Effective Positioning of Cable Profiles in Prestressed: I Girders

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Abstract: This paper explores an efficient approach to analyzing and designing bridges, with a focus on prestressed concrete components, using numerical modeling tools. The study utilizes CSi Bridge, a finite element-based solution designed for modeling, analyzing, and designing bridge structures. CSiBridge streamlines the handling of complex bridge configurations, parameter variations, diverse load scenarios, and boundary conditions through accessible commands within the modeling tool.

The analysis incorporates factors such as dead loads, superimposed dead loads, prestress forces, and live loads from vehicular traffic. The results demonstrate CSiBridge's exceptional ability to automate intricate design procedures. Specifically, the study reveals that flexural design is primarily governed by moment reactions from dead loads, while the shear design of girders is notably influenced by shear reactions from live vehicular loads.

An essential parameter for stability and strength is the cable profile, with its positioning significantly impacting the bridge structure. The paper emphasizes the effective positioning of the cable profile in prestress girders using CSiBridge software. This approach contributes to a more efficient and streamlined process for analyzing and designing bridges, particularly those involving prestressed concrete components, addressing the challenges of the contemporary industrial landscape.

Index Terms - Bridge design, Prestressed concrete, CSi Bridge, I-girder bridge, Cable profile

I. Introduction

Concrete girders, which can be reinforced or prestressed, are crucial components in highway bridge design. However, the analysis and design of these bridges can be challenging, especially when dealing with prestressed concrete sections. Bridge designers often use a semi-manual approach, which involves estimating and manually arranging bridge loadings based on influence lines. This method is time-consuming and focuses on local structure behavior, leading to overly cautious designs lacking economic efficiency.

Through advancements in three-dimensional computational mechanics, software applications like CSi Bridge and MIDAS Civil have evolved to better model, analyze, and design bridge structures. These tools allow for the easy establishment of various bridge configurations, parameters, load scenarios, and boundary conditions.

Prestressed I-girders are a promising solution to bridge design, as they introduce compressive forces by embedding high-strength steel cables before casting concrete. This approach enhances the load-bearing capacity, durability, and longevity of bridges. Precise tendon placement is crucial for optimal results, requiring careful consideration of load distribution, structural behavior, and material properties. Incorporating prestressed I-girders aims to create bridges with extended spans, improved safety, and longer service lives.

II. Bridge Components

The superstructure of a bridge consists of the deck, girders, trusses, arch, cables, and slab. The substructure includes abutments, pins, and foundations. The bridge's bearings include expansion joints, bearing pads, and restraints. Connection elements include bolts and nuts, welds, and rivets.

Deck systems include asphalt, concrete, grating, pedestrian walkways, barriers like parapets and guardrails, drainage systems like scuppers and drain pipes, lighting and signage like streetlights and traffic signs, monitoring and maintenance systems using sensors to detect structural changes, and access platforms for maintenance workers to inspect different areas.

The bridge's aesthetics and finishes include architectural features that enhance its visual appeal and paint or coatings to protect it from environmental factors and corrosion. Barrier systems include parapets and guardrails to prevent veering off and provide safety barriers. Drainage systems include scuppers and drain pipes to collect and channel water away from bridge components.In summary, a bridge's superstructure, substructure, bearings, connectors, deck systems, barriers, lighting, signage, monitoring and maintenance systems, and aesthetics all contribute to its overall functionality and safety.

III. I Girders

Prestressed I girders are a type of structural component commonly used in bridge construction and other applications that require extensive spans and substantial load-bearing capacities. These girders are designed to effectively support both permanent loads, such as the weight of the structure itself, and temporary loads, like vehicular traffic.

The key characteristics of prestressed I girders include their I-shaped profile, which facilitates efficient distribution of loads and contributes significantly to the overall structural integrity of the girder. The prestressing mechanism introduces internal forces (precompression) into the girder by means of tensioned steel strands or tendons, effectively counteracting anticipated tensile stresses that the girder will encounter under loads. This results in enhanced load-bearing capacity and minimized deflection.

Prestressed I girders often involve the use of high-strength materials, such as high-strength concrete and prestressing steel strands, to provide compressive strength and tensile strength. They can span greater distances than traditional reinforced concrete girders, making them suitable for diverse bridge applications such as highway overpasses and interchanges.

The prestressing process plays a pivotal role in minimizing deflections under applied loads, maintaining ride comfort and ensuring bridge safety. The I-shaped cross-section of the girder imparts remarkable flexural strength, enabling the girder to effectively withstand bending forces without succumbing to excessive deflection or failure. The ends of prestressed I girders are supported by either abutments or piers, designed to accommodate the diverse forces and moments acting upon the girder. Precast prestressed girders contribute to efficient construction practices, as they can be manufactured off-site and transported to the construction site, thereby curtailing on-site construction duration.

The design of prestressed I girders adheres rigorously to established design codes and standards pertinent to the specific region and structure type. While the initial cost of prestressed I girders might surpass that of traditional girders, their capacity to span longer distances, necessitate reduced maintenance, and carry increased loads often translates into cost savings over the lifespan of the structure.

In contemporary bridge engineering, prestressed I girders play a pivotal role in crafting robust and secure bridge structures capable of accommodating substantial traffic loads and spanning considerable expanses.

IV. Prestressed (Pre tensioning & Post Tensioning)

Prestressed concrete is a construction technique that involves placing concrete elements under compression before they are subjected to external loads. This process involves applying internal forces to the concrete using tensioned steel tendons or cables. The primary objective of prestressing is to counteract the potential tensile stresses that the concrete might experience under its service loads, thereby enhancing its structural performance and durability.

Prestressed concrete offers several advantages, including increased strength, reduced cracking, enhanced span lengths, improved load-carrying capacity, faster construction, and durability. It allows for the use of higher-strength concrete and steel materials, leading to greater load-carrying capacity. Cracking is significantly reduced by minimizing or eliminating tensile stresses in the concrete, improving both aesthetics and durability. Prestressed concrete beams and girders can achieve longer spans with shallower depths compared to traditional reinforced concrete, allowing for more efficient designs. Precast prestressed elements can be fabricated off-site and then transported and installed, saving construction time. The combination of reduced cracking and improved load-bearing capacity contributes substantially to the overall endurance of prestressed concrete structures.

Prestressed concrete finds application in various structures, including bridges, buildings, parking structures, railway sleepers, and beyond. This innovative construction approach optimizes material usage, diminishes maintenance demands, and offers cost-effective, enduring solutions across a diverse range of engineering projects.

In prestressed concrete, the tendons or cables are carefully stretched and anchored against the concrete, generating compressive forces within the concrete itself. This proactive measure prepares the concrete to better withstand external loads, such as the weight of a structure or live loads like vehicles.

The process of prestressing permits the use of higher-strength concrete and steel materials, resulting in a significantly elevated load-bearing capacity. Crack minimization is achieved by effectively reducing or eliminating tensile stresses within the concrete, diminishing the occurrence of cracking, enhancing both the appearance and longevity of the structure.

Prestressed concrete beams and girders exhibit the capacity to attain longer spans with shallower depths compared to the conventional reinforced concrete approach. This flexibility allows for more efficient and streamlined designs.

Precast prestressed elements can be fabricated off-site and then transported and installed, expediting the construction process and saving valuable time. The combination of reduced cracking and improved load-bearing capacity contributes substantially to the overall endurance of prestressed concrete structures.

Cable profiles are essential elements in the integrity, stability, and performance of cable-supported structures. They consist of various components, including main cables, suspender cables, anchorages, towers or pylons, cable saddles or sockets, cable tensioning systems, and dampers or dampening systems. Main cables are the primary load-bearing elements, enduring most applied loads and arranged in a predetermined pattern. Suspender cables connect the main cables to the bridge deck or other structural components, maintaining the desired vertical profile and stability.

Anchorages secure cable ends to their supports, such as towers or anchor points, transferring cable forces to the supporting structure and preventing unintended movement. Towers or pylons provide vertical support for the main cables, ensuring proper cable tension and withstanding imposed forces. Cable saddles or sockets provide a secure point for cables to be attached and facilitate force transfer. Cable tensioning systems adjust and maintain the desired tension in the cables, essential for structural stability and performance. In some cases, dampers or dampening systems may be employed to mitigate the effects of dynamic forces, such as wind-induced vibrations.

V. Theoretical Aspect

CSI Bridge is a software developed by Computers and Structures, Inc. (CSI) for designing and analyzing bridges. Engineers widely use it for various tasks related to bridges. Engineers can use CSI Bridge to create detailed 3D models of different types of bridges, including highways, pedestrians, and railways. The software also conducts structural analysis, checking codes to ensure that bridge designs meet safety standards set by authorities.

The software also assesses load capacity, determining if existing bridges can handle traffic and other loads. For complex bridge projects, CSI Bridge simulates construction stages to ensure the bridge's durability. Dynamic analysis examines how the bridge responds to vibrations from traffic or wind, ensuring the bridge's safety and functionality.

CSI Bridge can be used with other tools to facilitate collaboration between engineers and builders on bridge projects. Engineers can quickly try out different design ideas by changing parts of the design, ultimately finding the best design for performance and efficiency.CSI Bridge also helps engineers create detailed reports with all the necessary information. It is also used for teaching bridge engineering in schools.

When using CSI Bridge, engineers follow specific steps: define the shape, choose materials, figure out loads, make a model, analyze the bridge's response to forces, check designs, make adjustments, get details ready, support during construction, and keep an eye on the bridge after construction. These steps may vary depending on the type of bridge and the rules used, but understanding how bridges work and using CSI Bridge to design and analyze them is crucial.

VI. Research Methodology

CSI Bridge, a software developed by Computers and Structures, Inc. (CSI), is used by civil and structural engineers to design and analyze bridges and other structures.The steps for utilizing CSI Bridge in bridge design involve defining the bridge's geometry, specifying material properties, and determining various types of loads the bridge will experience. Following geometry definition, engineers input material properties such as concrete and steel characteristics into CSI Bridge software.

Engineers then specify the types of loads the bridge will face during its lifetime, including dead loads, live loads, wind loads, seismic loads, and temperature effects. Subsequently, engineers create a detailed computer model of the bridge using CSI Bridge software, inputting geometric data, material properties, and loadings.

Structural analysis is then performed using appropriate methods, such as finite element analysis, to calculate internal forces, displacements, and other relevant responses of the bridge under specified loads. Design criteria and codes are specified to ensure adherence to safety regulations and guidelines, with the software automatically performing design checks for various bridge elements based on selected codes.

Engineers review design results and make necessary adjustments to optimize the bridge's performance and efficiency, potentially modifying dimensions, reinforcement layouts, or other design parameters. Detailed drawings and reports are generated to provide construction information, including reinforcement details and section dimensions.

During construction, CSI Bridge assists engineers and contractors in understanding the design intent and ensuring that construction aligns with design specifications. Post-construction, the bridge undergoes periodic evaluations for structural integrity and safety, with CSI Bridge aiding in assessments and retrofitting designs to extend the bridge's service life.

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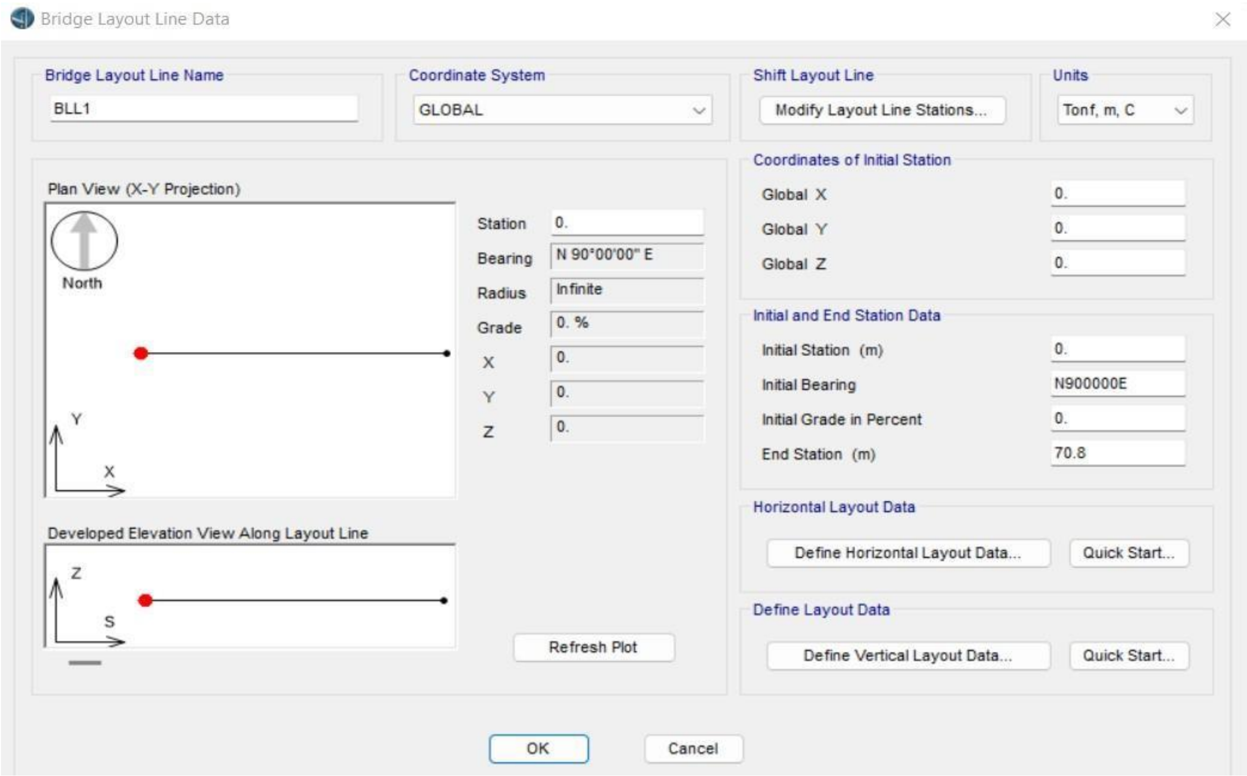
VII. Bridge Design Data



Bridge Layout Line Data

Bridge Layout Line Name: BLL1

Coordinate System: GLOBAL

Units: Tonf, m, C

Station	0.
Bearing	N 90°00'00" E
Radius	Infinite
Grade	0. %
X	0.
Y	0.
Z	0.

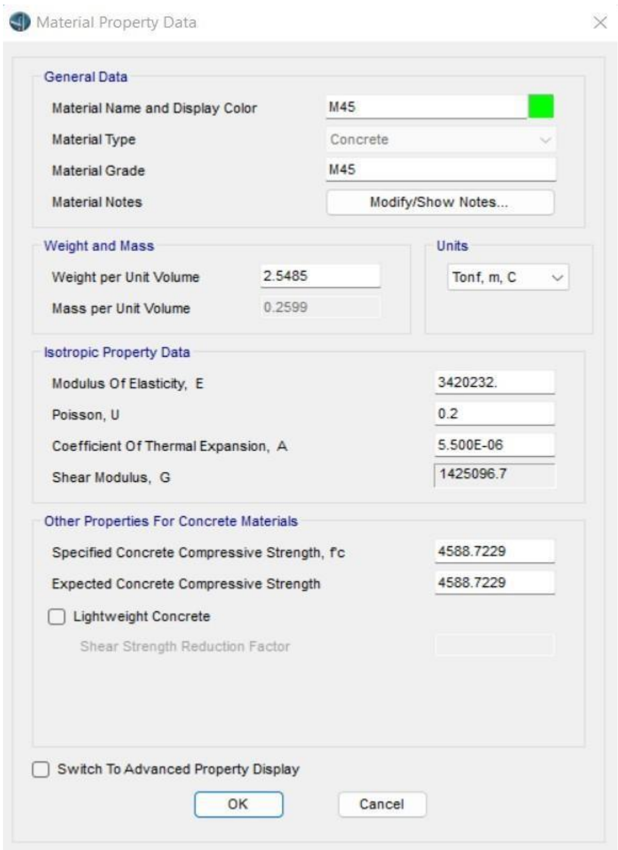
Coordinates of Initial Station

Global X	0.
Global Y	0.
Global Z	0.

Initial and End Station Data

Initial Station (m)	0.
Initial Bearing	N900000E
Initial Grade in Percent	0.
End Station (m)	70.8

Fig 1 Bridge Layout Line Data



Material Property Data

General Data

Material Name and Display Color: M45 🟩

Material Type: Concrete

Material Grade: M45

Material Notes: Modify/Show Notes...

Weight and Mass

Weight per Unit Volume: 2.5485

Mass per Unit Volume: 0.2599

Units: Tonf, m, C

Isotropic Property Data

Modulus Of Elasticity, E: 3420232.

Poisson, U: 0.2

Coefficient Of Thermal Expansion, A: 5.500E-06

Shear Modulus, G: 1425096.7

Other Properties For Concrete Materials

Specified Concrete Compressive Strength, f'c: 4588.7229

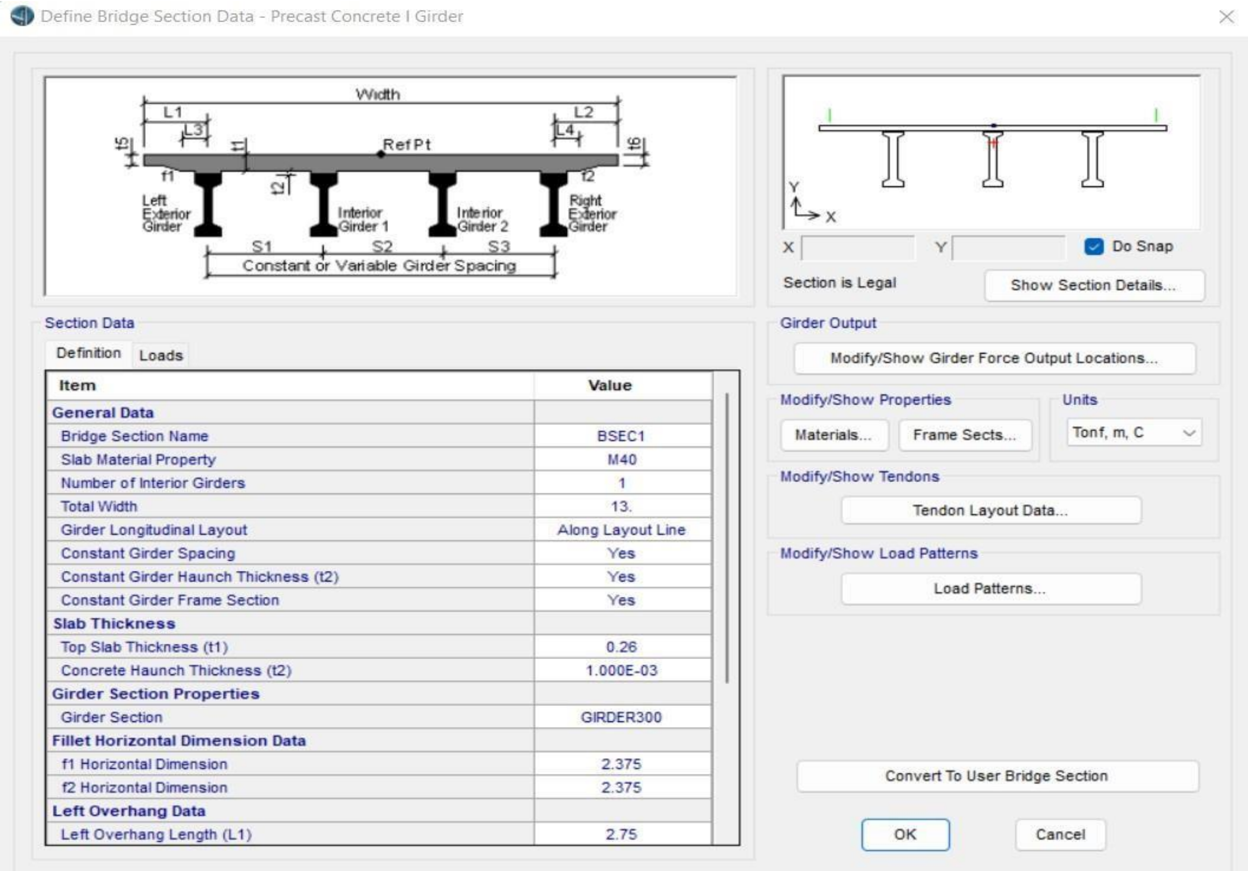
Expected Concrete Compressive Strength: 4588.7229

☐ Lightweight Concrete

Shear Strength Reduction Factor

☐ Switch To Advanced Property Display

Fig 2 Material Property Data



Define Bridge Section Data - Precast Concrete I Girder

X Y ☑ Do Snap

Section is Legal

Section Data

Item	Value
General Data	
Bridge Section Name	BSEC1
Slab Material Property	M40
Number of Interior Girders	1
Total Width	13.
Girder Longitudinal Layout	Along Layout Line
Constant Girder Spacing	Yes
Constant Girder Haunch Thickness (t2)	Yes
Constant Girder Frame Section	Yes
Slab Thickness	
Top Slab Thickness (t1)	0.26
Concrete Haunch Thickness (t2)	1.000E-03
Girder Section Properties	
Girder Section	GIRDER300
Fillet Horizontal Dimension Data	
f1 Horizontal Dimension	2.375
f2 Horizontal Dimension	2.375
Left Overhang Data	
Left Overhang Length (L1)	2.75

Girder Output

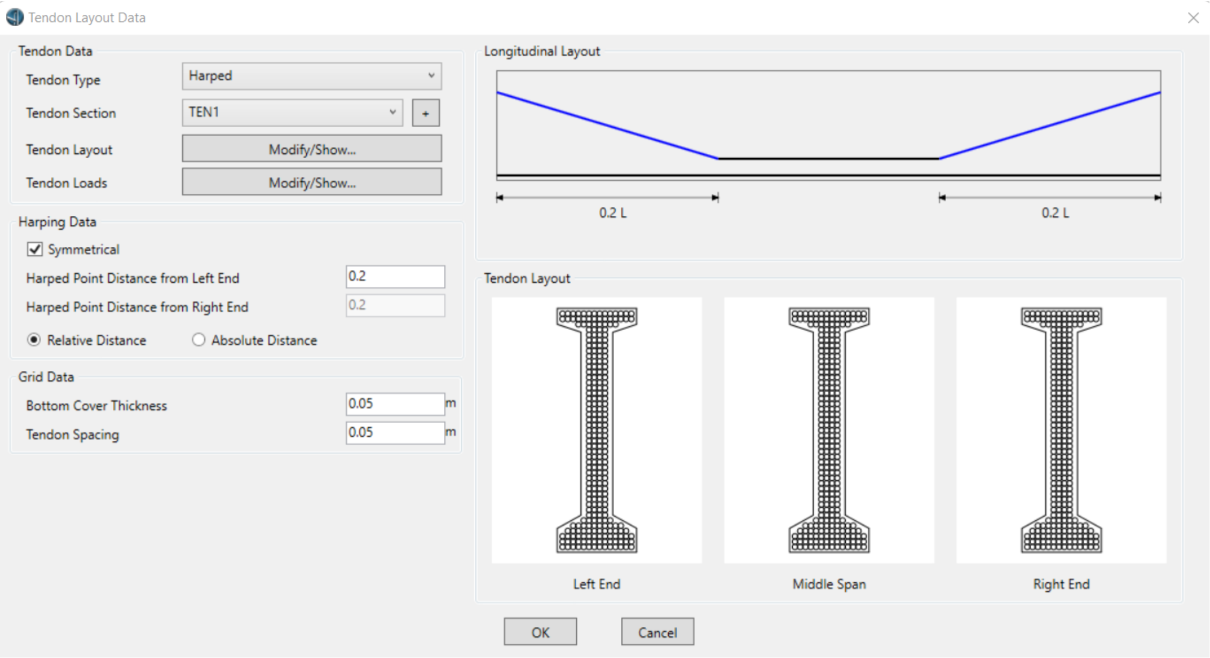
Modify/Show Properties

Units: Tonf, m, C

Modify/Show Tendons

Modify/Show Load Patterns

Fig 3 I-section Data

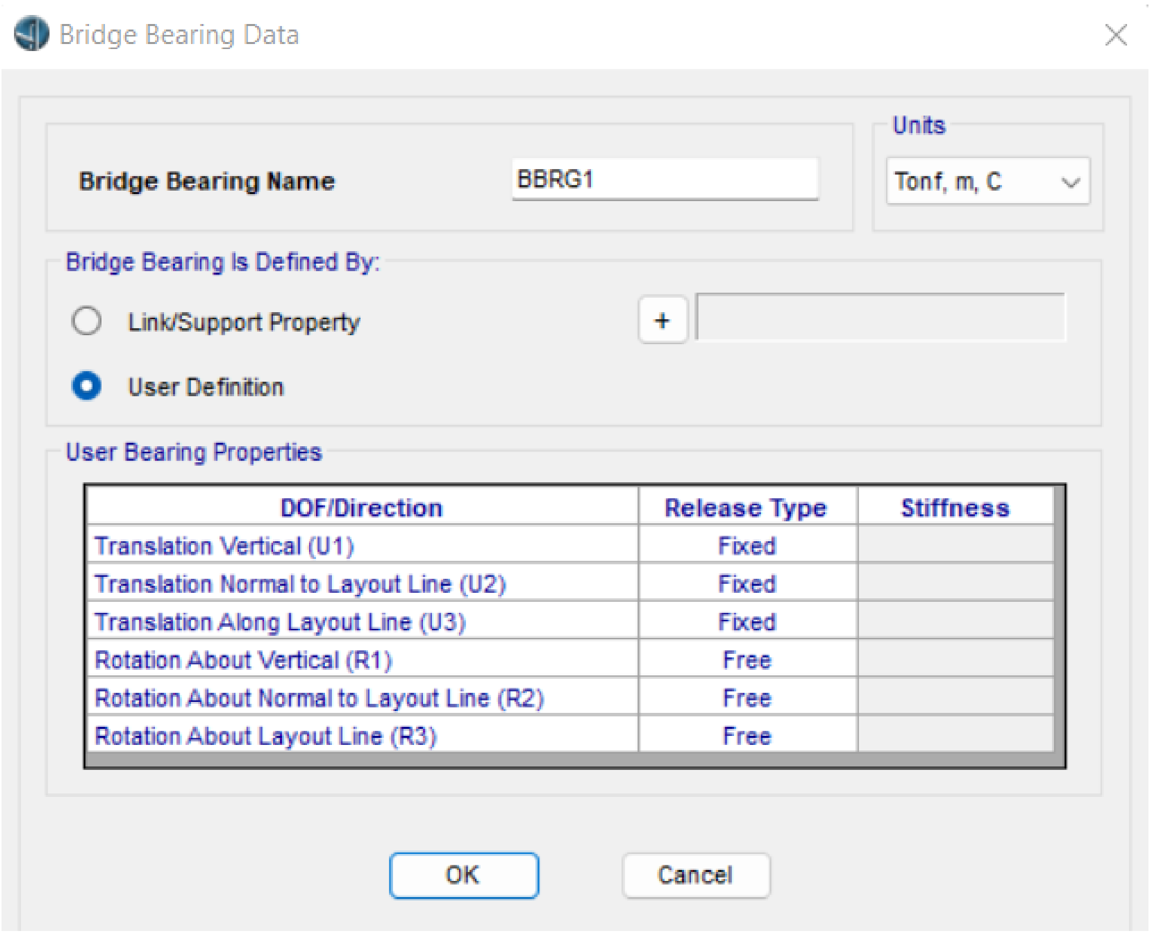

Tendon Layout Data

Tendon Data
Tendon Type: Harped
Tendon Section: TEN1
Tendon Layout: Modify/Show...
Tendon Loads: Modify/Show...

Harping Data
☑ Symmetrical
Harped Point Distance from Left End: 0.2
Harped Point Distance from Right End: 0.2
● Relative Distance ○ Absolute Distance

Grid Data
Bottom Cover Thickness: 0.05 m
Tendon Spacing: 0.05 m

Fig 4 Tendon Layout Data


Bridge Bearing Data

Bridge Bearing Name: BBRG1

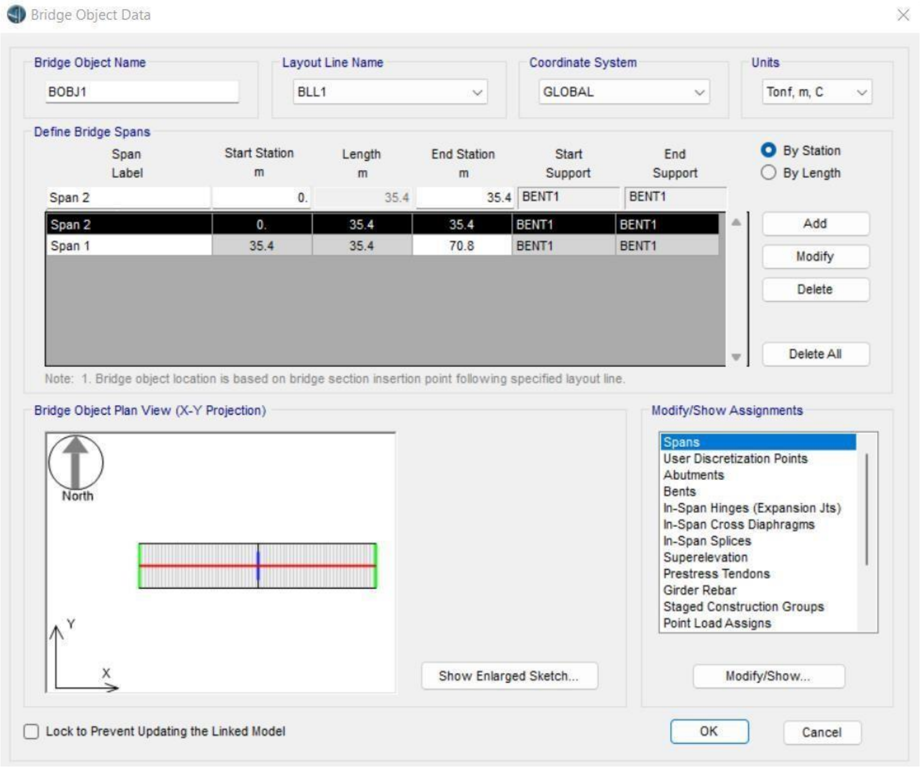
Units: Tonf, m, C

Bridge Bearing Is Defined By:
○ Link/Support Property
● User Definition

User Bearing Properties

DOF/Direction	Release Type	Stiffness
Translation Vertical (U1)	Fixed	
Translation Normal to Layout Line (U2)	Fixed	
Translation Along Layout Line (U3)	Fixed	
Rotation About Vertical (R1)	Free	
Rotation About Normal to Layout Line (R2)	Free	
Rotation About Layout Line (R3)	Free	

Fig 5 Bridge Bearing Data



Bridge Object Name: BOBJ1

Layout Line Name: BLL1

Coordinate System: GLOBAL

Units: Tonf, m, C

● By Station
○ By Length

Span Label	Start Station m	Length m	End Station m	Start Support	End Support
Span 2	0.	35.4	35.4	BENT1	BENT1
Span 2	0.	35.4	35.4	BENT1	BENT1
Span 1	35.4	35.4	70.8	BENT1	BENT1

Note: 1. Bridge object location is based on bridge section insertion point following specified layout line.

☐ Lock to Prevent Updating the Linked Model

Fig 6 Bridge Object Data

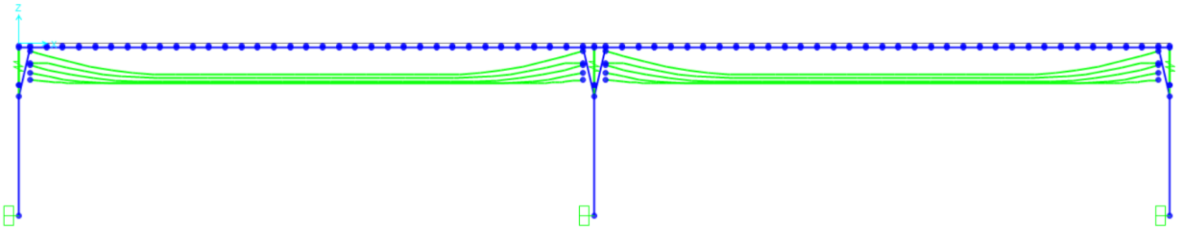


Fig 7 PLAN VIEW

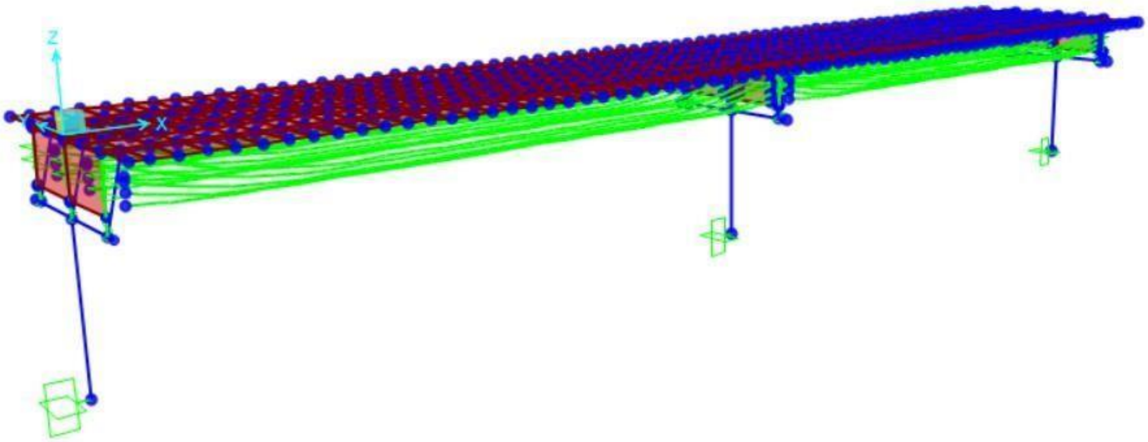


Fig 8 3D MODEL

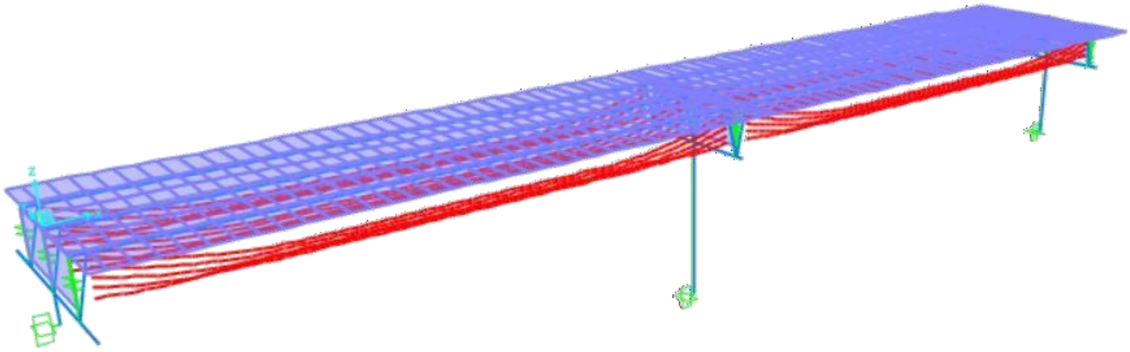


Fig 9 Analytical View

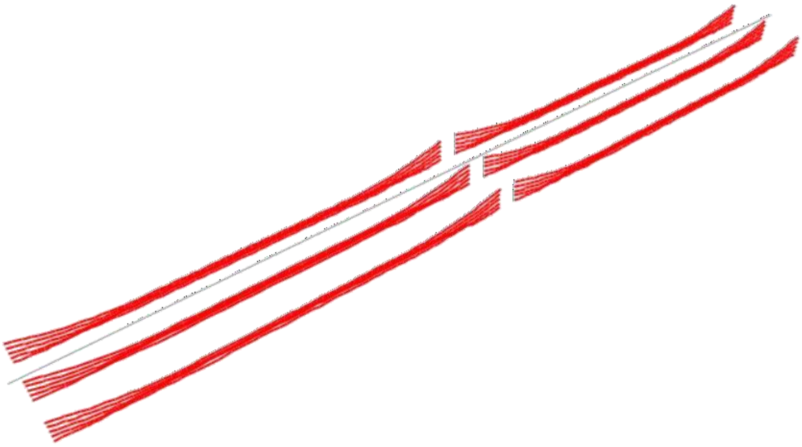


Fig 10 Cable Profile

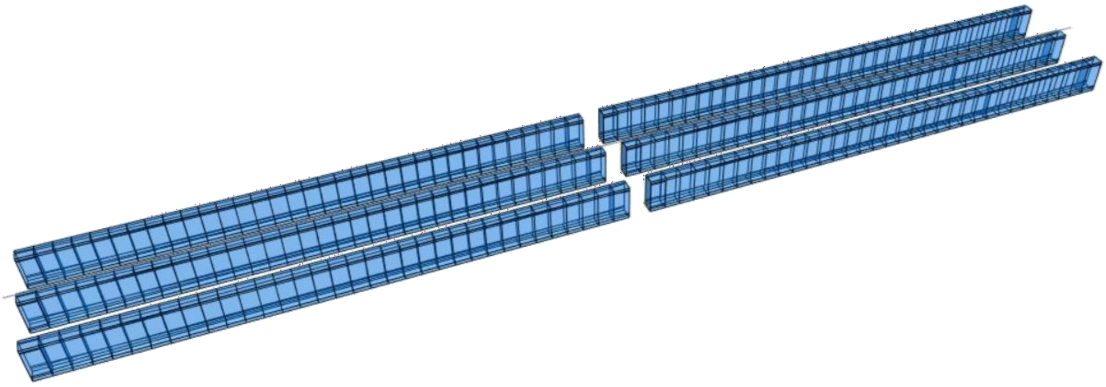


Fig 11 I Girder

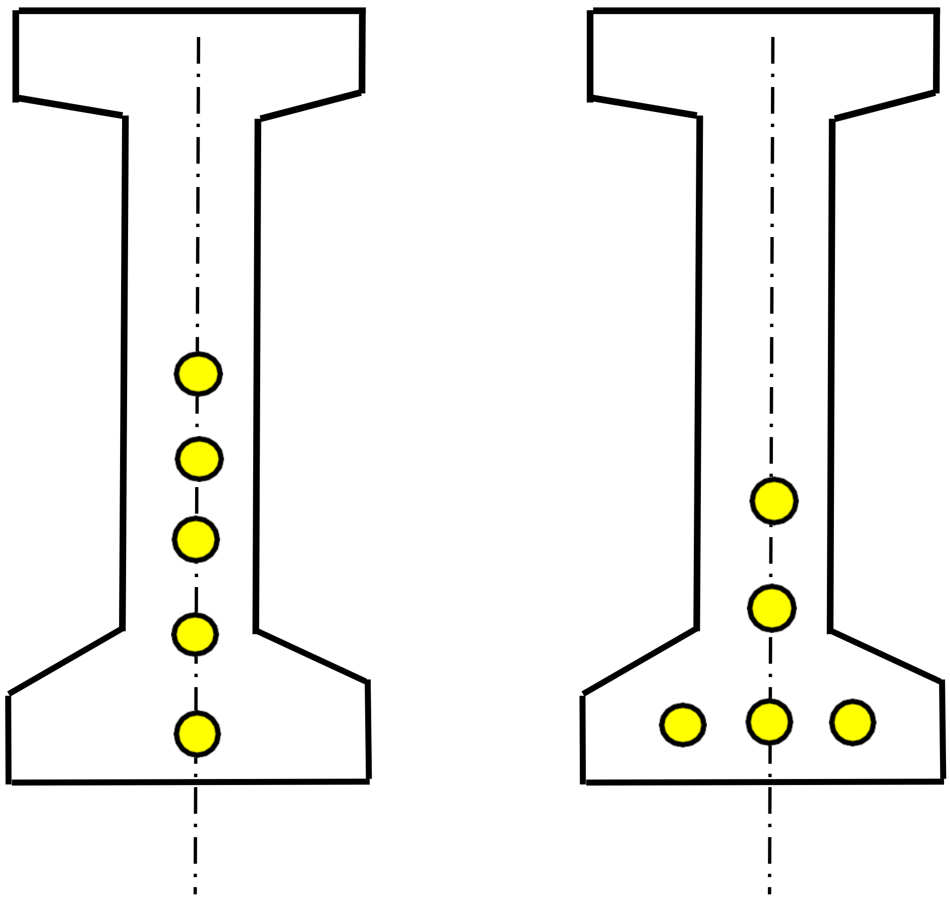


Fig 12 Effective Positioning Of Cable Profile

VIII. Statistical tools and econometric models

DESIGN DATA FOR PSC 'I' GIRDER:

SUPER STRUCTURE:				PSC I-Girder +SLAB	
No. of stages of prestressing				1	Stage
Grade of concrete for deck	Fck	=	M	40	N/mm2
Grade of concrete for girder	Fck	=	M	45	N/mm2
Density of concrete				2.5	t/m3
Density of wearing course				2.2	t/m3
Grade of untensioned reinf	Fyk	=	Fe	500	N/mm2
H.T.S.		=		19T13	
U.T.S for H.T.S.		=		1860	N/mm2
Type of H.T.S.				Uncoated stress relieved	
Sheathing dia		=		98	mm
				(As per manufacturer's schedule)	
Maximum jacking stress		=		0.783	of U.T.S.

Corrugated HDPE sheathing is used.

As per Table 7.1 of IRC 112:2011,wobble coefficient and coefficient of friction are as follow.

Wobble coefficient k	=	0.002	perm
Friction coefficient m	=	0.17	per rad

Cables used in webs. = 19T13 12T13 7T13
CABLE DIA = 98 90 63

Modulus of Elasticity
Concrete = 33000 Mpa
Steel = 200000 Mpa
Prestressing Cables = 195000 Mpa

Permissible stresses

Concrete

As per IRC 112:2012; Cl 12.2.1, allowable compressive stress in concrete

under rare combination of loads	0.48	fck	
	0.48	fcj	for jth days
under quasi-permanent loads	0.36	fck	
	0.36	fcj	for jth days
allowable tensile stress in concrete	3.318578906	Mpa	

Steel Fe

Max allowable tensile stress	0.8	fyk	(IRC 112:2012; Cl 12.2.1)

Prestressing Cables

Low relaxation strands confirming to IS 14268-1995 class (2) are used.

Jack end stress of cable	0.783	UTS	(IRC 112-2011 Cls-7.9.2(3))

DIMENSIONAL DETAILS:

Refer dimensional layout drawing

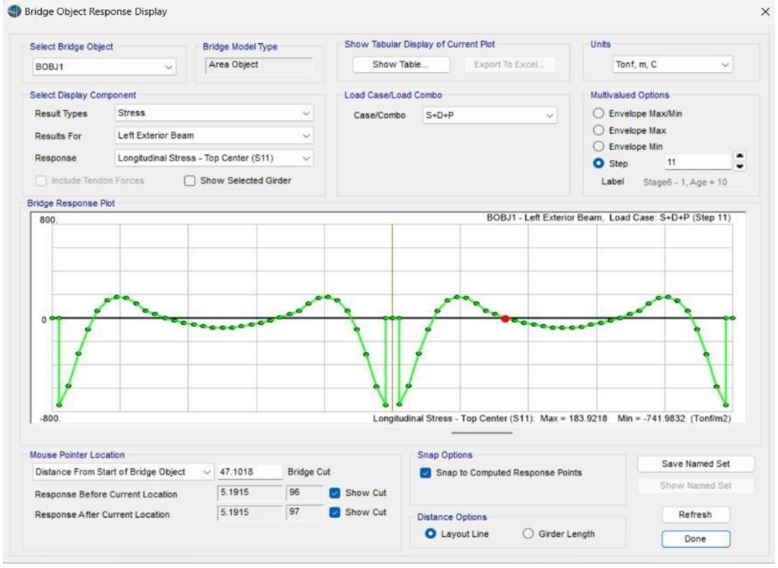
DESIGN Length Girder = 33.990 m

No. of Girders = 3 nos.
No. of End Diaphragms = 2 nos.
No. of Intermediate Diaphragm = 0 no.
Total width of deck = 13.00 m
Cast in situ deck slab thickness = 0.260 m
Width of top flange = 0.750 m
Width of web = 0.300 m
Width of bottom bulb = 0.750 m

IX. RESULTS AND DISCUSSION

X.

Cable Profile 1 Results of Tension, Displacement & Residual Stress

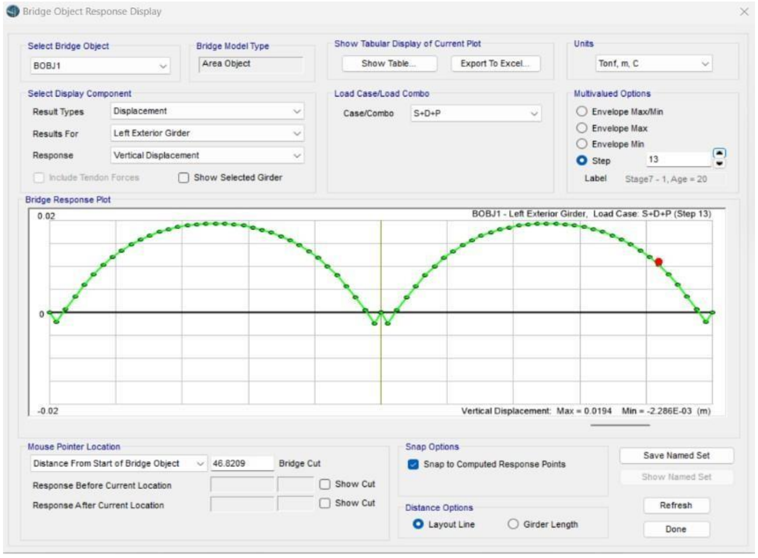

Bridge Object Response Display

Select Bridge Object: BOBJ1
Bridge Model Type: Area Object
Units: Tonf, m, C
Result Types: Stress
Results For: Left Exterior Beam
Response: Longitudinal Stress - Top Center (S11)
☐ Include Tendon Forces ☐ Show Selected Girder
Case/Combo: S+D+P
○ Envelope Max/Min ○ Envelope Max ○ Envelope Min ● Step 11
Label: Stage6 - 1, Age = 10

BOBJ1 - Left Exterior Beam, Load Case: S+D+P (Step 11)
Longitudinal Stress - Top Center (S11): Max = 183.9218 Min = -741.9832 (Tonf/m2)

Distance From Start of Bridge Object: 47.1018
Response Before Current Location: 5.1915 96 ☑ Show Cut
Response After Current Location: 5.1915 97 ☑ Show Cut
☑ Snap to Computed Response Points
Distance Options: ● Layout Line ○ Girder Length

Fig 13 Residual Stress for Cable Profile 1

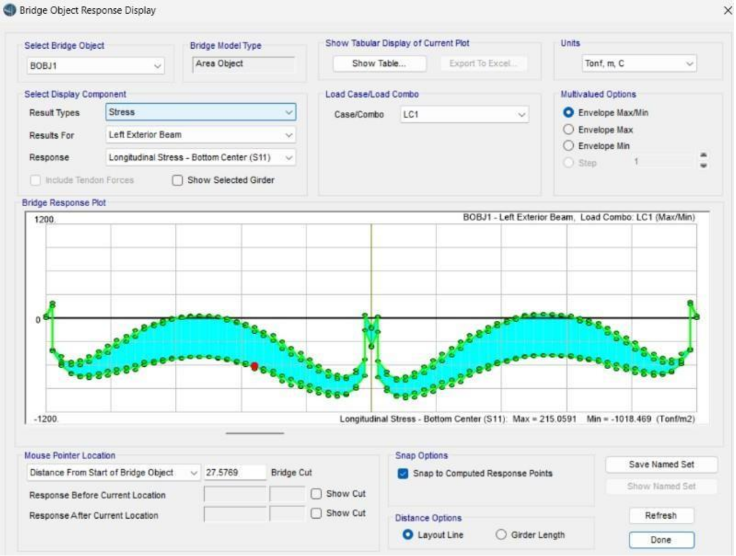

Bridge Object Response Display

Select Bridge Object: BOBJ1
Bridge Model Type: Area Object
Units: Tonf, m, C
Result Types: Displacement
Results For: Left Exterior Girder
Response: Vertical Displacement
☐ Include Tendon Forces ☐ Show Selected Girder
Case/Combo: S+D+P
○ Envelope Max/Min ○ Envelope Max ○ Envelope Min ● Step 13
Label: Stage7 - 1, Age = 20

BOBJ1 - Left Exterior Girder, Load Case: S+D+P (Step 13)
Vertical Displacement: Max = 0.0194 Min = -2.286E-03 (m)

Distance From Start of Bridge Object: 46.8209
Response Before Current Location: ☐ Show Cut
Response After Current Location: ☐ Show Cut
☑ Snap to Computed Response Points
Distance Options: ● Layout Line ○ Girder Length

Fig 14 Discplacement for cable profile 1


Bridge Object Response Display

Select Bridge Object: BOBJ1
Bridge Model Type: Area Object
Units: Tonf, m, C
Result Types: Stress
Results For: Left Exterior Beam
Response: Longitudinal Stress - Bottom Center (S11)
☐ Include Tendon Forces ☐ Show Selected Girder
Case/Combo: LC1
● Envelope Max/Min ○ Envelope Max ○ Envelope Min ○ Step 1

BOBJ1 - Left Exterior Beam, Load Combo: LC1 (Max/Min)
Longitudinal Stress - Bottom Center (S11): Max = 215.0591 Min = -1018.469 (Tonf/m2)

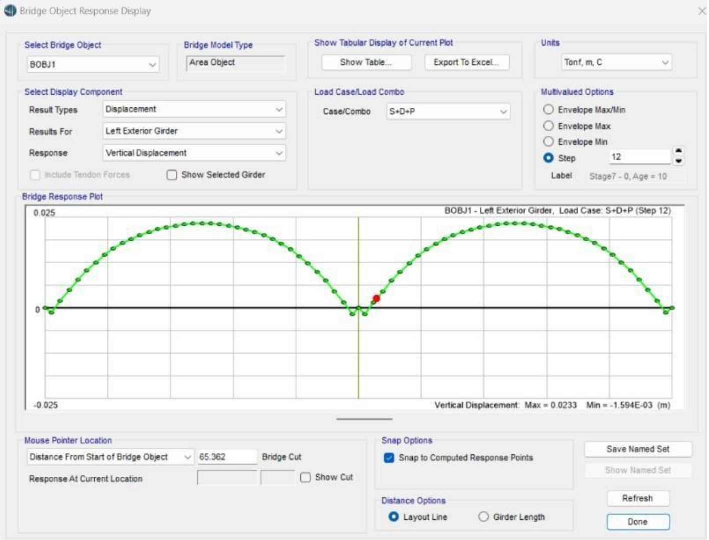
Distance From Start of Bridge Object: 27.5769
Response Before Current Location: ☐ Show Cut
Response After Current Location: ☐ Show Cut
☑ Snap to Computed Response Points
Distance Options: ● Layout Line ○ Girder Length

Fig 15 Tension for cable profile 1

Cable Profile 2 Results of Tension, Displacement & Residual Stress

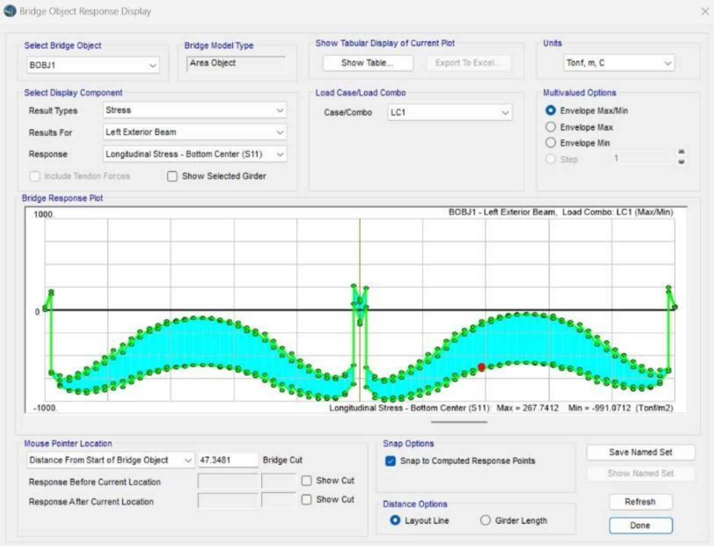
Select Bridge Object: BOBJ1
Bridge Model Type: Area Object
Units: Tonf, m, C
Select Display Component
Result Types: Stress
Results For: Left Exterior Beam
Response: Longitudinal Stress - Top Center (S11)
☐ Include Tendon Forces ☐ Show Selected Girder
Load Case/Load Combo
Case/Combo: S+D+P
Multivalued Options
○ Envelope Max/Min
○ Envelope Max
○ Envelope Min
● Step 12
Label: Stage7 - 0, Age = 10
Mouse Pointer Location
Distance From Start of Bridge Object: 18.3503 Bridge Cut
Response Before Current Location ☐ Show Cut
Response After Current Location ☐ Show Cut
Snap Options
☑ Snap to Computed Response Points
Distance Options
● Layout Line ○ Girder Length

Fig 16 Residual Stress for Cable Profile 2



Select Bridge Object: BOBJ1
Bridge Model Type: Area Object
Units: Tonf, m, C
Select Display Component
Result Types: Displacement
Results For: Left Exterior Girder
Response: Vertical Displacement
☐ Include Tendon Forces ☐ Show Selected Girder
Load Case/Load Combo
Case/Combo: S+D+P
Multivalued Options
○ Envelope Max/Min
○ Envelope Max
○ Envelope Min
● Step 12
Label: Stage7 - 0, Age = 10
Mouse Pointer Location
Distance From Start of Bridge Object: 65.362 Bridge Cut
Response At Current Location ☐ Show Cut
Snap Options
☑ Snap to Computed Response Points
Distance Options
● Layout Line ○ Girder Length

Fig 17 Displacement for cable profile 2



Select Bridge Object: BOBJ1
Bridge Model Type: Area Object
Units: Tonf, m, C
Select Display Component
Result Types: Stress
Results For: Left Exterior Beam
Response: Longitudinal Stress - Bottom Center (S11)
☐ Include Tendon Forces ☐ Show Selected Girder
Load Case/Load Combo
Case/Combo: LC1
Multivalued Options
● Envelope Max/Min
○ Envelope Max
○ Envelope Min
○ Step 1
Mouse Pointer Location
Distance From Start of Bridge Object: 47.3481 Bridge Cut
Response Before Current Location ☐ Show Cut
Response After Current Location ☐ Show Cut
Snap Options
☑ Snap to Computed Response Points
Distance Options
● Layout Line ○ Girder Length

Fig 18 Tension for cable profile 2

Tables 1

Cable Profile type	**Type 1**	**Type 2**
Tension	27.6	100
Displacement	0.0007	0.0233
Residual Stress	36.14	85.25

Comparison of cable profiles

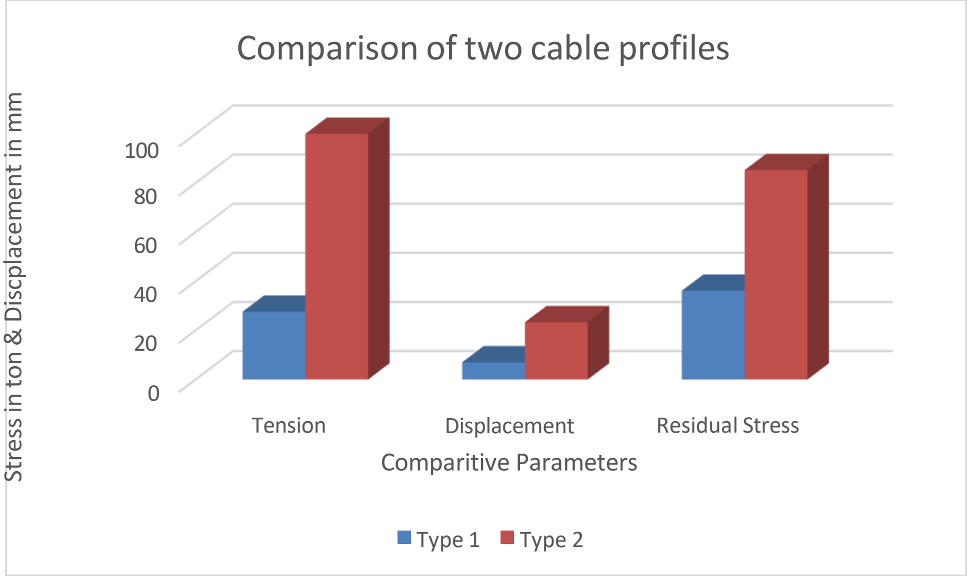


Fig 19

XI. Conclusion

Based on the analysis and design results for 2 different bridge sections with optimized position of cable profile, the conclusion is mentioned below:

- Achieved optimization in bridge system design, involving factors like material (steel, concrete, tendons, etc.), and design variables such as girder depth, cross-sectional dimensions, and tendon count.
- Utilized CSiBridge software, a 3D finite element model is constructed to replicate dynamic effects on three distinct bridges: one with different positioning of tendons.
- Effective postioning of Cable profile is 3 but it has bottom bulk which has to rectify as compare to cable profile 2
- Comparison based on initial stress, Displacement due to immediate prestress & final residual stress at the bottom in the girder with the following parameters critical tension ‘T’ critical discplacement ‘Δ’, final residual stress ‘σ’. σsb3 > σsb2
- Type 2 not effective for find residual compression as more strands requiredto achieve desire residual compression.
- Type 1 is although effective in residual compression but it has permaent moment develop due to bend in plan in cable.

XII. ACKNOWLEDGME

NT REFERENCES

[1] M. A. Akinpelu1* , A. M. Salman2 and J. O. Adeiza " CSibridge Modelling, Analysis and Design of Prestressed Concrete I-girder Bridge " USEP: Journal of Science and Engineering Production, Vol. 4, No. 1, 2022

[2] Avinash Kumar Vidyarthi1 , Dr. P. K. Singhai2 , Rohit Sahu " Analysis of Prestressed Concrete Girder for Bridges " International Journal of Trend in Scientific Research and Development (IJTSRD)

[3] Bhawar P.D1 , Wakchaure M.R2 , Nagare P.N3 "Optimization Of Prestressed Concrete Girder" IJRET: International Journal of Research in Engineering and Technology.

[4] M A Al Fadul1 and H H Darwash1 "Modeling and dynamic analysis of bridges designed with AASHTO and Florida I-beam girders" ICCEET 2020

[5] Mehrdad Aghagholizadeh1* and Necati Catbas2 "Comparative Analysis and Evaluation of Two Prestressed Girder Bridges" Current Trends in Civil & Structural Engineering.

[6] Viqar Nazir1, Mr. Sameer Malhotra "DESIGN OF A PRESTRESSED CONCRETE BRIDGE AND ANALYSIS BY CSiBRIDGE" IRJET

[7] T. A. H. Nishat*& R. Ahsan "Sensitivity Analysis of Cost Optimized Solution of Post-Tensioned Pre-Stressed Concrete I-Girder Bridge System" ICACE 2018

[8] Mahendrakar Hemanth Kumar, Mahendrakar Hemanth Kumar "Analysis and Design of Stress Ribbon Bridge with Csi Bridge Software" International Journal of Civil Engineering and Technology (IJCIET)