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EXPERIMENTAL ANALYSIS OF CURVED DECK SLAB

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Abstract: The objective is to study the deflection of curved deck slab subjected to uniformly distributed load and concentrated loads. This study was done with the help of Experimental work and Finite Element Analysis computer programmed. A comparative analysis to torsional moment was done with the done with the Witecki expression for tensional moment and with Finite element Analysis. The stability analysis was done with the help of computer programmed. When the deck slab is curved there is problem stability and torsional is of paramount importance. And first designing of curved deck was done then the physical model was casted .The suitable support frame arrangement was made to keep specimens stable. Loading taken was scaled class tracked vehicle loading and Uniformly Distributed Loading. The specimen was tested for deflections in laboratory .And a similarity was tried to make between crack pattern and values obtained of Maximum Stress. Then result is compared to the Finite Computer Programmed of deflection. And Longitudinal Bending Moment and torsional moments were also compared with A.A.Witecki method of calculating moments. There was also a check performed for stability with the help of computer programmed.

Keywords: Finite element analysis, concrete composite bridges, load distribution factors, cross bracing, I girders

I. INTRODUCTION

As a result of complicated geometrics, limited rights of way, and traffic mitigation, horizontally curved bridges are becoming the norm of highway interchanges and urban expressways. Bridge superstructure with horizontal curvature generally has higher cost than comparable structures on straight alignment due to increased design fabrication and construction costs. In most instances, however, the extra cost is nominal and offset by the associated functional improvement. In the past, curved bridges had deck formed to follow the roadway curvature, but were supported a straight beams and girders with changing direction to accommodate the deck alignment. Since the early 1960s, curved spans and framing systems have become standard features of highway interchanges and urban expressways. A curved deck may still be placed on a series of straight beams or girders if the curvature is not very steep and the maximum slab overhang resulting from this arrangement is compatible with the practical slab thickness. Roadway curvature with small radius is common in access ramps and elevated roadways where the plan alignment is restricted by site conditions. In such cases clearance requirement and structural optimization may indicate a curved framing system that limits the cross-sectional variation and may also be economically competitive .The appearance of a curved framing system is more pleasing compared to straight girders placed on chord configuration.

1.1 PROBLEM OF STATEMENTS

If the horizontal curvature of the deck is small say up to 20 degrees, the influence of torsion on bending moment is small. Thus the bending moments in the curved members may be calculated with the bridge straightened out to its full development length. If angle exceeds 20 degrees the bending and torsional moments for uniformly distributed loads may be obtained from design charts which have been presented by JF Toppleret.al.It was also investigated by Eduardo DE Santiago et.al. The vertical deflection curved bridge is 80% higher than deflection of straight bridge. When the angle curvature angle is 30° and reasonable design for lateral bracing support system are used. However, increase in spacing between lateral supports, the increases in the deflection becomes higher. In our present work the angle of curvature was taken 90degrees which was not investigated by most of previous researchers. It was decided to study the deflection and torsional moment on the deck slab.

II. LITERATURE REVIEW

Issam E. Harik (1983) gave the analytical solution to orthotropic sector. A solution for the bending of polar orthotropic pie and ring-sector plates was presented for three cases of boundary conditions along the straight edges. The classical method of separation of variables was employed and the basic function in the angular direction satisfied the boundary conditions of the radial edges. Satisfaction of governing differential equation the plates were achieved by derivation of radial functions. The deflection expression was generated. Isotropic and Orthotropic sector plates of various end conditions had been analyzed and compared with other methods wherever comparisons were possible. In his work three cases of radial edge conditions had been analyzed by an analytical solution for the flexural behavior of transversely loaded orthotropic sector plates.

Issam E. Harik and Bassam F. Haddad (1986) define the use of Analytical Stripstechnique of solution to the sector plates. The plates were known as a system of horizontal curved strips and beams/rib segments rigidly connected with each other. The behavior of systems wasgiven by imposing the continuity conditionsand edge on closed form of individual strips and beam element. These methods are applicable to the plate systems subjected to thedifferent boundary conditionsand different loading conditions along circular edges and straight.
Issam E. Harik and Joseph M. Abou-Khali (1986)define horizontally curve plates on the elastic foundations. Horizontally curve concretes pavements of the highway is problems of the considerable practical importance, which is related to solution of sector plate on the elastic foundation. The motive of this research is to present a analytical solution for the sector plates which are supported to the edges and resting on elastic foundation.
D.G. Linzell and J.F. Shura (2009) find out that appreciable warping stress was generated during the girder erection and the classical grillage model predictionwas less accurate during the girder. While the ``modified" models prediction was more accurate during the deck placement; and predicted grillage model deflection was smaller for exterior-to-interior girder erection procedure than interior-to-exterior procedure.
R.Shreedhar and RashmiKharde (2013) carried out the comparative study of the grillage method and limited element method of the RCC bridge deck used STAAD PRO and found out that, Therefore it can be concluded that the analysis by using these element method gives better economical designs when compare with grillage analysis. But the advantage for grillage analysis is easy to use and comprehend.

III. PROPOSED METHODOLOGY

3.1 CURVED DECK SPECIMEN SPECIFICATION

In order to facilitate analytical solution three curved deck slab specimens were casted which were curved at 90 degree of outer curved span of 2m arc length and .90m width and radius 1.27m.The depth of deck was 80mm. with reinforcements 6mm@ 115mmc/c.The two girders curved were placed to the bottom of curved deck at .30m spacing of sizes 150mm×200mm which were designed for torsional moments. Straight beams were provided along radial direction at 0degree, 45 degree and at90 degrees of sizes 150mm×200mm.Concrete used were of strength M40.

3.2 MAKING OF MODEL

3.2.1 MATERIAL

Cement, sand, course aggregate and steel of good quality is required for casting the test slab specimen. Material has been used after testing in the laboratory. Details of the material used are given below.
a) CEMENT
Fresh ACC cement of grade 43 (Portland pozzolana fly ash based confirming to IS: 1489) has been used for casting cubes and slab specimen.
b) FINE AGGREGATE
The crusher sand used for casting of test specimen was clean, course and free from organic matter. The sand was washed to remove any dust.
c) COARSE AGGREGATE
The crushed and graded hard stone coarse aggregate used in the project was clean and free from organic matter. The maximum size of coarse aggregate was 10mm.

d) STEEL
Steel use was of strength Fe-500 of size 6mm for deck slab and 10 mm used in curved girders and straight beams.

Table 3.2.1: Properties of Steel

Elastic Modulus(KN/mm^2)	205.00
Poisson Ratio	300E-3
Density (kg/m^3)	7833.413
Coefficient of thermal expansion(/K)	12E-6

e) WATER
Potable tap water as per IS: 456 (2000) has been used for concrete mixing and curing of test specimens.

3.2.2 CASTING OF SPECIMEN

1) Making of mould:-Themould of suitable size was made with the help of bricks and was made into proper shape with the proper plastering. A suitable mix of motor was used in its plastering. And it was cured properly to get the desired strength.
2) Making of reinforcement mesh:-Steel Bars were properly cut of required sizes with the help of steel cutter and were bended to desired shape .And stirrups of desired shape were also made. The reinforcement mesh was of made into the shape with the help of binding wires which were tied properly.

Fig 3.2.2: Reinforcement mesh

3) Casting:-The mould was properly oiled before the casting and the mesh of steel was put in the mould .The concrete was mixed in lab in this the cement and sand are first mixed with the help of shovels until the mixture attains a uniform colour.Aggregates are then added to this mixture and the whole mixture is then turned by shovels until the stone pieces are uniformly spread throughout After this, a computed quantity of water is poured into heap frame can fitted with a nose. The mass is then turned until a workable mixture is attained. The transported to the desired location with the help of buckets. The concrete was poured to the desired location with the help of bucket.

4) Curing of the specimens:-The curing was done with the help of jute bags which were made wet with the help of water .And they were kept over the specimens.

3.3. INSTRUMENTATION

Dial gauges reading to0.01mm were placed at all junctions of the longitudinal and the transverse stiffeners to measure the vertical deflections. Dial gauges were placed at the following position given in figure.

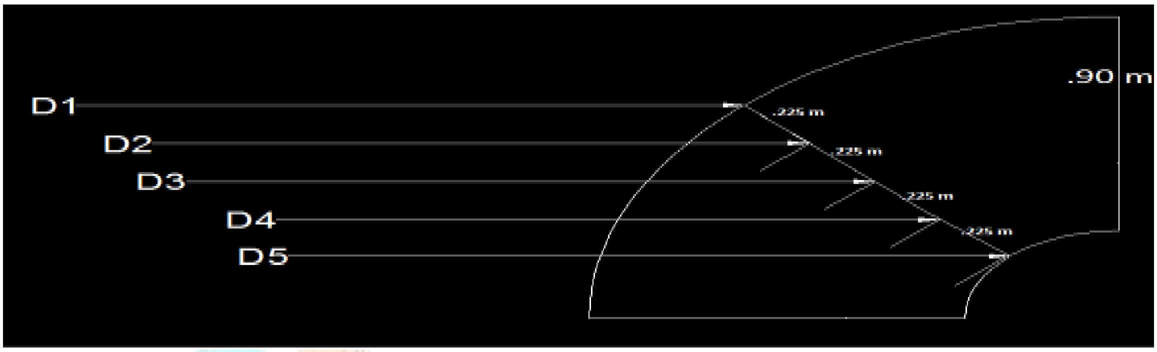


Fig 3.3: Positions of dial gauges

The model under test was placed on rigid steel supports which were restrained against vertical deflections as shown in figure.

Fig 3.3: CurvedDeck on testing frame with loading arrangement

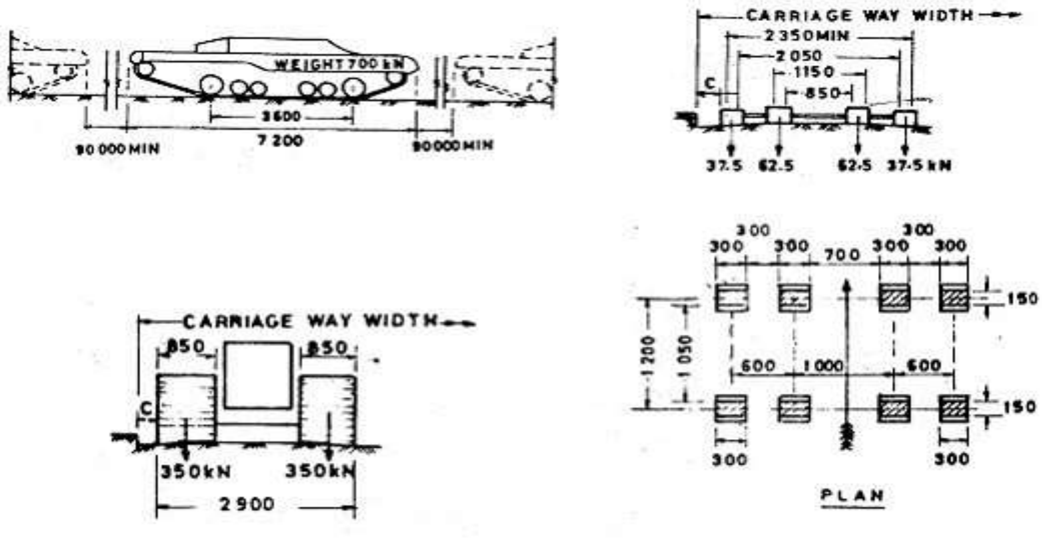
3.4 LOADING ARRANGEMENTS

It was tested by two types of loadings conditions:-

1. Uniformly Distributed loading:-In this three reading were taken of deflections at 5 points. For UDL testing cubes were used total 53 cubes were put in three layers .After putting the cube in one layer the readings of deflections were taken from 6 points then subsequently 2^{nd} layer and 3^{rd} layer.

   The average weight of cube was 8.24 kg.
   Load due to 1^{st} layer =0.003707N/mm^2
   Load due to 2^{nd} layer=0.007414N/mm^2
   Load due to 3^{rd} layer=.011121N/mm^2

2. Concentrated Loading: Scaled IRC CLASS AA TRACKED LOADING:-



(a) Tracked vehicle (a) Wheeled vehicle

Fig 3.4: IRC CLASS AA LOADING

Specification for this loading:-

1. The nose to tail spacing between two successive vehicles shall not be less than 90m.
2. For multi-lane bridges and culvets, one train of Class AA tracked or wheeled vehicles whichever creates severer conditions shall be considered for every two traffic lane width. No other live load shall be considered on any part of said 2-lane width carriageway of the bridge when the above mentioned train of vehicle is crossing the bridge.
3. The maximum loads for the wheeled vehicle shall be 20 tons (=200kN) for a single axle or 40 tons (=400kN) for bogie of two axles spaced not more than 1.2m centers.
4. The maximum clearance between the road face of the kerb and the outer edge of the wheel or track shall be as under:

a) Single Lane Bridge

Carriage way width	Minimum value of C
3.8m and above	0.3m

b) Multi-lane bridges

Less than 5.5m	0.6m
5.5 m or above	1.2m

3.5 TESTING OF CURVED DECK SLAB

After 28 days curing, slab specimens have been tested on reaction frame. Slab specimens have been lifted with chain pulley and placed on the reaction frame at proper position one by one. The following are the steps followed:-

1. Painting: - Painting of the specimen was done with lime .the reason of doing this was to get the visibility of cracks very easily.
2. Naming of specimen:-Naming was done in very judiciously way so that when taking the crack pattern. There was no confusion.
3. Marking:-Proper marking was done so that it was very clear where the load was to be applied and where the dial gauges are to be placed.
4. Application of loading

a) Uniformly Distributed Loading:-The cubes were taken to test for UDL in this the average value of the weights were taken and total 52 cubes were placed and the value of deflections was taken from respective positions. Then second layer of cubes were put on it and the readings of deflections were taken again. This was done till three layers and data of deflection was recorded.

Fig 3.5: Loading with one layer of cubes

Fig3.5: Loading with two layer of cubes

IV. RESULTS

1. Taking 1st specimen
Loading Condition: TESTING FOR UDL

Deflection Results:-

Table 3.2: Deflection readings for UDL in specimen 1

S.no	Load(KN/mm²)	Dial Gauge 1	Dial Gauge 2	Dial Gauge 3	Dial Gauge 4	Dial Gauge 5
1	0.003707	0.24	0.08	0.01	0.01	-0.01
2	0.007414	0.49	0.23	0.13	0.04	-0.03
3	0.011121	0.79	0.39	0.21	0.08	-0.05

GRAPHICAL REPRESENTATION OF RESULTS:-

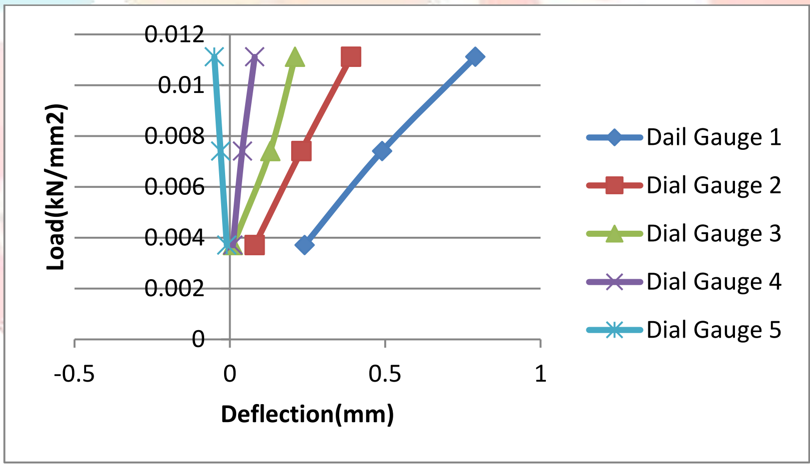


Fig 3.10: Load vs. Deflection curve for UDL on specimen 1

Loading Condition: CONCENTRATED LOADING

Deflection Results:-

Table 3.3: Deflection readings for concentrated loading on specimen 1

S.no	Load(KN)	Deflection(mm)				
		Dial Gauge1	Dial Gauge 2	Dial Gauge 3	Dial Gauge 4	Dial Gauge 5
1	10	0.41	0.2	0.07	0.05	-0.17
2	20	1.33	0.72	0.44	0.16	-0.33
3	30	2.00	1.13	0.73	0.33	-0.39
4	40	2.66	1.55	1.02	0.5	-0.49
5	50	3.33	1.96	1.31	0.67	-0.55
6	60	3.99	2.37	1.59	0.84	-0.60
7	70	4.66	2.78	1.88	1.01	-0.66
8	80	5.33	3.19	2.17	1.18	-0.72
9	90	5.99	3.6	2.46	1.35	-0.78

GRAPHICAL REPRESENTATION OF RESULTS:-

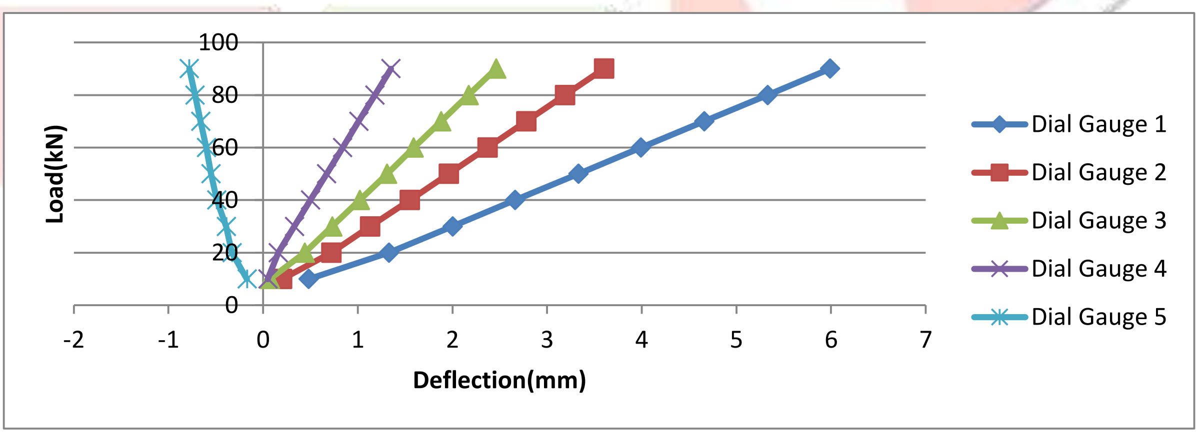


Fig 3.3: Load vs. Deflection curve for concentrated loading on specimen 1

1. Taking 3rd Specimen

Loading Condition: TESTING FOR UDL

Deflection Results:-

Table 3.4: Deflection readings for UDL in specimen 3

S.no	Load(KN/mm^2)	Dial Gauge 1	Dial Gauge 2	Dial Gauge 3	Dial Gauge 4	Dial Gauge 5
1	0.003707	0.28	0.12	0.02	0.04	- 0.02
2	0.007414	0.54	0.27	0.17	0.06	-0.04
3	0.011121	0.87	0.45	0.29	0.11	-0.06

GRAPHICAL REPRESENTATION OF RESULTS:-

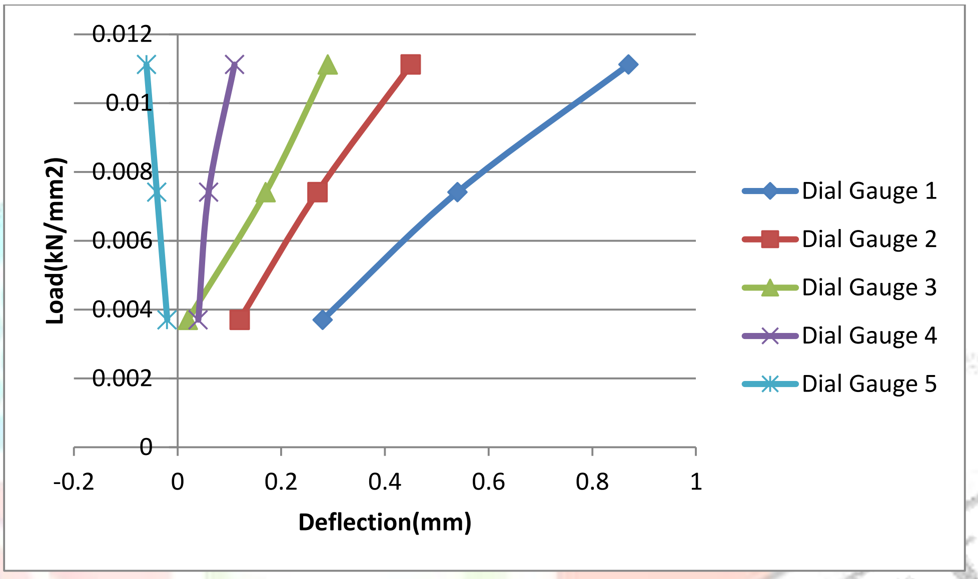


Fig 3.4: Load vs. Deflection curve for UDL on specimen 3

Loading Condition: CONCENTRATED LOADING

Deflection Results:-

Table 3.5: Deflection readings for concentrated loading on specimen 3

s.no	Load(KN)	Deflection(mm)				
		Dial Gauge 1	Dial Gauge 2	Dial Gauge 3	Dial Gauge 4	Dial Gauge 5
1	10	0.54	0.22	0.09	0.03	-0.18
2	20	1.37	0.75	0.45	0.14	-0.30
3	30	2.11	1.17	0.78	0.34	-0.51
4	40	2.69	1.59	1.02	0.57	-0.57
5	50	3.38	2.06	1.34	0.62	-0.59
6	60	3.99	2.37	1.68	0.80	-0.62
7	70	4.76	2.87	1.79	1.04	-0.66
8	80	5.35	3.21	2.12	1.23	-0.74
9	90	6.13	3.59	2.54	1.37	-0.78

GRAPHICAL REPRESENTATION OF RESULTS:-

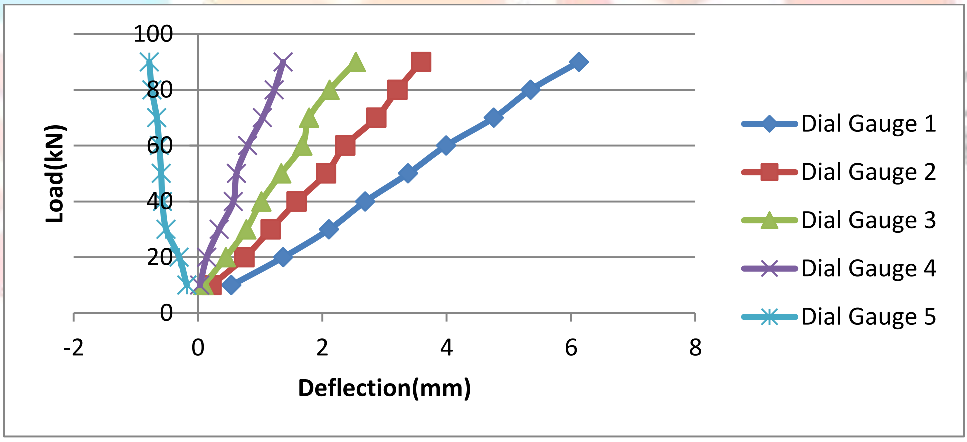


Fig 3.5: Load vs. Deflection curve for concentrated loading on specimen 3

V. CONCLUSIONS

1.Analysis and design of two main curved girders and three cross-girder with deck slab on top is accomplished for scaled vertical IRC Class AA tracked Vehicle loading on bridge deck.

2. One Important point in the analysis of curved deck slab and curved girder is to check its stability against overturning due to eccentricity of loading. This is checked by ensuring that negative reactions do not develop at supports.

3. The outer should be flexible because it suffers maximum deflections.

4. The analysis used in this present work is FE analysis which is most powerful and versatile method available at present because with a sufficiently large computer, the elastic behavior of almost any structure can be analyzed accurately. The drawbacks of other methods are as follows.

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