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# COMPARATIVE STUDY OF PRE-STRESSED CONCRETE I-GIRDER BRIDGE WITH DIFFERENT CODES USING MIDAS CIVIL AS A TOOL

**M Sai Preethi[1], Dr. E Arunakanthi[2]**
[1]M. Tech Student, Civil Engineering Department, JNTUA College of Engineering, Ananthapuram, India
[2]Professor in Civil Engineering, JNTUA College of Engineering, Ananthapuram, India.

**ABSTRACT:**

Bridges play a crucial role in modern transportation infrastructure, facilitating the efficient movement of people and goods across various regions. New and advanced developments are being made in these constructions. A pre-stressed concrete I-girder is a type of bridge structure widely used in civil engineering for spanning various distances. These bridges are designed for heavy loads, such as traffic and are known for their efficiency, durability and cost-effectiveness. This comparative study aims to investigate the effects of two well-known design codes, the Indian Road Congress (IRC) and the American Association of State Highway and Transportation Officials (AASHTO), on the behavior and performance of pre-stressed concrete I-girder bridges. A single-span pre-stressed concrete I-girder bridge is modeled and analyzed using the two standard loading codes, IRC 6: 2000 and AASHTO-LRFD. The modeling and analysis of the pre-stressed concrete I-girder bridge is done in MIDAS CIVIL. The use of MIDAS CIVIL as an advanced tool showcases its efficiency and accuracy in analyzing complex bridge structures, reaffirming its significance in modern engineering practices. The results obtained from the analysis are compared in detail, focusing on critical parameters such as maximum bending moments, shear forces, and torsion.

**Keywords:** Pre-stressed concrete, I-girder, MIDAS CIVIL, IRC, AASHTO, shear stress, bending moment, torsion

## I. INTRODUCTION

Bridges are vital civil engineering structures, serving as essential connectors that facilitate transportation and link communities across various landscapes, including challenging obstacles like rivers, valleys, and canyons. These remarkable structures play a crucial role in connecting communities and in the formation of human civilization, by enabling the movement of people, goods, and resources across diverse landscapes. Bridges come in various designs and materials, each tailored to meet specific engineering requirements and environmental conditions. The possibilities in civil engineering are constantly being expanded through the design and building of massive, inventive bridges. In the design of bridges, cross-sectional shapes including I-girders, box girders, arches, and trusses are frequently employed and they are designed under dynamic loads. Girders play a significant role in the overall stability and strength of the structure. I-girders have a cross-section resembling the letter "I," with top and bottom flanges connected by a vertical web. These are efficient in supporting heavy loads over long spans.

The Pre-stressed concrete is typically used to build structures, which has many advantages over regular reinforced concrete. Pre-stressed concrete I-girders are structural elements commonly used in the construction of bridges and other large infrastructure projects. These girders are designed to carry heavy loads and span long distances while minimizing the amount of concrete and steel required. Steel tendons or cables are placed inside the concrete before it hardens. These tendons are tensioned to induce compressive stresses in the concrete, counteracting the tensile stresses that occur when the girder is loaded. This preloading enhances the structural performance and reduces deflection under load. By adding pre-stressing, they can support heavy loads with less material, making them cost-effective and efficient. Numerous aspects that depend on the state of the moving loads as well as external environmental factors are taken into account when designing and analyzing bridges. The analysis of such a pre-stressed concrete (PSC) bridge also demands special consideration in standard codes like Indian Road Congress (IRC) and American Association of State Highway and Transportation Officials (AASHTO) codes.

This project uses MIDAS CIVIL software to analyse a single span pre-stressed concrete I-girder bridge under the loading standards of IRC 6: 2000 and AASHTO-LRFD standard codes. MIDAS Civil is a powerful software tool designed for civil and structural engineering analysis and design. It is a Finite Element Analysis (FEA) software created by Midas IT for bridge analysis and design. Midas Civil simplifies and accelerates bridge modeling and analysis by integrating powerful pre- and post-processing tools with a lightning-fast solver. There are also a variety of simple parameter modification tools that may be utilized for parametric analysis, resulting in an efficient and cost-effective design.

## II. LITERATURE REVIEW

**A. Shubham S. Hande et al. (2021):** This article discusses the comparative study of box girder under different codes. The model created was a two span pre-stressed concrete box girder bridge. The standard codes taken in consideration for the analysis and design are IRC and AASHTO standard codes. The created model is analysed in both standard codes and were compared and studied for shear for bending moment, shear force and torsion along the length of the bridge.

**B. Gokul Mohandas V (2017):** In this article, a box girder of two span bridge is modeled in MIDAS CIVIL software. In this, it discusses about the modeling and analysis pattern of pre-stressed concrete bridges for different tendon profiles. The super structure of the bridge is analysed for gravity loads and moving vehicular loads as per IRC: 6-2014 and as per IRC: 18-2000. Straight and parabolic tendons are created for the four cell pre-stressed girder and study on the effect of pre-stressing force, cable profile and eccentricity. It concluded that straight tendon profile produces more stress at top and shear force is greater than parabolic tendon profile and when for uniformly distributed parabolic tendon profile reduces the stresses than straight tendon profile.

**C. Shubham Landge et al. (2018):** The paper explains the longitudinal girder bridge's analysis, design, and analysis. STAAD-Pro software is used in this instance for analysis. With dead load and live load applied, finite element 3D modeling is completed in STAAD Pro, and final stresses, principles, deflection, etc. are computed. When analyzing precast pre-stressed concrete girder bridges, a 28 m length bridge is taken into consideration. In every case, the deflection and stresses are within the allowable bounds as defined by the IRC code. The use of precast pre-stressed concrete girder configuration is more effective than regular deck slab configuration because it provides most design parameters within acceptable bounds for serviceability, deflection, and shear.

**D. Abrar Ahmed (2017):** In this article, comparative analysis of Pre-stressed concrete T-Beam and Box girders is done. The software used in this article is CSI Bridge software. The working stress approach and Microsoft Excel sheets, together with an adaptation of Corbon's theory, are used to manually validate the results. The main objective of this paper is to choose between T-beam and box girder bridge sections that are appropriate for various spans. The aim of this article is to analyse and design the sections for IRC vehicles. It found that IRC 70R vehicle produced more maximum effect on the sections. It concluded that for higher span bridges box girder is suitable compared to T - Beam girder. Based on the results, it was determined that the software results were appropriate and could also be used for the design of substructures.

**E. M Jagandatta (2021):** In this article, it describes about the analysis and design of composite single span PSC - I girder bridge. MIDAS software is used to analyze and design the bridge under IRC loading conditions. Several outputs, including shear force, bending moment, and time-dependent variables like creep and shrinkage, were obtained through the analysis. At the construction phase, the IRC standards are followed in the PSC (prestressed) design of the span to obtain output parameters like the principal stresses for the prestressing tendon. The section properties, primary and secondary moments, the size and location of the prestressing force, the profile of the tendons, the losses from prestressing, and the shear stresses on the section must all be calculated as part of the design process.The bridge is designed under IRC loading standards using IRC vehicles. It was found that designing and analyzing post tensioned girders and deck slabs with MIDAS CIVIL is very simple and safe.

## III. METHODOLOGY

A single span composite pre-stressed concrete I-girder is modeled in MIDAS CIVIL software. Two similar models are prepared based on the same geometrical properties and material specifications. The loading conditions are provided differently for both the models as per IRC 6:2000 and AASHTO - LRFD standard loadings. Careful attention is given to accurately representing the bridge's geometry, including the dimensions of the girders and deck. Material properties, including concrete and steel, are defined in accordance with the chosen design codes (IRC and AASHTO) to ensure realistic structural behavior.

MIDAS CIVIL is utilized as the primary analytical tool for this study. The software enables rigorous finite element analysis, incorporating the loading conditions stipulated by IRC and AASHTO. Structural responses, including deflections, maximum bending moments, shear forces, and torsional effects, are computed and recorded. These responses serve as critical performance indicators, allowing for an in-depth comparison between the two design codes.

Pre-stressed concrete bridges are evaluated using the following process by MIDAS/Civil:

1. Defining materials for concrete grade, rebar grade and section properties for girders, deck, diaphragm and abutments. Specifying material properties like Young's modulus, Poisson's ratio, and density.
2. Defining time dependent material characteristics such as creep and shrinkage for the concrete grade and then defining elements, boundary conditions and loadings for each construction step.
3. Determining the tendon's cross sectional area, duct diameter, material qualities, frictional coefficients, ultimate strength and other characteristics.
4. Creating a profile for the placement of the model involves assigning the specified tendons.
5. Defining load cases that represent different loading scenarios or combinations, such as different load combinations per design codes and assigning the loads to load cases.
6. Performing the analysis and the results are obtained.

### 3.1 SCOPE OF STUDY

The study will focus on pre-stressed concrete I-girder bridges, which are commonly used in civil engineering for spanning various distances. While the geographic scope is not limited to a specific region, the findings will be applicable to regions where the IRC and AASHTO design codes are commonly employed. The study will consider single-span bridge configurations.

### 3.2 OBJECTIVES OF STUDY

The primary objective of this study is to conduct a comparative analysis of pre-stressed concrete I-girder bridges, focusing on the influence of two prominent design codes, the Indian Road Congress (IRC) and the American Association of State Highway and Transportation Officials (AASHTO). The study aims to understand how these design codes affect the behavior and performance of such bridge structures. Specific research goals include:

1. Creating two similar models of pre-stressed concrete I-girder bridges using MIDAS CIVIL
2. To evaluate the structural behavior, safety, and performance of pre-stressed concrete I-girder bridges designed under the IRC and AASHTO design codes.
3. To compare and contrast the analysis and load provisions of the two design codes, identifying key differences and similarities.
4. To determine and recommend the most suitable design code based on structural performance, safety, efficiency, and other relevant factors.

## IV. BRIDGE MODELLING AND ANALYSIS

For the analysis in MIDAS CIVIL firstly define the material properties and sectional properties which we use in design of the bridge.

### 4.1 PROPERTIES OF PSC - I GIRDER BRIDGE:

| | |
|---|---|
| Bridge Type | PSC Composite I girder |
| Length of the bridge | 30 m |
| No. of spans | 1 |
| Deck width | 15 m |
| No. of lanes | 4 |
| No. of girders | 5 precast, spaced @ 3m c/c |

**Table 1: Geometrical properties**

| | |
|---|---|
| PSC Girder & Diaphragm | M-45 (IRC)<br>C7000 (AASHTO) |
| PSC Deck | M-40 (IRC)<br>C6000 (AASHTO) |
| Grade of steel | Fe-540 |
| Thickness of slab | 250 mm |

**Table 2: Material properties**

| | |
|---|---|
| Tendons / Strands | 12 nos. of 15.2 mm diameter |
| Type of pre-stressing | Internal - Post tension |
| Duct diameter | 100 mm |
| Type of Bond | Bonded |
| Jacking | Both ends |
| Time dependent materials | Creep & Shrinkage, Compressive strength |

**Table 3: Tendon properties**

### 4.2 LOADING DETAILS

There are some common loading conditions in both the models. They are:

**a) Dead Load (DL):**

The dead load of a PSC I-girder bridge is a fundamental consideration in structural engineering. It comprises the inherent weight of the prestressed concrete I-girders, the bridge deck, and any permanent fixtures. The self-weight of the bridge components, along with portions of the superstructure's weight, contributes to this static load.

Moreover, the dead load is not only confined to the structure itself. It extends to the superimposed dead load (SIDL), which includes additional elements like the bridge deck's wearing course, ballast, waterproofing, conduits, cables, and pipes. The cumulative effect of this dead load, often estimated at around 20 kN/m³, plays a pivotal role in the comprehensive load analysis and design of the bridge, ensuring its stability and functionality over its lifespan.

**b) Live Load (LL):**

The live load on a PSC I-girder bridge refers to the dynamic and transient forces exerted by moving vehicles, pedestrians, and any other temporary loads. Unlike the static dead load, the live load is variable and changes over time as traffic conditions fluctuate. This includes vehicular traffic, pedestrians, and any other mobile elements that may traverse the bridge.

| | |
|---|---|
| Loads | Static loads, Prestress loads, Moving loads |
| Load combinations | IRC: 6-2000<br>AASHTO - LRFD |
| Vehicles as per IRC | Class A & Class 70R |
| Vehicles as per AASHTO | HL-93 TDM & HL-93 TRK |

**Table 4: Loading Details**

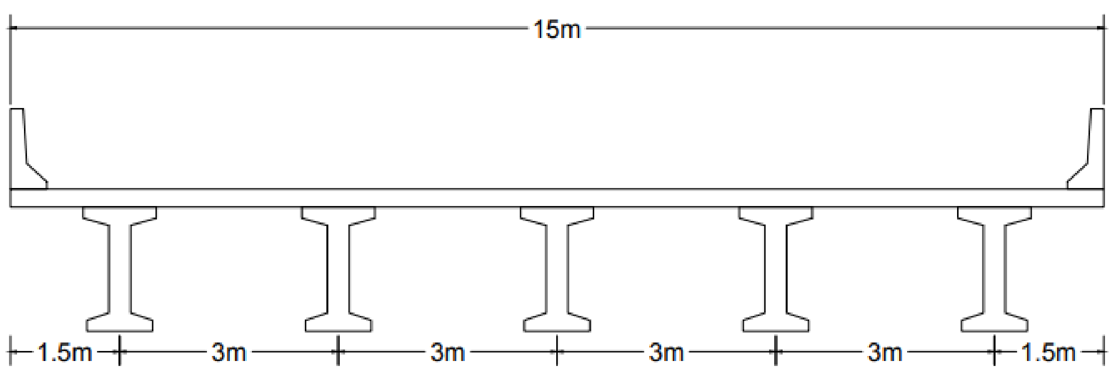



**Fig 1. Cross Section of PSC - I Girder Bridge**

A composite I-girder, illustrated below, shows the dimensions and features of the girder. This cross-section showcases the collaborative strength of materials, resulting in a high-performance and resilient framework designed to meet the demands of modern infrastructure.

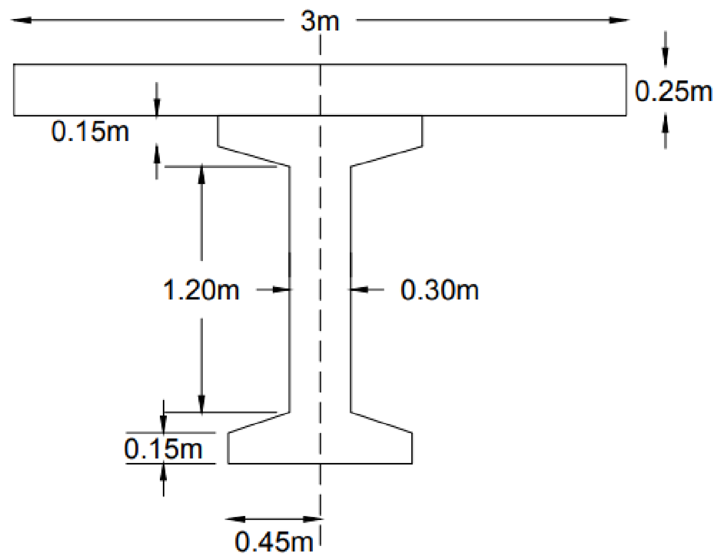



**Fig 2. Composite I-Girder**

The following figure illustrates a sophisticated and detailed computer-generated model of a PSC composite I-girder bridge, meticulously designed and analyzed using the advanced capabilities of MIDAS-CIVIL software. The model showcases a high level of precision, capturing the intricate geometry and structural elements inherent to the PSC composite design.

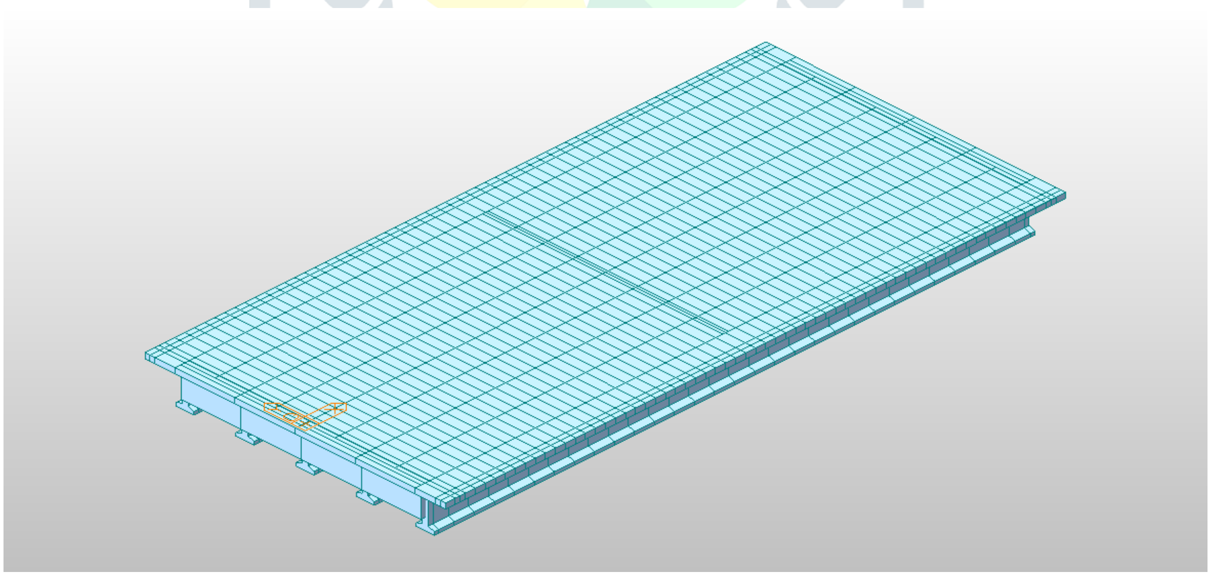
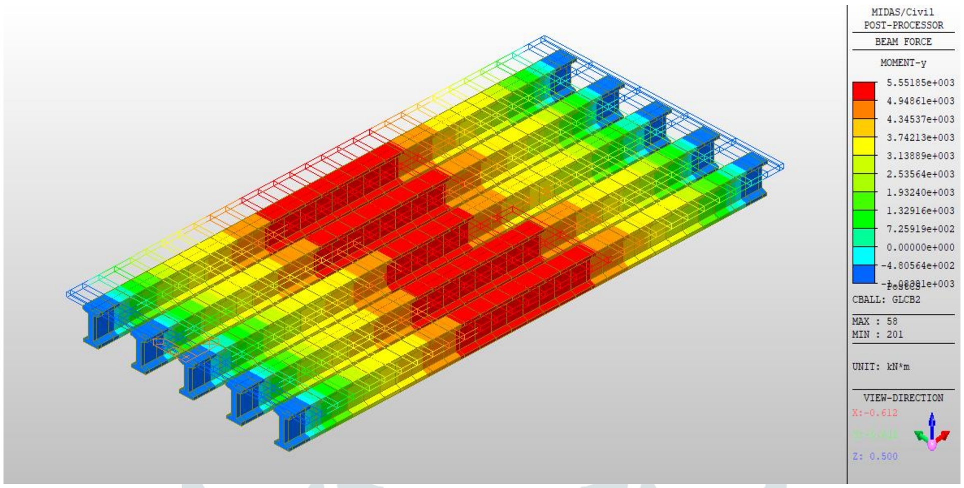


**Fig 3. Model of single span PSC - I girder bridge in MIDAS CIVIL**

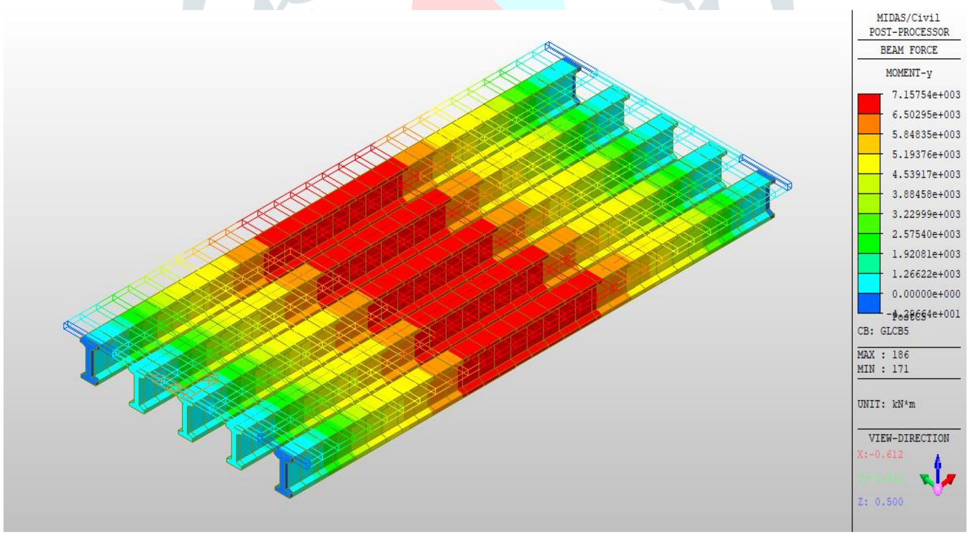
# V. RESULTS AND DISSCUSIONS

After carrying the analysis using the MIDAS CIVIL software, the PSC I - Girder Bridge results were examined. Under various loading scenarios, key structural analysis parameters such as shear force, torsion, and bending moment were examined and they are compared in the both models.

The comparison of the results, which shows the torsion, bending moment, and shear force applied to each bridge segment along its length, is given below.




**a) IRC**




**b) AASHTO**

**Fig 4. Bending moment of PSC I Girder Bridge under (a) IRC and (b) AASHTO loading conditions along with Moment-Y values**

In the figure 4, the bending moments exhibited by girders designed under IRC and AASHTO loading conditions reveal noteworthy variations. Under AASHTO standards, with its emphasis on heavier and more robust vehicles, girders are subjected to higher bending moments, particularly in mid sections of the bridge. The analysis results found out that AASHTO standards got more values compared to IRC standards.

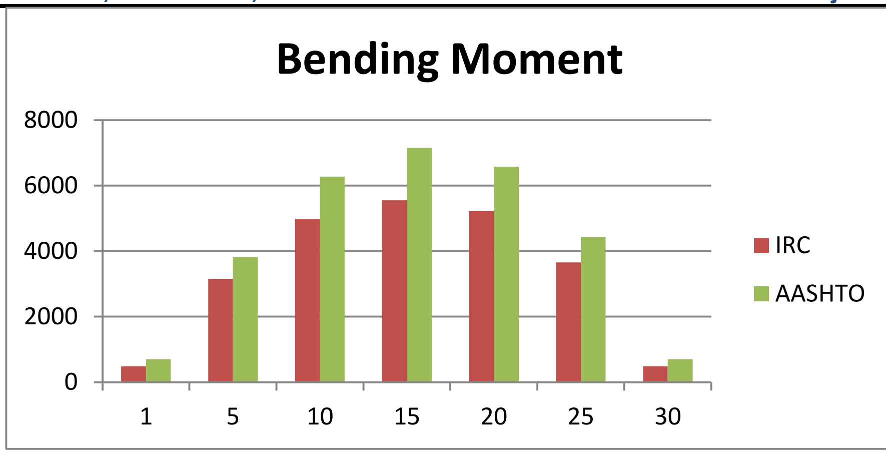



**Fig 5. Bending moment**

The figure 5 shows the Bending moment variation of the two models using IRC and AASHTO loading conditions. The graph shows the variation along the length of the bridge. It shows that the maximum bending moment occurs at the center of the bridge in both IRC and AASHTO loading conditions.

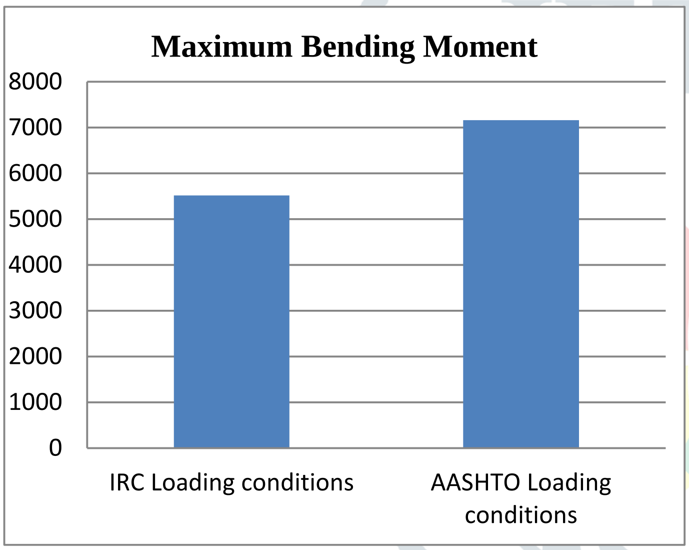



**Fig 6. Maximum Bending moment**

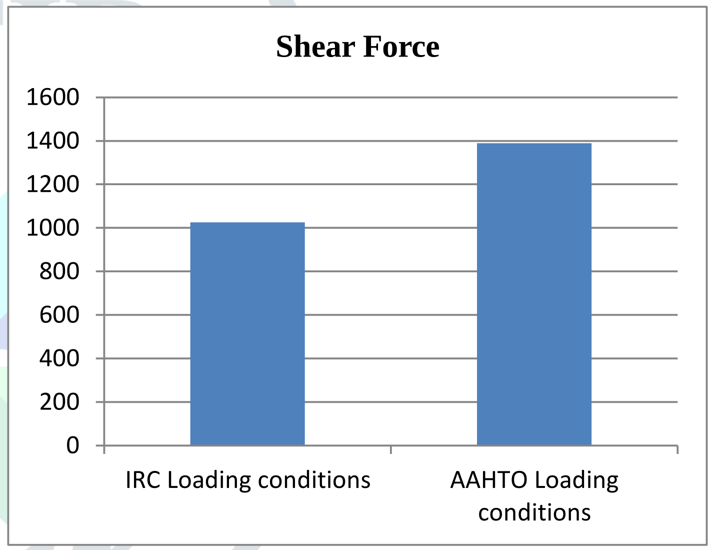



**Fig 7. Maximum Shear Force**

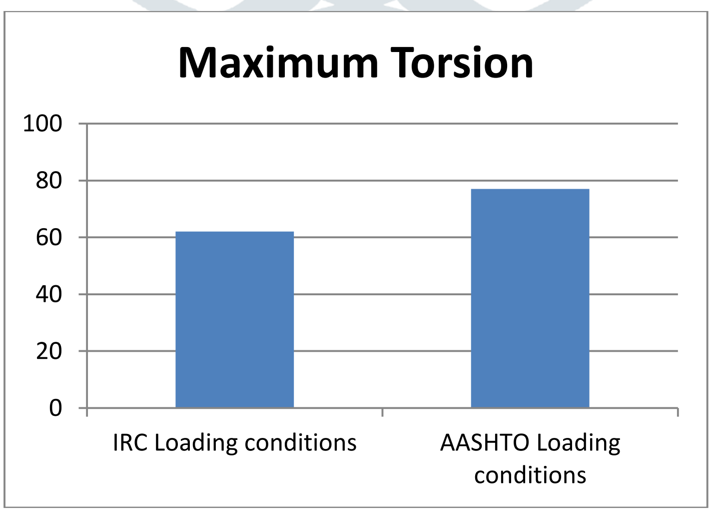



**Fig 8. Maximum Torsion**

Furthermore, as can be seen in Figures 6, 7, and 8, the values of bending moment, shear force and torsion were higher for mid-elements only and not for the remaining elements. Shear force, bending moment, and torsion values were nearly different for every element in both loading circumstances, with the exception of end elements. This was due to the heavy loading of AASHTO vehicles compared to IRC standard vehicles.

## VI. CONCLUSION

1. MIDAS CIVIL simplifies the analysis of prestressed concrete (PSC) I-girder bridges through its user-friendly interface, efficient section definition tools, and intuitive modeling capabilities, enables to conduct comprehensive analyses with ease.
2. The observed trend indicates that under AASHTO loading conditions occurs maximum values whether referring to bending moments, shear forces, or other structural responses and they tend to be higher compared to those under IRC loading conditions.
3. The inclusion of heavier vehicles in the AASHTO standard causes higher shear forces, torsional stresses, and bending moments across all elements of the PSC I - girder bridge.
4. It concludes that IRC loading standards provide less vehicular weight and can be considered to use for the analysis and design of the PSC I - girder bridge.
5. The implication of IRC loading conditions often involve lighter vehicle specifications, result in structurally sound designs while potentially minimizing construction costs and to make an economical structure.

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