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COMPARATIVE ANALYSIS OF I-GIRDER MULTI-SPAN SIMPLY SUPPORTED BRIDGE BY FINITE ELEMENT METHOD (FEM)

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Abstract: **In this study, we have designed and analyzed a multi-span bridge. For analysis and design, we used Staad-Pro software. In this project, we have used Staad-Pro software to analyze our bridge deck design and girder. In this project, we have worked on a multi-span simply supported bridge design. We have analyzed the maximum Deflection, bending moment, and shear force applied to the bridge. also done static analysis and dynamic analysis. We looked at the structure and behavior of different loads acting on the bridge deck and girder. In this project, we have used different types of codes, which include IRC 5-2015, IRC 6-2016, IRC 112- 2011, IRC 21-2000. In this project we have also used IRC class AA tracked load and class A load. Multi-span has been used in the bridge in this project. Also, pre-stressed girder has been used in it. This project study aims to analyze the multi-span simply supported bridge, which also includes observing the effect on the bridge due to the load spread on the bridge due to an increase in traffic or various vehicular loads. This includes analyzing the changes that occur to the bridge as a result of sudden changes in nature, as well as knowing the difference between analyzing the span of an individual part of a bridge and analyzing the structure of the entire bridge.**

Keywords: - IRC CLASS AA LOADING, IRC CODE, I-Girder BRIDGE, STAAD-PRO SOFTWARE, MULTI-SPAN, FEM, STATIC ANALYSIS, DYNAMIC ANALYSIS.

1. INTRODUCTION

1.1 GENERAL: A bridge is a man-made structure that spans a physical obstacle, such as a river or valley, to connect two points. Bridges have evolved from simple wood and rope structures to complex multi-span bridges several kilometers long. In civil engineering, software is used to design and analyze civil structures, including bridges. Staad-Pro is a software used for the design and analysis of bridges, with two main types of loading: dead load (self-weight) and live load (vehicle load), as well as other types of loading such as wind load and impact force.

1.2 STAAD PRO SOFTWARE: STAAD stands for Structural Analysis and Design. It is the abbreviation of the Structural Analysis and Design Pro software created by Research Engineers International in 1997. Bentley Systems acquired it in 2005. Staad Pro is a widely used software program for designing and analyzing structures made of materials such as wood, concrete, steel, or cold-formed steel. It supports 90 international design codes and is used by government departments, private construction companies, and structural engineering firms worldwide.

1.3 BRIDGE TYPES:

- BEAM BRIDGE
- Truss Bridge
- Arch Bridge
- Cantilever Bridge
- Suspension Bridge
- Cable-stayed Bridge
-

2. RESEARCH OBJECTIVE

1. To create a model of an I-girder span and analyze it in the Staad Pro software.
2. To perform Finite Element Method (FEM) analysis on the I-girder simply supported on pinned support.
3. To analyze and design the bridge span using Staad Pro software and compare the results with manual calculations.
4. To determine the maximum bending moment of the bridge's structural performance under various loading scenarios.
5. To determine the maximum shear forces of the bridge's structural performance under various loading scenarios.
6. To determine the maximum deflection of the bridge's structural performance under various loading scenarios.
7. To gain an understanding of the Class A and Class AA loading conditions.

2.1 SCOPE

The following points will be covered in the project work

1. this study aims to ensure that the design calculation is carried out using the Staad Pro software.
2. To reduce the time involved in designing the structure.
3. The results of this study can be used for future development and construction of the bridge.
4. To understand the basic principles of the structure using IS code.
5. To analyze the structural details of the structure.
6. The primary objective is to analyze and design the multi-span bridge using Staad Pro software.

3. METHODOLOGY

3.1 STATIC ANALYSIS

Static analysis is used to determine how a structure will respond to external forces. It is performed on systems that are in perfect equilibrium, meaning that they have zero acceleration and no loading that changes with time. Static analysis is useful for systems where the load is constant and does not change. The most common form of finite element structural analysis is static stress analysis. In dynamic analysis, the system under consideration is observed for the changes taking place during a sequence of time, and the causes of those changes are analyzed. Dynamic loads are always applied as a function of time or frequency and result in frequency-varying responses such as displacements, velocities, accelerations, forces, and stresses.

3.2 DYNAMIC ANALYSIS:

Dynamic analysis tests and evaluates an application while it runs, while static analysis examines the code without executing it. Both methods detect software defects. Real physical structures behave dynamically when subjected to loads or displacements. Dynamic analysis is necessary when loads change over time. There are three primary types of dynamic analysis: frequency, transient, and random response. It is used in applications such as impact, drop test, vibrational, and buckling analysis, and calculates stress, strain, and deformation under time-varying loads. It is more accurate than static analysis for problems involving time, but it may be more complicated and take a longer run.

3.3 LOAD ANALYSIS:

3.3.1 LIVE LOAD:

Highway bridges are designed to withstand live loads set by the Indian Roads Congress (IRC). There are two types of loading: IRC class A and IRC 70R. Bridges on highways are usually designed for IRC loadings, and those designed for class A must also be checked for IRC class 70R loading. Live loads are caused by vehicles, and IRC recommends hypothetical vehicular loading systems for bridge design. IRC Class A two-lane, Class AA Tracked and Wheeled, and Class 70R Tracked and Wheeled loads are illustrated.

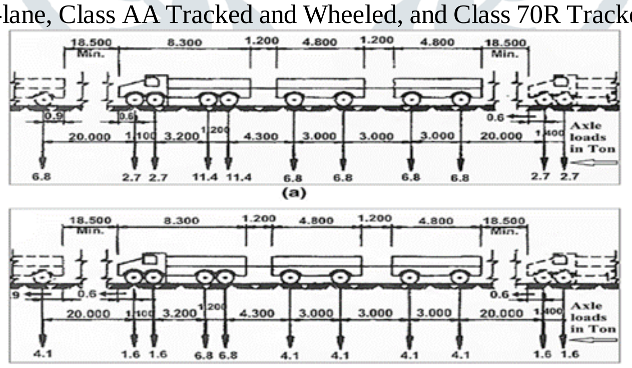

Figure 1. Live load

3.3.2 Dead load:

Dead load is the weight of a structure and its permanently attached items. Superimposed load is the weight of non-structural parts of a bridge, which increases over time. Bridges have a high proportion of their total loading due to these loads. The deck of a bridge is subject to dead loads, which are accounted for by distributed loads on longitudinal grid members. If the distributed load is not uniform, equivalent nodal loads are used. If the dead load is uniform, it can be handled as a uniformly distributed load (UDL). If the dead load is UDL but not coincident with the longitudinal grid line, it is substituted by a vertical UDL.

3.4 Comparison with Manual Calculations:

To ensure the accuracy of the STAAD PRO software, the analysis results are cross-checked with manual calculations based on the IS codes. and also say that to check the accuracy of the STAAD PRO software, its analysis results are compared with manual calculations based on the IS codes. For specific load cases, hand calculations are performed, and the results are compared with those obtained from the software analysis. This comparison ensures that the software is reliable and adheres to the design standards specified by the IS codes.

3.5 Design Optimization:

After analyzing the data, we propose several strategies to improve the performance of the girder bridge. These strategies may involve optimizing the dimensions of the various bridge elements, selecting appropriate reinforcement details, or considering alternative construction materials. Our goal is to ensure that the bridge remains structurally sound, safe, and cost-effective while adhering to the design requirements specified by the IS codes.

4. STRUCTURAL MODELING

The STAAD PRO program is a software tool that helps in creating precise structural models of various constructions including girder bridges. This program empowers users to define each component of the bridge like girders, piers, abutments, and deck slabs with great accuracy. The software specifies the geometry of the bridge, which includes span, width, and height, along with material properties like concrete grade and reinforcing information. Staad-Pro software is a powerful tool that is widely used to create precise structural models of buildings, bridges, and other structures. In this report, we will focus on modeling bridge spans that range from 25 to 50 meters. Different parts of the bridge, such as girders, piers, abutments, and slabs, can be easily modeled in this software. Staad Pro pays special attention to the bridge's height and width, as well as the properties of the materials used in construction, such as concrete and steel grade. These features are essential in accurately modeling structures.

Table 1 Bridge Parameters

Parameters	Unit	Design Value					
Total Span Length	m	25	30	35	40	45	50
No of Span		1	1	1	1	1	1
No of Girder		5	5	5	5	5	5
Bridge Width	m	16	16	16	16	16	16
Slab Thickness	m	0.3	0.3	0.3	0.3	0.3	0.3
Diameter of Circular Column	m	1	1	1	1	1	1
Hight of Column	m	6	8	10	10	10	10

Table 2 Cross-section of I - girder bridge

Cross-Sectional Properties	Length m					
	25	30	35	40	45	50
Depth (D) of girder	1.9	2	2.25	2.23	2.65	3.1
Thickness of web (tw)	0.3	0.3	0.3	0.3	0.3	0.3
Thickness of top flange (ttf)	0.150	0.2	0.22	0.23	0.25	0.35
Thickness of bottom flange (tbf)	0.250	0.250	0.250	0.250	0.30	0.40
Width of Top Flange	0.9	1.1	1.2	1.3	1.4	2
Width of Bottom Flange	0.9	1.1	1.2	1.3	1..4	2

4.1. Create a project file and specify units.

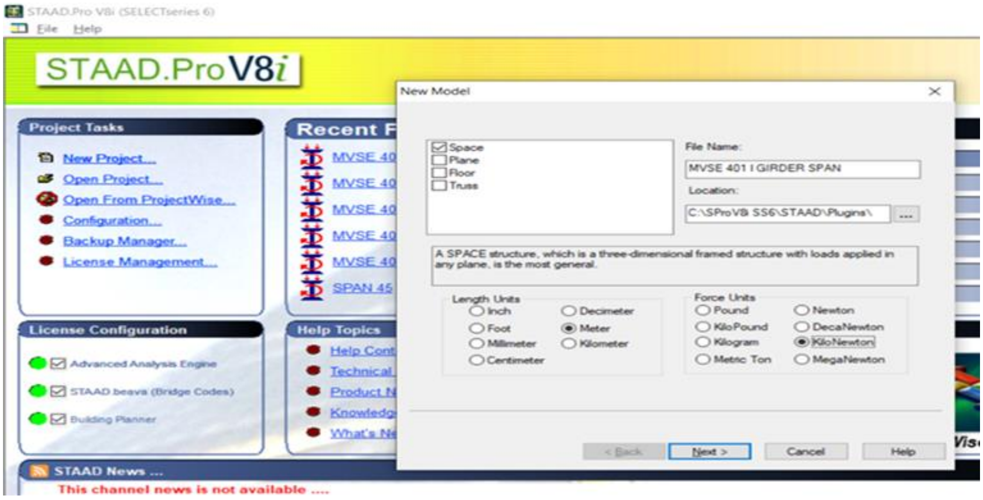

Figure 2. Staad-Pro software

4. 2. Use commands to create geometry and apply member properties.

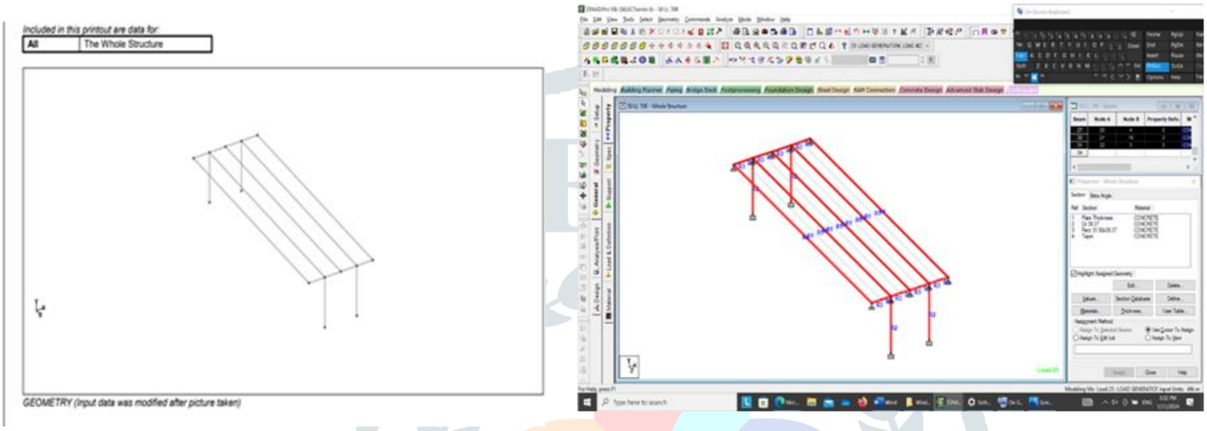

Figure 3. Create Geometry and Apply Properties

4.3. Provide support and apply loads to simulate real-world conditions.

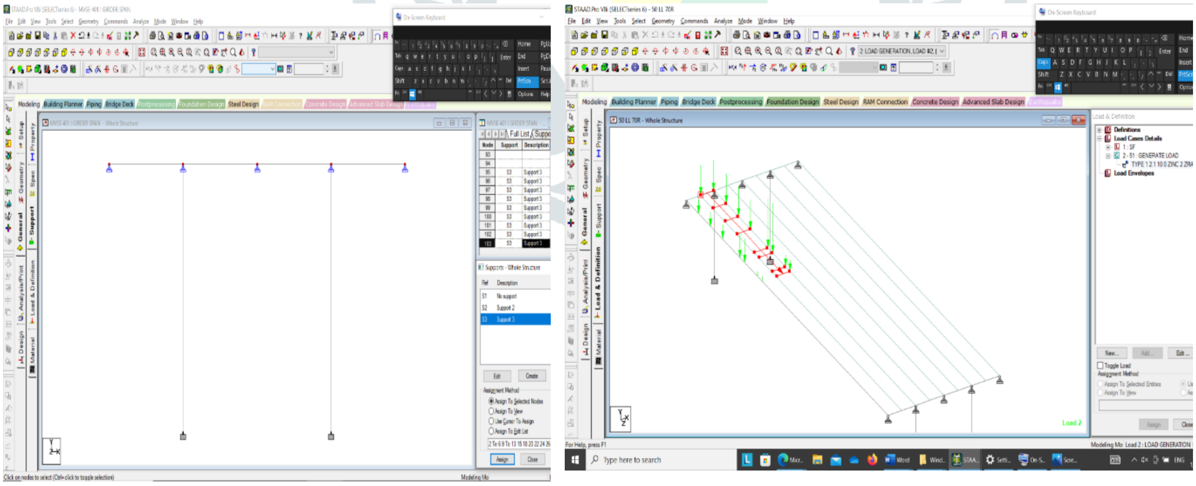

Figure 4. Provide support and Apply Load

4.4. Define design codes and execute commands accordingly.
4.5. Print support reaction and produce output to evaluate results.

5. Results and Discussion

The paper discussed the behavior of I-girder bridges under moving loads, analyzing their deflection, shear force, and bending moments. The IRC Class AA tracked and Class A loadings output data are analyzed through Staad Pro, which provides information such as nodal displacement summary, beam end force summary, reaction summary, axial forces, beam moments, live load effect, and many other effects. According to IRC 6-2016 bridge design, bridges designed for Class AA loadings should also be checked for Class A loadings, as it has been found that heavier stress may occur under certain conditions. Class A loading is used on all roads where permanent bridges are built, as per IRC 6-2016. The study involved a comparison I Girder bridge with spans of 25 m, 30 m, 35 m, 40 m, 45 m, and 50 m. These girders were subjected to both dead and live loads, and the resulting maximum compressive stress and deflection values of each girder were compared. The maximum deflection values for each span length (25 m, 30 m, 35 m, 40 m, 45 m, and 50 m) are displayed in the corresponding figure. Additionally, the figure shows the comparison of the maximum shear force and bending moment values for each span length.

1. **Bending Moment:** The maximum bending moment is observed during increments in live loads. Also, an increase in span length will cause the effect of bending moment on bridges. The maximum Bending moments for I-girder bridges are presented graphically along with a table for easy comparison and readability.

Table 3 Maximum Bending Moment(kN.m)

Table.4 Maximum Bending Moment(kN.m) +Positive And -Negative

SPAN	DEAD LOAD	LIVE LOAD CLASS A	LIVE LOAD CLASS AA	LIVE LOAD 70R
25	7.603	1160	1600	3760
30	6.729	1390	1990	4610
35	5.138	1580	2460	5200
40	2.991	1130	3130	6740
45	2.953	2140	3520	7450
50	2.728	2170	3650	7640

SPAN	MAXIMUM BENDING MOMENT (kN,m)	
	POSITIVE	NEGATIVE
25	3760	776.23
30	4610	1120
35	5200	1470
40	6740	1750
45	7450	2100
50	7640	2520

Figure 5. Maximum Bending Moment (kN,m)

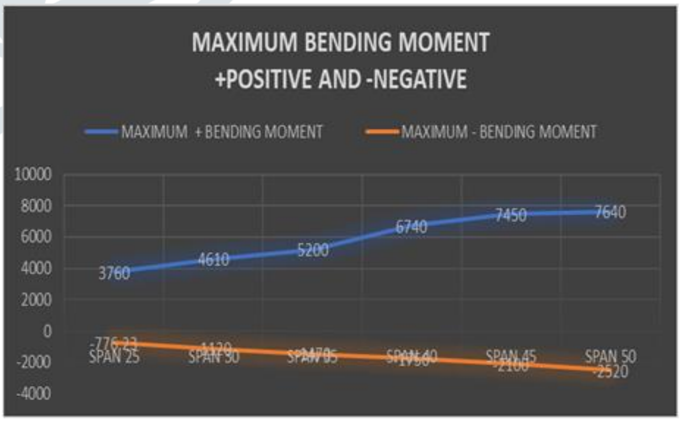

Figure 6. Maximum Bending Moment Positive and Negative

2. Shear Force: The maximum shear forces for I-girder bridges are presented graphically along with a table for easy comparison and readability.

Table 5 Maximum Shear Force

Table 6 Maximum Shear Force +Positive And -Negative

SPAN	DEAD LOAD	LIVE LOAD CLASS A	LIVE LOAD CLASS AA	LIVE LOAD 70R
25	9.8	439.3	579	1340
30	2.5	434.17	592.9	1460
35	1.5	453.7	639.6	1460
40	0.9	556.7	651.8	1530
45	0.8	645.7	743.8	1520
50	0.8	700	1300	1550

SPAN	MAXIMUM SHEAR FORCE (kN)	
	POSITIVE	NEGATIVE
25	990.198	1340
30	1110	1460
35	1210	1460
40	1300	1530
45	1350	1520
50	1370	1530

Figure 7 Maximum Shear Force (Kn)

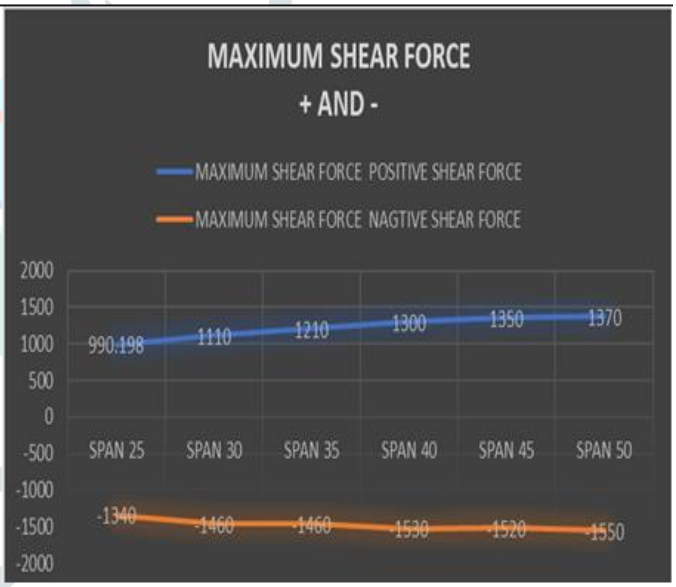

Figure 8 Maximum Shear Force Positive and Negative

3. Maximum Deflection: The Maximum Deflection for I-girder bridges is presented graphically along with a table for easy comparison and readability

Table 7 Maximum Deflection

SPAN	DEAD LOAD	LIVE LOAD CLASS A	LIVE LOAD CLASS AA	LIVE LOAD 70R	PERMISSIBLE DEFLECTION (MM)
25	16.857	0.191	0.153	26.509	31.25
30	18.331	0.162	0.245	35.707	37.50
35	28.019	0.225	0.366	42.17	43.75
40	43.662	0.125	0.149	48.557	50.00
45	55.135	0.039	0.151	55.135	56.25
50	59.073	0.083	0.141	59.073	62.50

Table 8 Maximum Deflection +Positive And -Negative

SPAN	MAXIMUM DEFLECTION (mm)	
	POSITIVE	NEGATIVE
25	26.509	0.333
30	35.707	0.363
35	42.17	0.786
40	48.557	0.138
45	55.135	0.137
50	59.073	0.128

Figure 9 Maximum Deflection in Dead Load and Live Load 70R

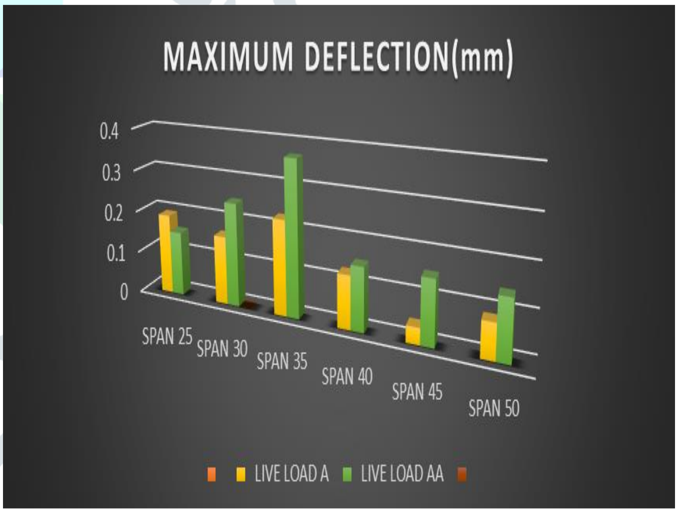

Figure 10 Maximum Deflection in Live Load Class A and AA

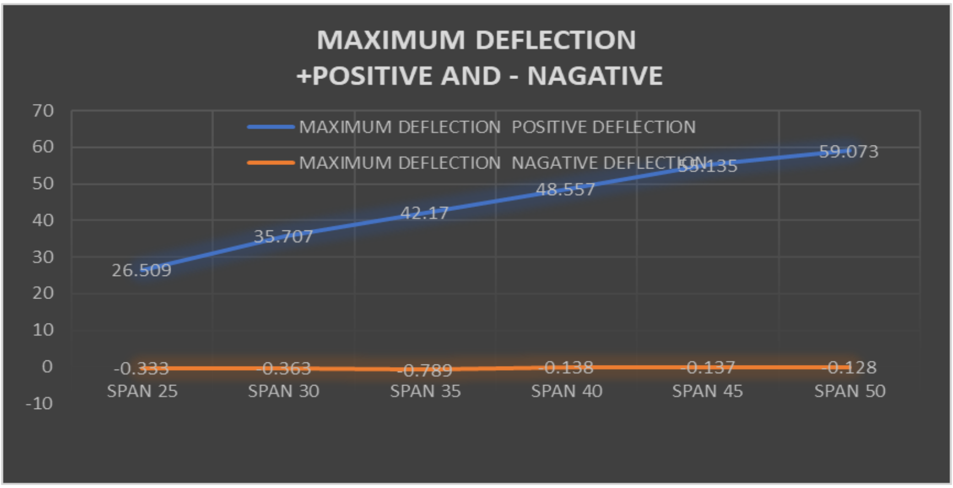

Figure 11 Maximum Deflection Positive and Negative

6. CONCLUSIONS

A report analyzed an I-Girder bridge using the Finite Element Method in STAAD.Pro. Different cross-sections and loading classes were considered. The results showed that I girders were used for higher stability. The maximum deflections, maximum shear forces, and maximum bending moments were calculated for different girder lengths. The analysis shows that the maximum compressive stress generated at the middle span of the bottom slab of the girder increased as the span length increased. The results indicate that the IRC Class 70R loading gave more significant results compared to the IRC Class loading in maximum Deflection, bending moment, maximum shear force cases, and all other parameters. The deflection of the longitudinal girder increased with an increase in the span of the I Girder Bridge. The analysis of precast prestressed concrete girder bridges showed that for all the cases of 25m, 30m, 35m, 40m, 45m, and 50m length bridges, deflection and stresses were within the permissible limits.

The maximum deflections for each girder length were as follows:

for a 25m span girder, the maximum deflection was 26.509 mm, which was below the deflection limit of 31.25 mm. For a 30m span girder, the maximum deflection was 35.707 mm, which was below the deflection limit of 37.5 mm. For a 35m span girder, the maximum deflection was 42.17 mm, which was below the deflection limit of 43.5 mm. For a 40m span girder, the maximum deflection was 48.557 mm, which was below the deflection limit of 50 mm. For a 45m span girder, the maximum deflection was 55.135 mm, which was below the deflection limit of 56.25 mm. For a 50m span girder, the maximum deflection was 59.073 mm, which was below the deflection limit of 62.50 mm.

The maximum Shear Force (kN) for each girder length is as follows: for a 25m span girder, the maximum Shear Force was 990.198kN. For a 30m span girder, the maximum Shear Force was 1110kN. For a 35m span girder, the maximum Shear Force was 1210kN. For a 40m span girder, the maximum Shear Force was 1300kN. For a 45m span girder, the maximum Shear Force was 1350kN. For a 50m span girder, the maximum Shear Force was 1370kN.

The maximum Bending Moment for each girder length is as follows: for a 25m span girder, the maximum Bending Moment was 3760(Kn/m). For a 30m span girder, the maximum Bending Moment was 4610(Kn/m). For a 35m span girder, the maximum Bending Moment was 5200(Kn/m). For a 40m span girder, the maximum Bending Moment was 6740(Kn/m). For a 45m span girder, the maximum Bending Moment was 7450(Kn/m). For a 50m span girder, the maximum Bending Moment was 7640(Kn/m).

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