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Comparative Study Of Precast I-Girder Bridge By Using The IRC And AASHTO Codes

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Abstract

The main objective of paper is the comparison for axial force, shear force, torsion, longitudinal stress and bending moment at various positions in I-Girder section. We considered the three span bridge model with lane width is 14.8m. Each span length is having 40m and total length of the bridge is 120m. The live loads assigned for the bridge model is class AA and class A from IRC code and HL -93K and HL-93M from AASHTO code. The Codes considered for bridge design like Indian code (IRC-2000) and American code (AASHTO LRFD-2007). The design of the bridge and structural analysis is done by using the computer software CSi Bridge v17.0.
The obtained results shows the maximum difference in longitudinal stress for IRC is 7.6% more than the AASHTO results. The torsion moments are minimum difference for both codes. The max bending moment for IRC value is 2.2% high compare to AASHTO. The IRC results are obtained max in all forces and AASHTO results are less. Hence the pre-cast I-Girder bridge is more stable in IRC code when compared with AASHTO code values.

Keywords: *IRC-21, IRC-06, AASHTO LFRD-2007, axial force, torsion, shear force, influence line, bending moment, CSi Bridge v17.0*

1. Introduction

The suitability of a particular type of bridge depends on different aspects, including topography, geotechnical conditions, height, clearance, and method of construction. Girder bridges that are built non-segmentally should have constant depth over their entire length to reduce false work and formwork costs. This type of bridge is economical for spans of up to roughly 80m in length. An efficient use of materials and a simple layout of pre stressing steel result from choosing span lengths to minimize the difference between the moment diagrams of any two adjacent spans. Girder depth is determined by economic and aesthetic considerations and may also be influence by clearance requirements. The principal advantage of precast components is ease of erection. Their use can substantially Reduce construction time and elimination of false work often result in low construction cost.

The design of various components of bridges is now done in most countries almost invariably with the use of computers. Designers are going in for longer and longer spans and adopt different forms and geometry in alignment. Designs have to be competitive and during conceptual and design stage, this calls for an iterative approach to arrive at the optimal span, type and structural arrangements. Design by hand calculations for such cases is very difficult and time consuming, if not impossible, naturally, this calls for use of computers and custom made programs. Here we considered the CSi Bridge software for analysis of pre-cast I-Girder bridge.

2. Components of R.C.C Bridge

A girder bridge, in general, is a bridge that utilizes girders as the means of supporting the deck
Bridges having mainly three components, i.e Super structure, Sub structure and Foundation

2.1 Super Structure Components:

The superstructure is everything from the bearing pads, up - it is what supports the loads and is the most visible part of the bridge. Girders are main load carrying components.

- Steel or concrete girders
- Segmental boxes

- Suspension or cable stayed
- Trusses

  -Deck

  -Wearing surface- bituminous or concrete

2.2 Substructure:

The Substructure is the foundation, which transfers the loads from the superstructure to the ground. Both parts must work together to create a strong, long-lasting bridge.

- Piers
- Abutments

In a beam or girder bridge, the beams themselves are the primary support for the deck, and are responsible for transferring the load down to the foundation. Material type, shape, and weight all affect how much weight a beam can hold.

Due to the properties of inertia, the height of a girder is the most significant factor to affect its load capacity. Longer spans, more traffic, or wider spacing of the beams will all directly result in a deeper beam.

3. Loading Standards in Bridge Design:

Loading standards for design of bridges are specified by various countries through either their standardization organization or recognized professional bodies. They may vary considerably country to country, depending on the type of vehicles in use or proposed for use in their country. The wide variation in Highway Bridge loading adopted by different countries, as they were some time back in different countries in the world.

The concept of design has also undergone changes. Earlier practice was to use working stress or allowable stress concept for design of bridge structures. Most countries now follow limit state design concept in design of bridge structures also. The load factors assumed may vary from standard to standard.

4. Loading on I-Girder Bridge:

Any bridge structure has to support moving loads, i.e. laden vehicles, and transmit their effects, through its various components, to the soil on which it is constructed. It has also to support and convey in a similar manner the self-weight of its various components. In addition, the structure is subjected to other external forces, such as those caused by the wind, velocity of water and earthquake, to which the area may be subjected to and stresses caused due to temperature variation.

4.1 Dead load:

It consists of the portion of the weight of superstructure and fixed loads coming thereon, wholly or partly supported by the member or girder considered and self- weight.

4.2 Live load:

Live load covers a range of forces produced by vehicles moving on the bridge. It includes the static and dynamic components. The effect of live load depends on many parameters including the span length, truck weight, axle loads, position of the vehicle on the bridge, girder spacing, and stiffness of structural members. In this case we considered two codes of vehicles loads in bridge analysis.

According to IRC	– Class AA and Class A
According to AASHTO	– HL-93K and HL-93M

4.3 Wind load:

WS – horizontal and vertical pressure on superstructure or substructure due to wind.
WL – horizontal pressure on vehicles due to wind.

5. Specifications Considered In Bridge Design:

Span length	-	40.00 m c/c
No. of Spans	-	3
Total length of bridge	-	120m
Length of the slab	-	39.96 m
Expansion joint width	-	40 mm
Width of the slab	-	14.80 m
Slab thickness	-	0.22 m
Grade of concrete	-	M45
Carriage way width	-	10.50 m
Foot path (on both sides) width	-	1.50 m
No. of Girders on each slab	-	5 no.
Crash barrier width (on both sides)	-	0.45 m
Hand rails width (on both sides)	-	0.20 m
Drainage spouts (on both sides)	-	2 x 7 no.s

5.1 Precast girders:

Concrete strength at transfer f_{ci} $= 0.75f_{ck}$
$= 0.75\times45$
$= 33.75$
$= 40$ MPA

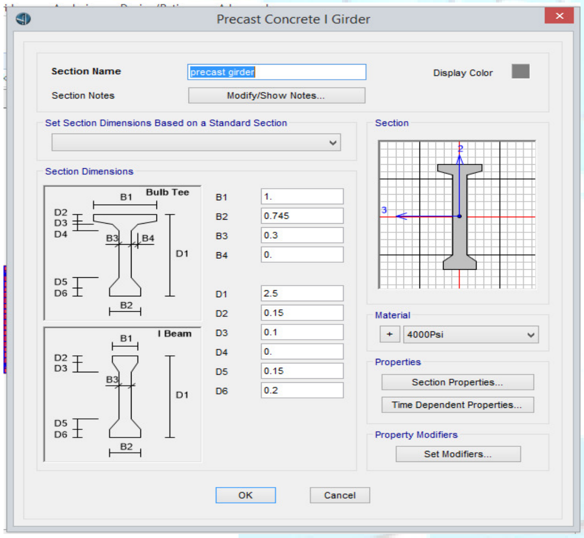
Concrete strength at 28 days f_c	= 45 MPA
Concrete unit weight	= 24 KN/M
Overall girder length	= 39960 mm
	= 40040mm
Design of span	= 40m

5.2 Pre-Stressing Strands:

12.7 dia , seven wire low relaxation strands

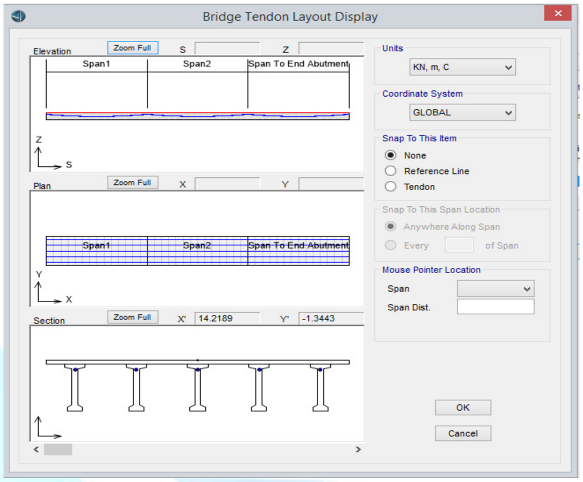
Area of strands	= 98.71 mm^2
No of strands in one cable	= 15
No of cable	= 5
Ultimate strength f_{pu}	= 1860 Mpa
Yield strength	=0.9 f_{pu}
	=0.9×1860
	=1674 Mpa

6. Model Generation and Analysis In CSi Bridge Software:



Section Name: precast girder
B1: 1.
B2: 0.745
B3: 0.3
B4: 0.
D1: 2.5
D2: 0.15
D3: 0.1
D4: 0.
D5: 0.15
D6: 0.2
Material: 4000Psi

Fig 1: Specifications of I-Girder



Units: KN, m, C
Coordinate System: GLOBAL
Snap To This Item: ● None ○ Reference Line ○ Tendon
X: 14.2189
Y: -1.3443

Fig 2: Bridge Tendon Layout Display

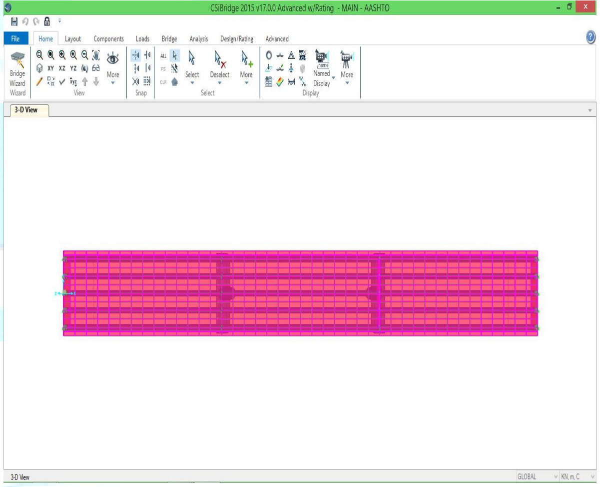


Fig 3: Top view of bridge

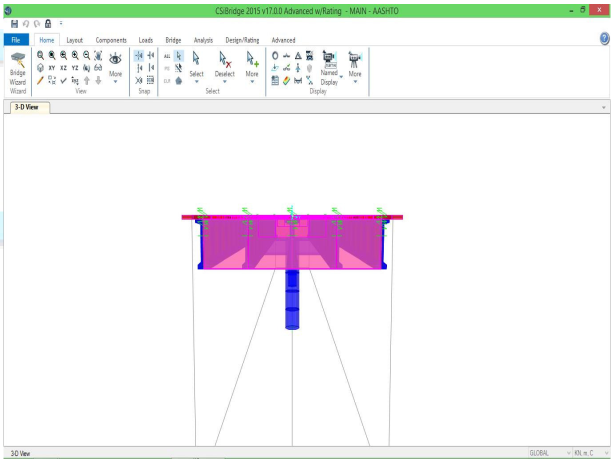


Fig 4: Front view of bridge

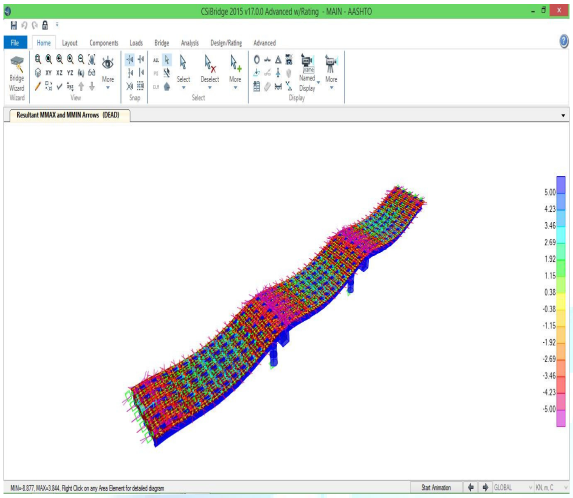


Fig 5: Resultant Max and Min Arrows for Dead Load

7. TABLES:

7.1 Longitudinal Stress Results of Slab and Girder in AASHTO and IRC codes:

	Stress KN/M^2	Left Ext. Girder		Int. Girder 1		Int. Girder 2		Int. Girder 3		Right Ext. Girder	
		IRC	AASHTO	IRC	AASHTO	IRC	AASHTO	IRC	AASHTO	IRC	AASHTO
1	SLAB TOP LEFT	4513.9	3914.7	3887.1	3373.8	3596.3	3123.7	3092.2	2689.7	2978.9	2597.9
		-1311.8	-1100.5	-1433.7	-1206.1	-1458.8	-1229.1	-1464.2	-1231.8	-1372.1	-1151.7
2	SLAB TOP AT GIRDER CENTER	3769.2	3275.9	3484.5	3027.4	3596.3	3123.7	3484.5	3027.4	3769.2	3275.9
		-1339.0	-1123.6	-1446.7	-1217.1	-1458.8	-1229.1	-1446.7	-1217.1	-1339.0	-1123.6
3	SLAB TOP RIGHT	2978.9	2597.9	3092.2	2689.7	3596.3	3123.7	3887.1	3373.8	4513.9	3914.7
		-1372.1	-1151.7	-1464.2	-1231.8	-1458.8	-1229.1	-1433.7	-1206.1	-1311.8	-1100.5
4	ENVELOPE-SLAB TOP	4513.9	3914.7	3887.1	3373.8	3596.3	3123.7	3887.1	3373.8	4513.9	3914.7
		-1372.1	-1151.7	-1464.2	-1231.8	-1458.8	-1229.1	-1464.2	-1231.8	-1372.1	-1151.7
5	SLAB BOTTOM LEFT	1974.7	1605.9	1833.4	1553.7	1915.5	1623.8	2103.2	1784.9	2019.4	1715.1
		-1771.5	-1516.3	-1751.7	-1497.3	-1755.8	-1515.8	-1762.5	-1506.5	-1792.2	-1534.1
6	SLAB BOTTOM AT GIRDER CENTER	1851.5	1570.3	1968.3	1669.3	1915.5	1623.8	1968.3	1669.3	1851.5	1570.3
		-1781.5	-1524.8	-1755.6	-1500.8	-1775.8	-1515.8	-1755.6	-1500.8	-1781.5	-1524.8
7	SLAB BOTTOM RIGHT	2019.4	1715.1	2103.2	1784.9	1915.5	1623.8	1833.4	1553.7	1974.7	1605.9
		-1792.2	-1534.1	-1762.5	-1506.5	-1775.8	-1515.8	-1751.7	-1497.3	-1771.5	-1516.3
8	SLAB BOTTOM	2019.4	1715.1	2103.2	1784.9	1915.5	1623.8	2103.2	1784.9	2019.4	1715.1
		-1792.2	-1534.1	-1762.5	-1506.5	-1775.8	-1515.8	-1762.5	-1506.5	-1792.2	-1534.1

1	GIRDER TOP LEFT	5559.9	4804.0	5312.0	4583.7	5279.3	4561.1	5209.1	4505.2	5062.3	4376.4
		-1651.5	-1410.4	-1665.6	-1421.2	-1688.1	-1439.9	-1693.7	-1446.9	-1666.7	-1422.8
2	GIRDER TOP CENTER	5311.0	4590.1	5260.5	4544.4	5279.3	4561.1	5260.5	4544.4	5311.0	4590.1
		-1657.4	-1414.3	-1675.5	-1429.7	-1688.1	-1439.9	-1675.5	-1429.7	-1657.4	-1414.3
3	GIRDER TOP RIGHT	5062.3	4376.4	5209.1	4505.2	5279.3	4561.1	5312.0	4583.7	5559.9	4804.0
		-1666.7	-1422.8	-1693.7	-1446.9	-1688.1	-1439.9	-1665.6	-1421.2	-1651.5	-1410.4
4	ENVELOPE -GIRDER TOP	5559.9	4804.0	5312.0	4583.7	5279.3	4561.1	5312.0	4583.7	5559.9	4804.0
		-1666.7	-1422.8	-1693.7	-1446.9	-1688.1	-1439.9	-1693.7	-1446.9	-1666.7	-1422.8
5	GIRDER BOTTOM LEFT	3424.7	3051.4	3417.4	3041.6	3445.7	3065.5	3396.7	3023.3	3413.2	3041.9
		-7583.9	-6714.6	-7604.1	-6729.2	-7667.1	-6777.8	-7680.6	-6787.6	-7954.2	-1732.8
6	GIRDER BOTTOM CENTER	3416.0	3043.5	3403.4	3028.6	3445.7	3065.5	3403.4	3028.6	3416.0	3043.5
		-7769.1	-6873.7	-7642.3	-6758.4	-7662.1	-6777.8	-7642.3	-6758.4	-7769.1	-6873.7
7	GIRDER BOTTOM RIGHT	3413.2	3041.9	3396.7	3023.3	3445.7	3065.5	3417.4	3041.6	3424.7	3051.4
		-7954.2	-7032.8	-7680.6	-6787.6	-7662.1	-6777.8	-7604.1	-6729.2	-7583.9	-6714.6
8	ENVELOPE -GIRDER BOTTOM	3424.7	3051.4	3417.4	3041.6	3445.7	3065.5	3417.4	3041.6	3424.7	3051.4
		-7954.2	-7032.8	-7680.6	-6787.6	-7662.7	-6777.8	-7680.6	-6787.6	-7954.2	-7032.8

7.2 Axial force, shear force, torsion, and bending moment at different girders:

S. NO	Forces	Left Ext. Girder		Int. Girder 1		Int. Girder 2		Int. Girder 3		Right Ext. Girder	
		IRC	AASHTO	IRC	AASHTO	IRC	AASHTO	IRC	AASHTO	IRC	AASHTO
1	AXIAL FORCE (P)	1398.1	758.0	1254.4	377.4	658.6	451.4	1254.4	377.4	1398.1	758.0
		-2044.3	-786.0	-1252.8	-581.1	-908.8	-636.1	-1252.8	-581.1	-2044.3	-786.6
2	SHEAR VERTICAL (V2)	1228.8	547.6	1181.5	596.5	1033.1	701.45	1181.5	596.5	1228.8	547.6
		-1005.1	-545.8	-1051.1	-595.4	-1032.5	-703.3	-1051.1	-595.4	-1005.1	-545.8
3	SHEAR HORIZONTAL (V3)	270.0	128.0	312.0	164.6	313.5	126.3	288.6	164.8	246.5	129.6
		-246.5	-129.6	-288.6	-164.8	-313.5	-126.3	-312.0	-164.8	-270.0	-128.0

4	TORSION (T)	634.9	175.2	324.4	190.3	354.4	143.2	284.6	190.4	490.2	176.1
		-490.2	-176.3	-284.6	-190.4	-354.4	-143.2	-324.4	-190.3	-634.9	-175.2
5	MOMENT ABOUT VERTICAL AXIS (M2)	582.9	179.4	254.7	139.9	226.7	103.2	264.3	119.5	217.5	109.1
		-217.5	-109.1	-264.3	-119.5	-226.7	-103.2	-254.7	-139.9	-582.9	-179.4
6	MOMENT ABOUT HORIZONTAL AXIS (M3)	4251.5	2304.4	3513.8	2114.1	3285.3	2224.4	3513.8	2114.1	4251.5	2304.4
		-6556.4	-3403.1	-5240.6	-3134.1	-4751.7	-3337.8	-5240.6	-3134.1	-6556.4	-3403.1

Table: comparison of axial force, torsion, shear force and bending moment in both codes

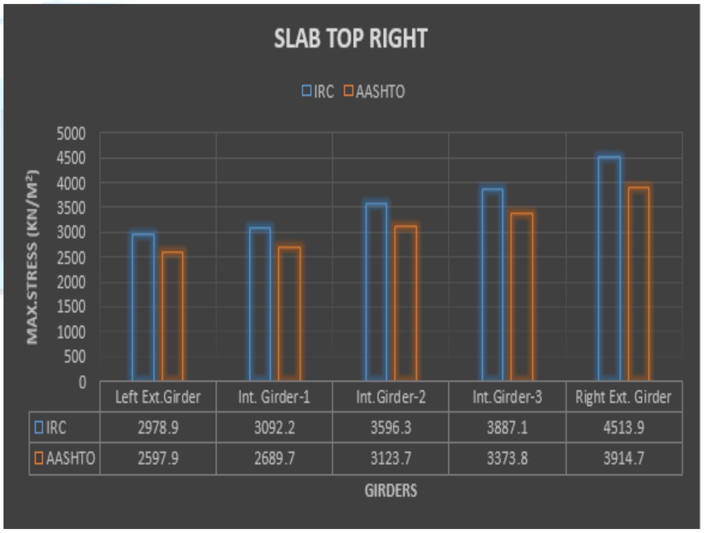
The above table shows the results of different forces in different girders for both IRC and AASHTO codes. The values of axial force in IRC shows maximum at left ext. girder and right ext. girder. When compare to axial forces in IRC and AASHTO. The results of IRC axial forces are high. Similarly when comparing the shear vertical and shear horizontal results are more in IRC codes and AASHTO code results are less.

Moment at vertical axis values are high in IRC code and very less in AASHTO code results. The moment at vertical axis values of interior girders are very weak and high in the exterior girders for both codes.

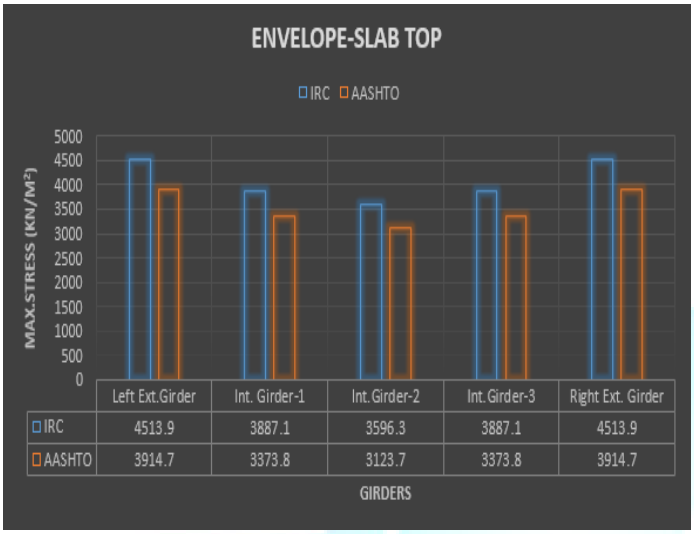
Moment at horizontal axis values are very less in AASHTO code and high in IRC code results. The interior girders are having the less values and exterior girders are having the high values in both the codes.

8 GRAPHS:

Graph 1: Max stress at slab top left in IRC and AASHTO

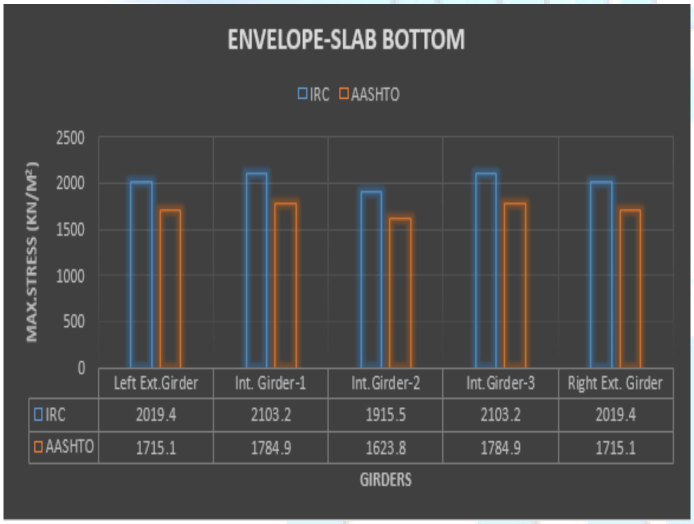


Graph 2: Max stress at slab top right in IRC and AASHTO



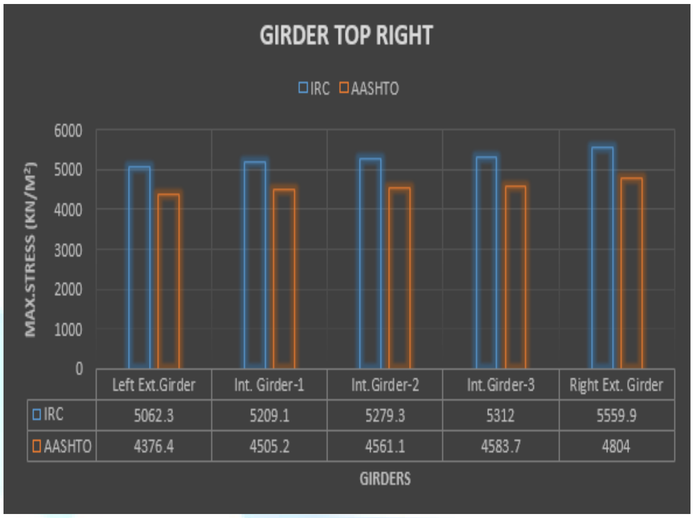
	Left Ext.Girder	Int. Girder-1	Int.Girder-2	Int.Girder-3	Right Ext. Girder
☐ IRC	4513.9	3887.1	3596.3	3887.1	4513.9
☐ AASHTO	3914.7	3373.8	3123.7	3373.8	3914.7

Graph 3: Max stress at envelop slab top in IRC and AASHTO



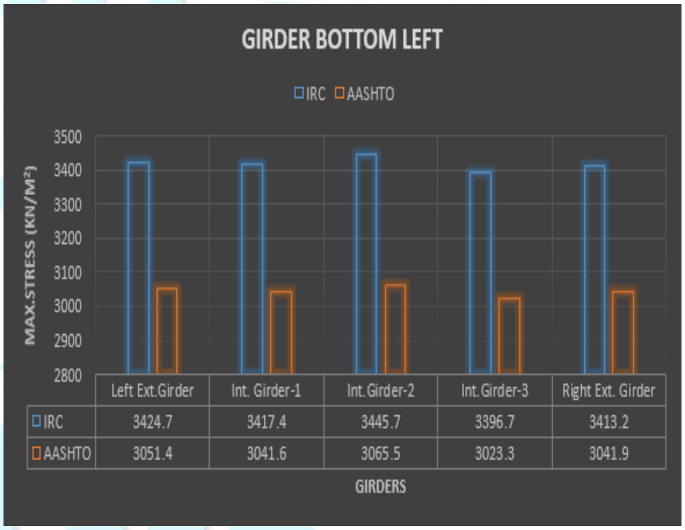
	Left Ext.Girder	Int. Girder-1	Int.Girder-2	Int.Girder-3	Right Ext. Girder
☐ IRC	2019.4	2103.2	1915.5	2103.2	2019.4
☐ AASHTO	1715.1	1784.9	1623.8	1784.9	1715.1

Graph 4: Max stress at slab bottom in IRC and AASHTO



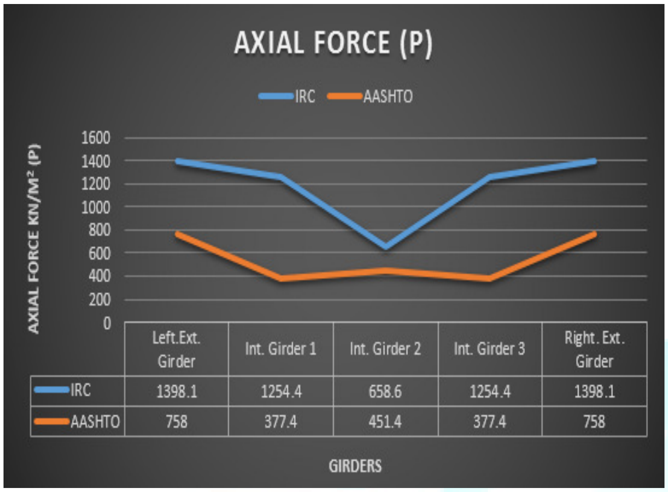
	Left Ext.Girder	Int. Girder-1	Int.Girder-2	Int.Girder-3	Right Ext. Girder
☐ IRC	5062.3	5209.1	5279.3	5312	5559.9
☐ AASHTO	4376.4	4505.2	4561.1	4583.7	4804

Graph 5: Max stress at girder top right in IRC and AASHTO

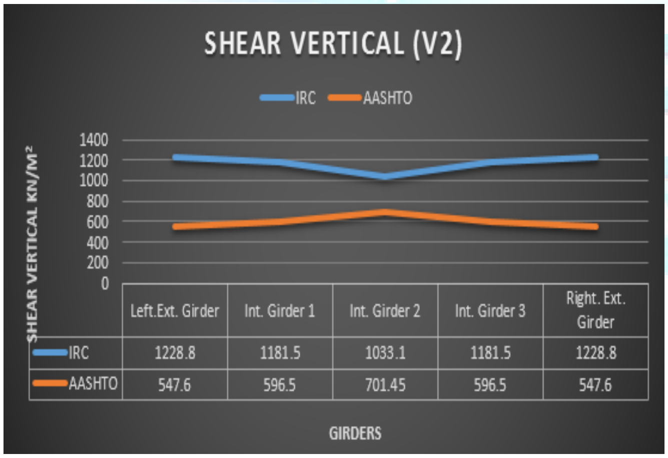


	Left Ext.Girder	Int. Girder-1	Int.Girder-2	Int.Girder-3	Right Ext. Girder
☐ IRC	3424.7	3417.4	3445.7	3396.7	3413.2
☐ AASHTO	3051.4	3041.6	3065.5	3023.3	3041.9

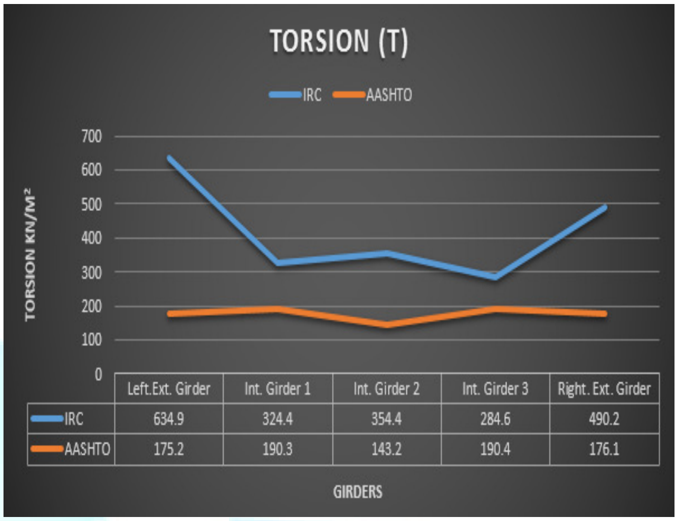
Graph 6: Max stress at girder bottom left in IRC and AASHTO



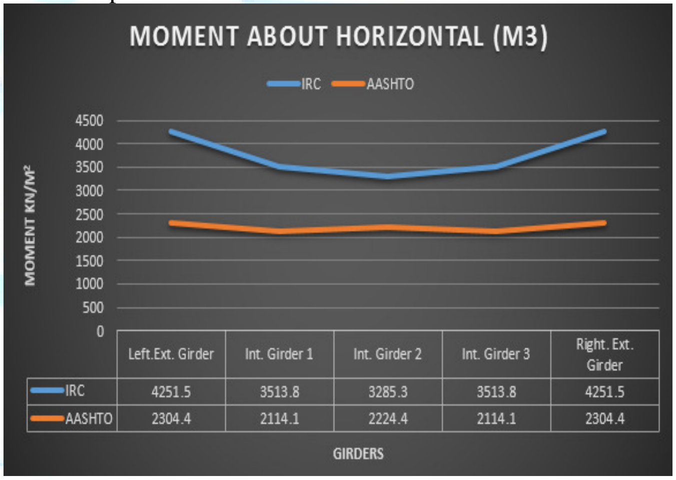
Graph 7: Axial force in IRC and AASHTO



Graph 8: Shear vertical force in IRC and AASHTO



Graph 9: Torsion force in IRC and AASHTO



Graph 10: Moment about horizontal in IRC and AASHTO

9 CONCLUSION:

This paper presents comparative analysis of Precast I Girder Bridge considering the IRC and AASHTO codes. The maximum stress values are considered for different sections of bridge in slab and girders of IRC and AASHTO codes.

Graph-1 shows the results of Slab top left in left exterior girder, the maximum stress for IRC the code value is 7.6% high compare to the AASHTO code value.

Graph-2 shows the Slab top right in exterior girder, the maximum stress for IRC the code value is 5.1% more than the AASHTO code value.

Graph-3 shows the results of Envelop-slab top at left exterior girder, the maximum stress for IRC the code value is 7.6% more than the AASHTO code value.

Graph-4 shows the results of Envelop-slab bottom at interior girder-3, the maximum stress for IRC the code value is 5.1% high compare to the AASHTO code value.

Graph-5 shows the results of Girder top right at right exterior girder, the maximum stress for IRC the code value is 3.4% more than the AASHTO code value.

Graph-6 shows the results of Girder bottom left at interior girder-2, the maximum stress for IRC the code value is 0.4% almost equal to the AASHTO code value.

Graph-7 shows the results of the Axial force in right exterior girder for IRC the code value is 5.05% more than the AASHTO code value.
Graph-8 shows the results of shear vertical in left exterior girder for IRC the code value is 3.5% high compare to the AASHTO code value.

Graph-9 shows the results of torsion in left exterior girder for IRC the code value is 3.1% high compare to the AASHTO code value.

Graph-10 shows the results of moment about horizontal in right exterior girder for IRC the code is 2.2% more than the AASHTO code value.

The Torsion and Moment about Horizontal values are having Minimum difference. The Moment about Vertical values is more in IRC and less in AASHTO code values. The Axial force and Shear Vertical values are having less difference between both codes.

In all forces IRC code results are more, Because in IRC the codes given for the Vehicle loads is more when compared with AASHTO Codes. Hence the pre-cast I-Girder bridge is more stable in IRC code when compared with AASHTO code values.

10 REFERENCES:

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