridges are straight for simplicity of construction and design, but sometimes the site condition for bridges is such that it is not possible to have straight bridge. In such case it is necessary to construct the skew or curved bridge. The analysis of straight bridge is relatively easy but the analysis of skew bridge is somewhat difficult. In present paper girder Type Bridge is analyzed for different skew angles varying form 0° to 20° by finite element method and grillage analogy method. The variation of shear force and bending moment obtained by both the methods are compared. For the analysis of bridge girder finite element based software SAP 2000 computer program is used for both the methods.**

Index Terms—**Skew Bridge, finite element analysis, grillage analogy.**

I. Introduction

Girder type deck slab generally comprises of longitudinal girder, cross girders and continuous deck slab.

In the present study deck slab is analysis by grillage analogy and Finite Element Method for two types of loading as

- Uniform Deal load
- Vehicular Load
  - Class AA-tracked
  - Class AA-Wheeled

Vehicles are placed at mid span for maximum bending moment condition and at support for maximum shear force condition.

A. Grillage Analogy Method

In a grillage analysis [1], the structure is idealized as a number of longitudinal and transverse beam elements in a single horizontal plane and rigidly interconnected at nodes. Transverse beams may be orthogonal or skewed with respect to the longitudinal beams, so the skew, curved tapered or irregular decks can be analyzed.

In simple grillage analysis each beam is assigned a flexural stiffness in the vertical plane and a torsional stiffness. Vertical loads are applied at the nodes. If loads are not acting directly at a node they are converted into equivalent nodal loads by some mechanics. For the analysis computer software is used to determine the displacements at each node and the force in the beams connected to each node.

Grillage analysis does not determine warping and distortional effects, as well as the effects of shear lag. Local effects under wheel loads can only be studied with a grillage analogy by the use of a fine mesh of beams locally in the region of load. Local effects are usually determined separately and added to global results as required.

General steps for grillage analogy method are as:

1. Idealization of physical deck into equivalent grillage, i.e. grid of longitudinal & transverse beams.
2. Evaluation of equivalent elastic inertia of members of grillage
3. Application and transfer of loads to various nodes of grillage
4. Determination of force responses and design envelopes
5. Interpretation of results

B. Finite Element Method

In a FEM analysis [2], deck slab is discretized in finer mesh of quadrilateral element. The longitudinal girder and transverse girder are modeled by frame elements. The nodal connectivity of each frame and shell element is done. This model is analyzed in SAP2000.

Finite element model of typical slab bridge is shown in figure 1.

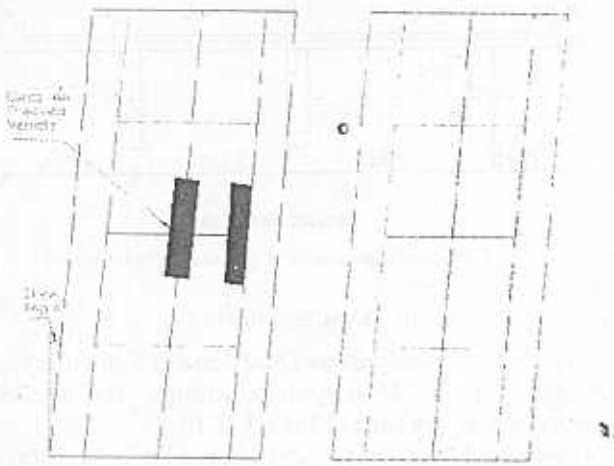

Fig. 1: Finite element model of skew bridge with position of vehicle

The bridge is made skew at an angle varying form 0° to 20°, modeled in SAP2000 [3] with finer mesh and analyzed for all skew angles at an interval of 5 degree.

II. Detail of Bridge Deck Under Study

The cross section of deck is shown in figure 2. Kerb beam is of 600*500 mm. Main girders are 1400 × 300 mm and crossbeams are of 1400 × 300 mm.

Cross girders are provided at 4 m c/c in 16 m span. Total 5 cross girders are provided two at each end, two at quarter span on either side and one at mid span.

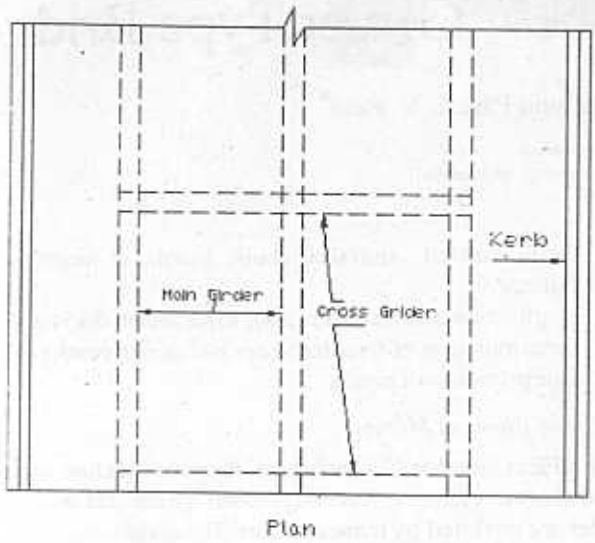

Fig. 2: Plan and cross-section of deck under consideration

III. Analysis Results

The girders are analyzed for Dead load and Vehicular load by both the method FEM & Grillage analogy. The results are obtained and are tabulated in Table I, II, III.

Here in result maximum bending moment and shear force are tabulated for each case.

TABLE I
ANALYSIS RESULTS FOR DEAD LOAD

Skew Angle	Girder No.	Bending Moment (KN m)		Shear Force (KN)	
		FEM	Grillage	FEM	Grillage
0	1	1149.01	1107.01	-276.60	-263.66
	2	1159.66	1123.75	-251.37	-249.03
	3	1149.01	1107.01	-276.60	-263.66
5	1	1154.77	1114.51	-278.90	-263.56
	2	1165.49	1131.46	-251.51	-249.71
	3	1154.77	1114.51	278.84	263.56
10	1	1172.25	1136.10	-281.27	-264.45
	2	1183.27	1158.24	-251.95	-249.67
	3	1172.25	1136.10	281.21	264.45
15	1	1202.30	1175.58	-283.59	-267.02
	2	1213.81	1198.90	-252.73	-253.97
	3	1202.30	1175.58	283.53	267.02
20	1	1246.38	1234.07	-285.63	-271.28
	2	1258.61	1259.10	-253.90	-260.25
	3	1246.38	1234.07	285.63	271.28

TABLE II
ANALYSIS RESULTS FOR VEHICULAR LOAD
(CLASS AA TRACKED VEHICLE)

Skew Angle	Girder No.	Bending Moment (KN m)		Shear Force (KN)	
		FEM	Grillage	FEM	Grillage
0	1	1576.05	1587.95	-378.55	-309.40
	2	2077.52	2118.43	-526.12	-559.40
	3	2463.29	2481.40	-566.54	-466.50
5	1	1583.36	1590.03	-377.82	-308.74
	2	2086.10	2075.06	-522.83	-518.65
	3	2473.85	2366.40	-563.90	-468.91
10	1	1609.47	1556.14	-378.00	-316.42
	2	2111.18	2062.23	-482.03	-533.89
	3	2502.73	2374.03	-544.33	-480.74
15	1	1674.10	1570.15	-374.35	-320.98
	2	2116.83	2139.88	-478.04	-523.78
	3	2482.56	2524.85	-532.37	-491.42
20	1	1709.97	1646.34	-390.42	-326.20
	2	2114.45	2230.46	-418.19	-516.36
	3	2414.15	2661.69	-511.75	-501.06

TABLE III
ANALYSIS RESULTS FOR VEHICULAR LOAD
(CLASS AA WHEELED VEHICLE)

Skew Angle	Girder No.	Bending Moment (KN m)		Shear Force (KN)	
		FEM	Grillage	FEM	Grillage
0	1	1278.55	1243.29	-245.50	-268.23
	2	1442.85	1400.21	-238.97	-303.54
	3	1536.25	1492.70	-287.61	-290.90
5	1	1285.57	1250.99	-307.76	-269.13
	2	1449.77	1409.36	-332.41	-304.76
	3	1542.55	1502.89	-284.97	-295.23
10	1	1306.96	1262.53	-308.65	-270.10
	2	1470.85	1439.36	-335.52	305.52
	3	1561.69	1541.85	-273.90	-304.77
15	1	1343.73	1303.90	-305.52	-273.52
	2	1507.00	1485.23	-336.38	-309.89
	3	1589.37	1591.22	-256.53	-314.01
20	1	1397.68	1365.22	-306.97	-278.57
	2	1559.90	1552.72	-260.15	-315.89
	3	1641.82	1663.57	-225.13	-325.64

The above results are combined as follows for design purpose:

- DL + Vehicular Load (Class AA Wheeled)
- DL + Vehicular Load (Class AA Tracked)

The design bending moment and shear force for external and internal girders are calculated and compared as obtained by finite element (FEM) and grillage analogy (GA) methods. The results are presented Fig. 3 to 6.

A. Comparison of Bending Moment

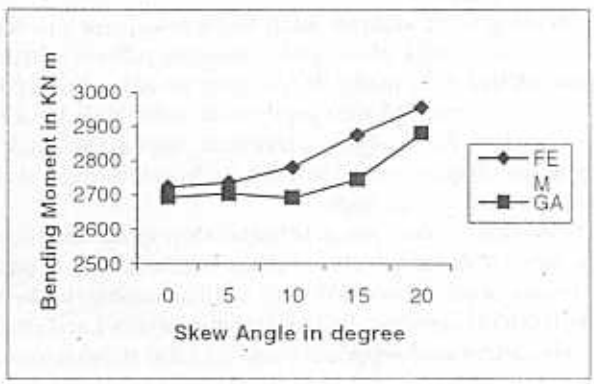

Fig. 3: Bending Moment in External Girder

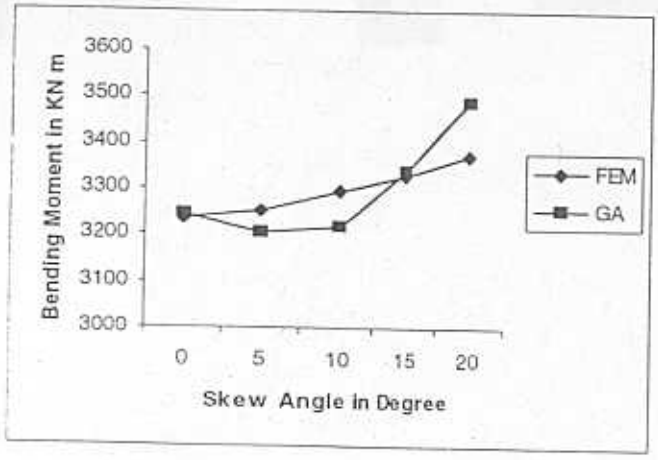

Fig. 4: Bending Moment in Internal Girder

B. Comparison of Shear Force

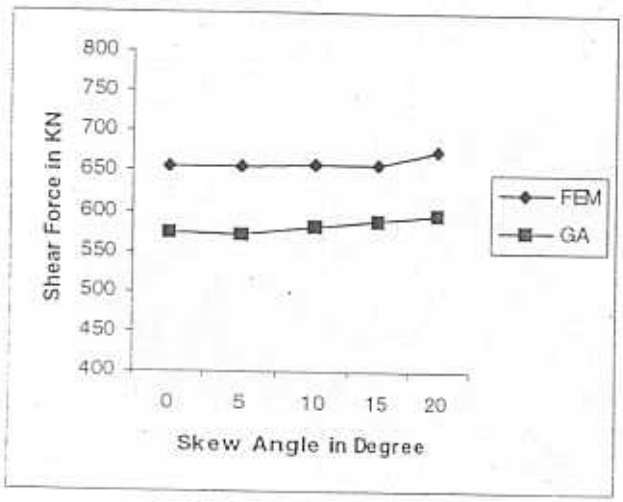

Fig. 5: Shear Force in External Girder

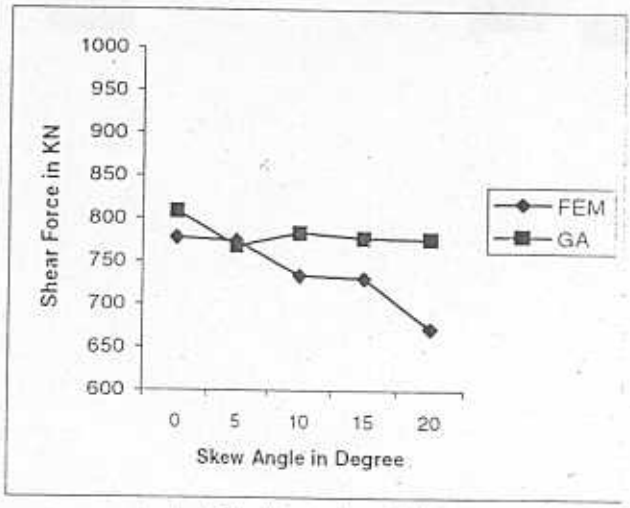

Fig. 6: Shear Force in Internal Girder

IV. Conclusion

In the present work, analysis of girder for right and skew bridge by finite element method and grillage analogy method is covered. From above results, it is found that the finite element and grillage analysis results give good agreement for bending moment and shear force in girder for all skew bridges. From above study, it is also seen that as the skew angle increases the maximum bending moment also increases in all case of loading.

References

1. C. S. Surana, R. Agrawal, "Grillage Analogy In Bridge Deck Analysis", Narosa Publishing House, 1998
2. A. R. Cussens and R. P. Pama, "Bridge Deck Analysis", John Wiley and Sons, 1975
3. E. L. Wilson and A. Habibullah, "Structural Analysis Program SAP2000 version '9.0' users manual Computer and Structures, Inc. Berkeley, California, 2002.