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Railway bridge design analysis with deck bulb tee WF98DG type bearer using bridgelink V.8.0.0.2

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Abstract

The railroad track is crucial for people to cross the train, especially on lines with quite high elevations where the railroad is not permitted to have particularly high gridlines on its tracks. In its literal sense, a bridge is a construction that connects two areas that are divided by a barrier, which can be man-made or natural, such as highways, irrigation canals, and railroads, or it can be a river, valley, strait, or sea. The researcher will model the bridge girder with Bridgelink software for tracks on public railways, using pre-stressed concrete material with the type of grinder is Deck Bulb Tee WF98DG with a bridge span of 30 m. Referring to the railway geometry planning parameters according to the Minister of Transportation regulation No. PM. 60 of 2012. From the results of this study it is known that with a bridge cross-section of 3.124 m wide according to the needs of the width of the cross-section of a one-lane railway, which is a minimum of 3 m with a span length of 30 m using a single axle load of 20 tons requires a girder cross-section type Deck Bulb Tee WF98DG with the number of straight strand recommendations from bridge link is 18 pieces and Harped Strand as many as 7 pieces using fc' 35.16 MPa.

Keywords: Bridgelink, DeckBulbTee, Girder, Railroad, Stress.

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1. Introduction

The railroad track is crucial for people to cross the train, especially on lines with quite high elevations where the railroad is not permitted to have particularly high gridlines on its tracks. In its literal sense, a bridge is a construction that connects two areas that are divided by a barrier, which can be man-made or natural, such as highways, irrigation canals, and railroads, or it can be a river, valley, strait, or sea.

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When choosing the type of bridge to use, consideration can be given to the many designs, materials, and roles that bridges have in the building industry [1]. The girder bridge offers time and cost savings, but it also has advantages and downsides depending on the materials to be utilized. The interaction between trains and bridges has become increasingly important in rail and bridge design with the development of contemporary railroads. The impact of the temperature differential on the bridge is substantial and cannot be ignored because this movement could cause the bridge to bend like a traffic load [2]. In this study, researchers carried out a numerical design of a railroad bridge using Bridgelink software where the bridge girder used was a Pretrial Girder type Deck Bulb Tee WF98DG and carried out loading with live loads on each railroad axle. By referring to the railway geometry planning parameters according to the Minister of Transportation regulation No. PM. 60 of 2012 concerning Railway Engineering Requirements, using the design boundary conditions according to the criteria used referring to the SNI 2847: 2019 standard on "Structural Concrete Requirements for Building Buildings". For prestressed flexural structural components refer to SNI 2847-2019 article 18.4.2, for prestressed flexural structural components, the stress in concrete at service load is based on the properties of the uncracked section. It is expected that this research can provide a good repertoire and contribution to the world of railways, especially in the railroad bridge section which is part of an important element in the world of railways, and provide excellent supporting data for railroad construction.

2. Research Method

In this study the authors will model the bridge girder with Bridgelink software for tracks on public railways, using pre-stressed concrete material with the type of grinder is Deck Bulb Tee WF98DG with a bridge span of 30 m, description as shown in Figure 1.

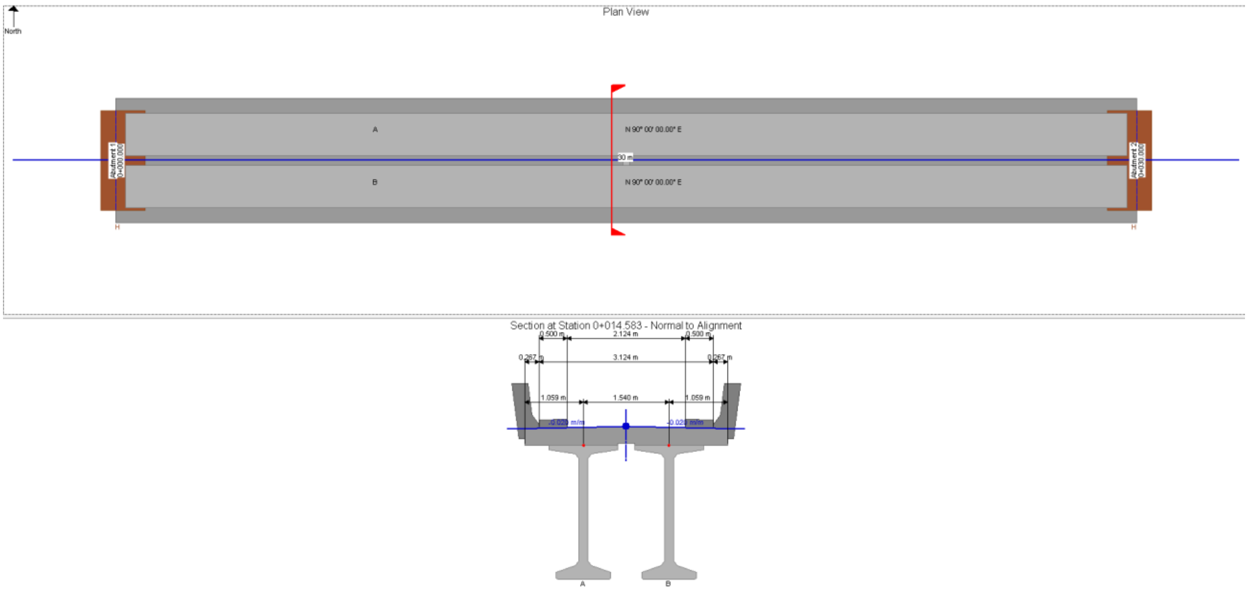

Figure 1. Typical of railroad bridges

The Regulation of the Minister of Transport of the Republic of Indonesia No. PN. 60 of 2012 on the technical standards for the railway line applies to the size of the railway bearing. The use and installation of a normal 1435mm rail width railway in a specified cant location. According to Figure 1, the rail structure is created as well as possible to be able to withstand heavy loads, or the term AXLE

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LOAD, of the train series running on it. This way, the steel road can survive for a long time and the train series may travel quickly, safely, and comfortably.

2.1. Project Criteria

Implementing the use of the design boundary conditions by the standards established by SNI 2847: 2019 on "Structural Concrete Requirements for Building Buildings." Regarding prestressed flexural structural components, see SNI 2847-2019 article 18.4.2. The properties of the uncracked section determine the stress in the concrete at service load, as shown in figure 2.

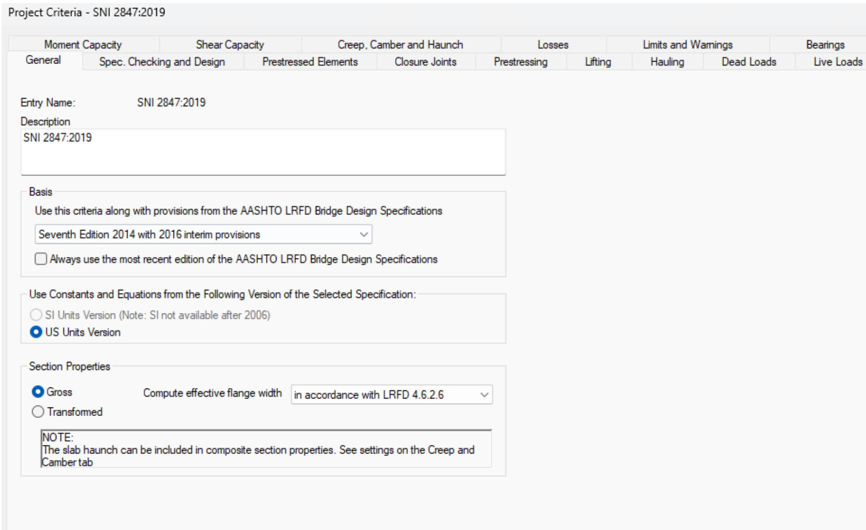

Figure 2. General Parameter

In the checking and design within the bridge link parameters, the Harped Strand Slope Limit and Deflection limit are emphasized and designed, as shown in Figure 3.

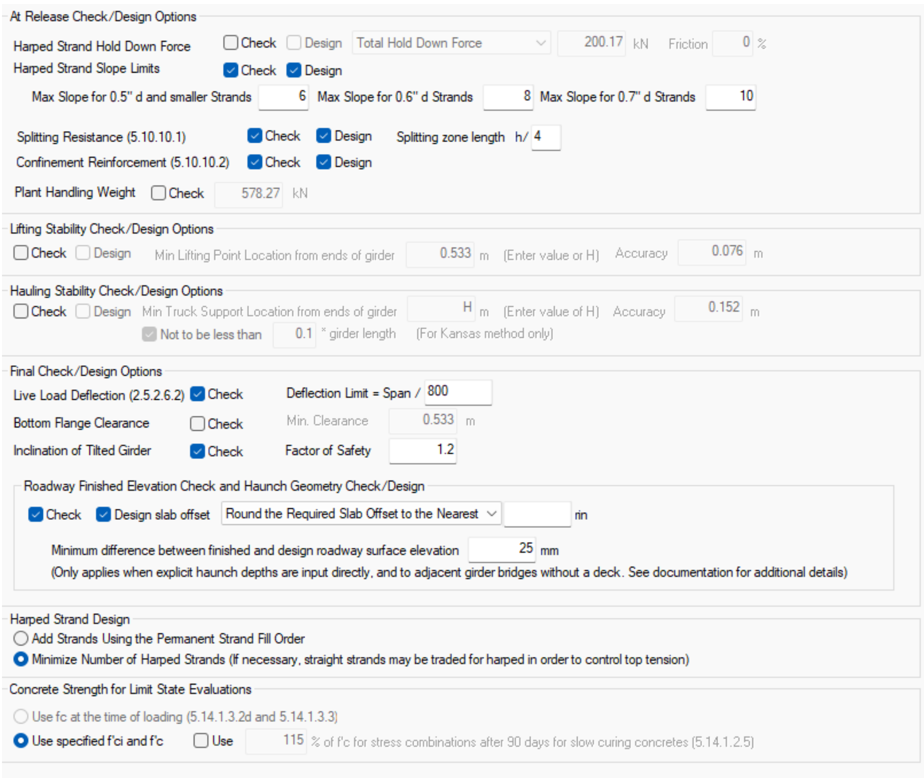

Figure 3. Checking and Design Option

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In addition, Stress Limits for temporary stresses before losses are also carried out as shown in Figure 4

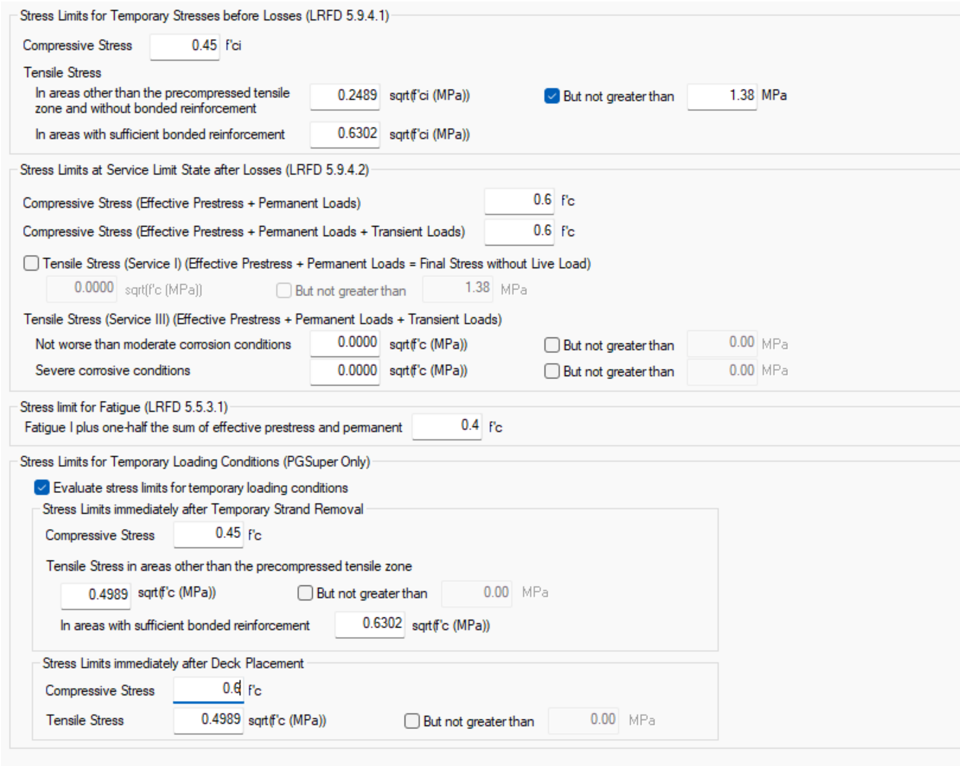

Figure 4. Stress Limits

Prestressing stress limit conditions also adjusts SNI 2847-2019, as shown in Figure 5.

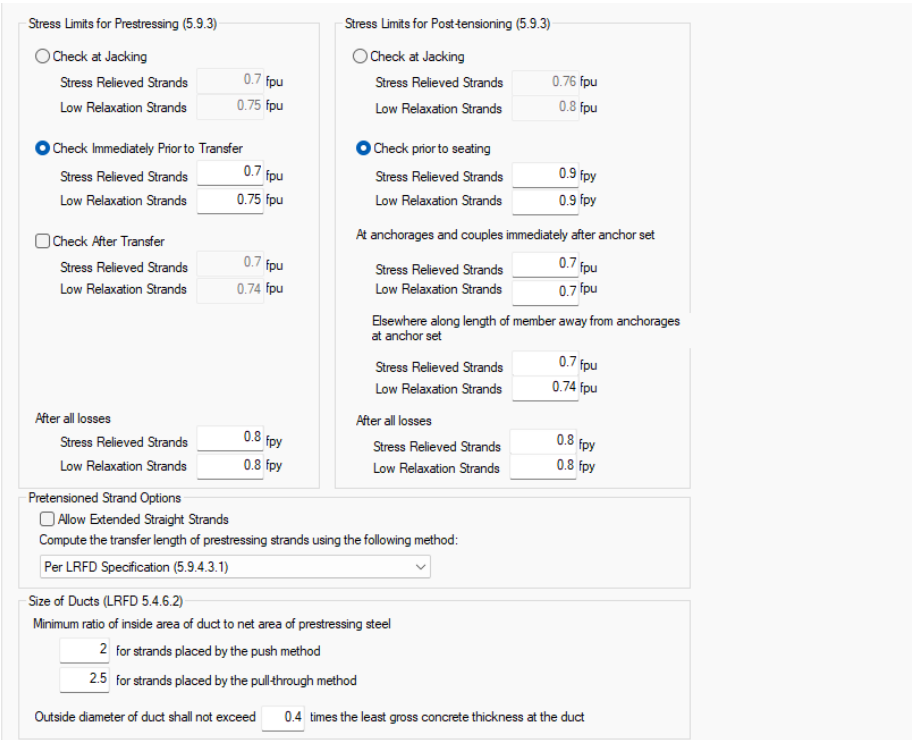

Figure 5. Prestressing stress limit

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In the analysis process, design checks and recommendations are carried out by determining the boundary conditions and warning design boundary conditions shown in Figure 6.

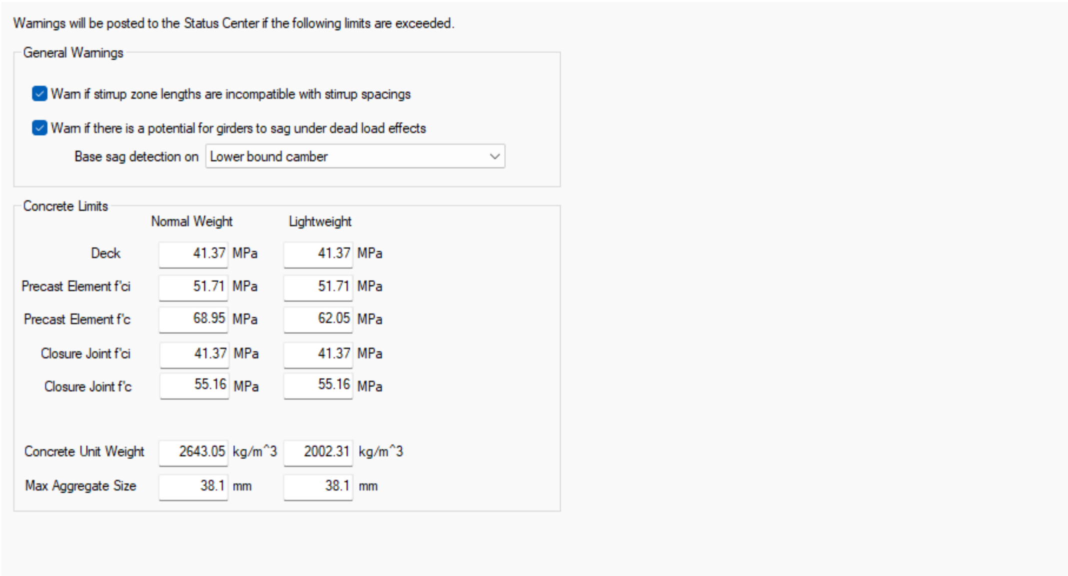

Figure 6. Warning recommendation design

2.2. Load

The available load cases for defining a load are DW (dead load, worn surface), LL+IM (live load plus impact), and DC (dead load, component). Assuming that the sidewalk and rail are situated at the edge of the slab, PGSuper models this situation by dividing the live loads of the sidewalk, rail, and pedestrian evenly among the three external beams. On the other hand, 1/3 of the rail weight is applied to the first inside beam and 2/3 to the external beam when modeling U beams. You can set the rail to "none" and add the rail load using the "Add Distributed Load" tool in "User Defined Loads" if you'd want to distribute the weight differently. Anyone can choose which vehicle to utilize for Service and Strength Limit States, Fatigue Limit States, and Permit Limit States using this application. HL-93, the Fatigue truck, and no truck are the default options.

PGSuper will activate the Pedestrian on Sidewalk load immediately if you model a sidewalk. PGSuper will automatically enclose both the vehicle and sidewalk live loads by default. Unchecking the box next to the load case will disable the pedestrian live load. To determine whether loading vehicular and pedestrian live load, vehicular only, or pedestrian solely is best suited for the design, engineering judgment, and experience should be employed.

The AASHTO LRFD Bridge Design Specifications' Section 4.6.2.2 contains the Ranges of Applicability (ROA), which are limits on the research that was done on distribution factors. The range for which the formulas are valid is not always indicated by the ROA; rather, they reflect the boundaries of the research that was done to develop the formulas. It is up to the engineer's discretion to determine whether to use the formulas or find the live load distribution factor using an alternative method when a design is outside the ROA. An engineer could first ascertain how sensitive the formula in question is to the relevant variable to help with this decision. When using 8 Axles, Standard Axle Spacing for Steam Locomotives is The heaviest plus the coal train has a total load of 168 tonnes or 8.75 tonnes/m^2[1], [3].

In this study, the earthquake load was carried out by simulating the area in earthquake region 3 with a base shear coefficient of 0.15 with medium soil conditions. The rail structure is made as best as possible to be able to withstand heavy loads, in this study using the weight of one train axle by the

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Regulation of the Minister of Transportation of the Republic of Indonesia No. 60 of 2012 concerning technical standards for railroad tracks applicable to simulating loading on railroad tracks, from a series of trains running on it. Thus, the steel road can last a long time and trains can travel quickly, safely, and comfortably.

Table 1. User Define Loads

Type	Event	Load Case	Location	Magnitude
Point	Event 7: Final with Live Load	LL + IM	Span 1, All Girders, 50%	200.00 Kn
Uniform	Event 4: Cast Deck	DW	All Spans, All Girders, the Entire Span	1,15 kN/m
Uniform	Event 4: Cast Deck	DC	All Spans, All Girders, the Entire Span	1,03 kN/m
Uniform	Event 7: Final with Live Load	LL + IM	All Spans, All Girders, the Entire Span	1,01 kN/m
Uniform	Event 7: Final with Live Load	LL + IM	All Spans, All Girders, the Entire Span	0,49 kN/m
Uniform	Event 7: Final with Live Load	LL + IM	All Spans, All Girders, the Entire Span	2,23 kN/m

In this study, the factored load adjusts the loading combination based on SNI 1725: 2016 concerning Loading for Bridges shown in Figure 7, and is used as a parameter in the analysis in Bridgelink according to Table 2.

Table 2. Load combination based on SNI 1725: 2016

Keadaan Batas	*MS* *MA* *TA* *PR* *PL* *SH*	*TT* *TD* *TB* *TP*	*EU*	EW_S	EW_L	*BF*	*EUn*	*TG*	*ES*	*Gunakan salah satu*		
										EQ	*TC*	*TV*
Kuat I	γ_P	1,8	1,00	-	-	1,00	0,50/1,20	γ_{TG}	γ_{ES}	-	-	-
Kuat II	γ_P	1,4	1,00	-	-	1,00	0,50/1,20	γ_{TG}	γ_{ES}	-	-	-
Kuat III	γ_P	-	1,00	1,40	-	1,00	0,50/1,20	γ_{TG}	γ_{ES}	-	-	-
Kuat IV	γ_P	-	1,00	-	-	1,00	0,50/1,20	-	-	-	-	-
Kuat V	γ_P	-	1,00	0,40	1,00	1,00	0,50/1,20	γ_{TG}	γ_{ES}	-	-	-
Ekstrem I	γ_P	γ_{EQ}	1,00	-	-	1,00	-	-	-	1,00	-	-
Ekstrem II	γ_P	0,5	1,00	-	-	1,00	-	-	-	-	1,00	1,00
Daya Layan I	1,00	1,00	1,00	0,30	1,00	1,00	1,00/1,20	γ_{TG}	γ_{ES}	-	-	-
Daya Layan II	1,00	1,30	1,00	-	-	1,00	1,00/1,20	-	-	-	-	-
Daya Layan III	1,00	0,80	1,00	-	-	1,00	1,00/1,20	γ_{TG}	γ_{ES}	-	-	-
Daya Layan IV	1,00	-	1,00	0,70	-	1,00	1,00/1,20	-	-	-	-	-
Fatik (TD dan TR)	-	0,75	-	-	-	-	-	-	-	-	-	-

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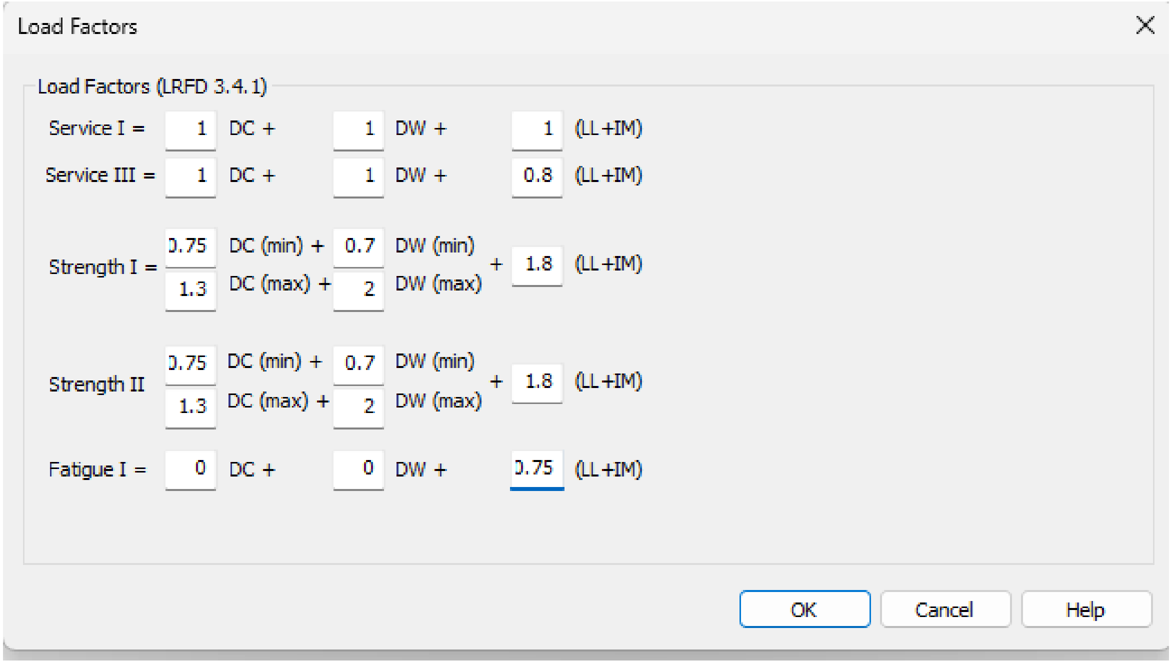

Figure 7. Load combination on Bridgelink

2.3. Rail

A. Rails must adhere to the following standards:

1. 10% or more of an elongation;
2. at least 1175 N/mm^2 in terms of tensile strength;
3. The rail head's hardness shouldn't be less than 320 BHN.

The rail cross-section needs to match the rail measurements, as shown in the chart and the image below.

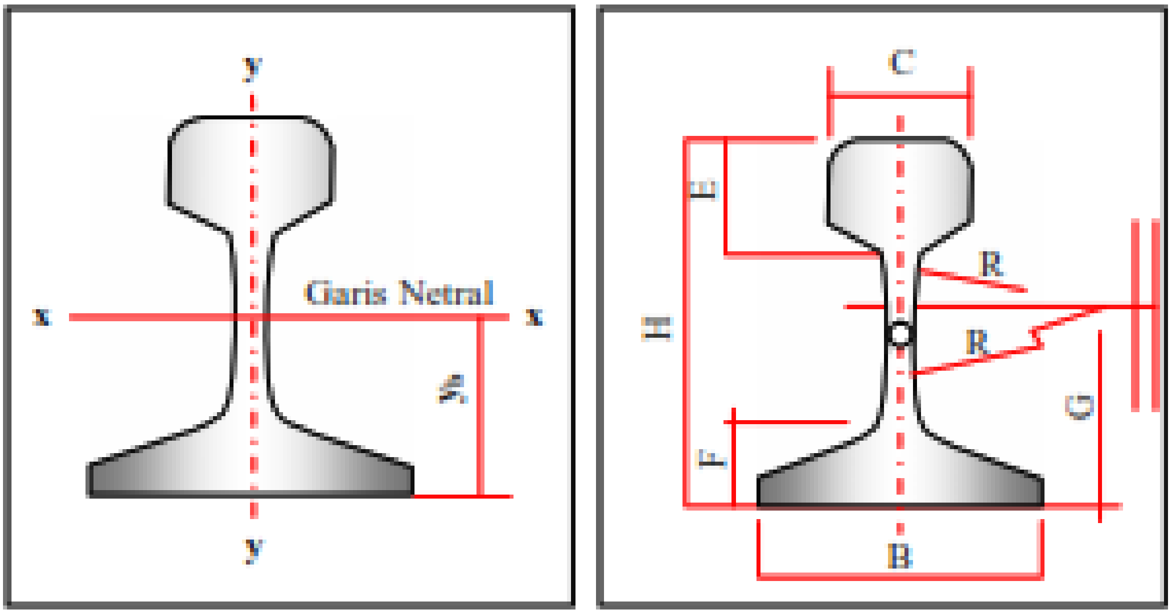

Figure 10. Rail dimensions

The different types of rail rods have an impact on both the maximum pressure (axle load) the rail can withstand during a train pass and the maximum speed of the train as it passes the rail. With an ncrease

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in "R," the axle load that the rail can support increases, enabling trains to cross it safely and steadily at high speeds.[4].

Table 3. Rail Section Dimensions

Geometric size	Rail Type			
	R 42	**R 50**	**R 54**	**R 60**
H (mm)	138.00	153.00	159.00	172.00
B (mm)	110.00	127.00	140.00	150.00
C (mm)	68.50	65.00	70.00	74.30
D (mm)	13.50	15.00	16.00	16.50
E (mm)	40.50	49.00	49.40	51.00
F (mm)	23.50	30.00	30.20	31.50
G (mm)	72.00	76.00	74.79	80.95
R (mm)	320.00	500.00	508.00	120.00
A (cm^2)	54.26	64.20	69.34	76.86
W (kg/m)	42.59	50.40	54.43	60.34
I_x (cm^4)	1,369.00	1,960.00	2,346.00	3,055.00
Y_b (mm)	68.50	71.60	76.20	80.95

The explanation of the symbol above is

A = cross-sectional area

W = rail weight per meter

I_x = moment of inertia about the x-axis

Y_b = the distance from the bottom of the rail to the neutral line

2.4. Railway components

After the foundation layer is completed as the foundation of the railway, the next stage is to build the railway tracks. Please note that each component affects the quality of the railway itself. Figure 8 below shows a railroad schematic and its components.

Figure 8. Railroad track components

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2.5. Fenite element Method (FEM)

The finite element method (FEM) is a mathematical strategy used to deal with specific evaluation problems. The limited component approach combines a few numerical concepts to generate straight or nonlinear framework conditions. The number of conditions produced is usually extremely large, exceeding 20,000 conditions. As a result, unless a decent PC is used, this approach is of little practical value.

When a design is subjected to forces such as stress, pressure, temperature, stream rate, and severity, the result is strain (distortion), stress, temperature, tension, and stream rate. The concept of the following action (twisting) on a body is based on the characteristics of the power and stress structure itself. The dissemination of this effect, conveyed as dislodging, can be tracked down in the limited component approach.

To deal with the problem of tracking down relocations of vertices/associations/grids and primary powers, the finite element technique employs a component discretization method. Discrete component conditions are linked with the lattice method for initial examination, and the results obtained are indistinguishable from those obtained from conventional structural inquiry. Discreteness should be achievable using one-layered components (line components), two-layered components (planar components), or three-layered components (volume/continuum components). This method employs a continuous component to determine a more accurate response.[5], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18].

2.6. Bridgelink-PGSuper

BridgeLink™ is an integrated suite of bridge engineering software. BridgeLink™ links together several different bridge engineering software tools into one convenient and easy-to-use platform.
BridgeLink™ currently supports the following software tools:

1. Barlist™ - Reinforcing steel quantity estimating tool
2. BEToolbox™ - Bridge Engineering Toolbox utility programs
3. PGSplice™ - Precast-Prestressed Spliced Girder Design, Analysis, and Load Rating
4. PGSuper™ - Precast-Prestressed Girder Design, Analysis, and Load Rating
5. TOGA™ - TxDOT Optional Girder Analysis tool
6. XBRate™ - Reinforced Concrete Cross Beam Load Rating

Precast-Prestressed Girder design, analysis, and load rating software is called PGSuperTM. Precast-prestressed girder bridges can be designed, verified, and loaded according to DOT agency-specific requirements and the AASHTO LRFD Bridge Design Specification using PGSuperTM. The minimum necessary concrete release strength as well as the quantity and arrangement of prestressing strands are calculated by the flexural design feature. For vertical shear, horizontal shear, bursting, and strand confinement, the number, size, and spacing of transverse reinforcement are determined by the shear design feature. Girders are assessed for compliance with strength, service, and detailing criteria through specification checking. Girders are assessed for stability and stress while being handled and transported. It is also possible to use temporary prestressing to reduce concrete release strengths, enhance stability, and control camber.

This software has taken into consideration the limitations and capabilities of local fabricators. Because of its adaptable design, PGSuperTM can be expanded upon and updated in the future as user demands and design specifications shift[19], [20], [20], [21].

3. Results And Discussion

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In this study, researchers used 1 axle with a standard axle spacing with a load of 20 tons. The largest axle load plan suitable for operating rolling stock, or load plan scheme, is the live load used. The load plan scheme 1921 (RM 21) can be applied to axle loads up to 20 tons. The axle load on which the planning process is based should be by the route classification and the maximum load of the operating rolling stock, while the materials used in modeling are as follows.

3.1. Section Parameters

The girder type used is a pre-stressed girder of the Deck Bulb Tee WF98DG type with an upper wingspan of 1540 mm and a height of 2476.5 mm, as shown in Figure 9 with some detailed parameters as shown in Figure 10 with a bridge span of 30 m.

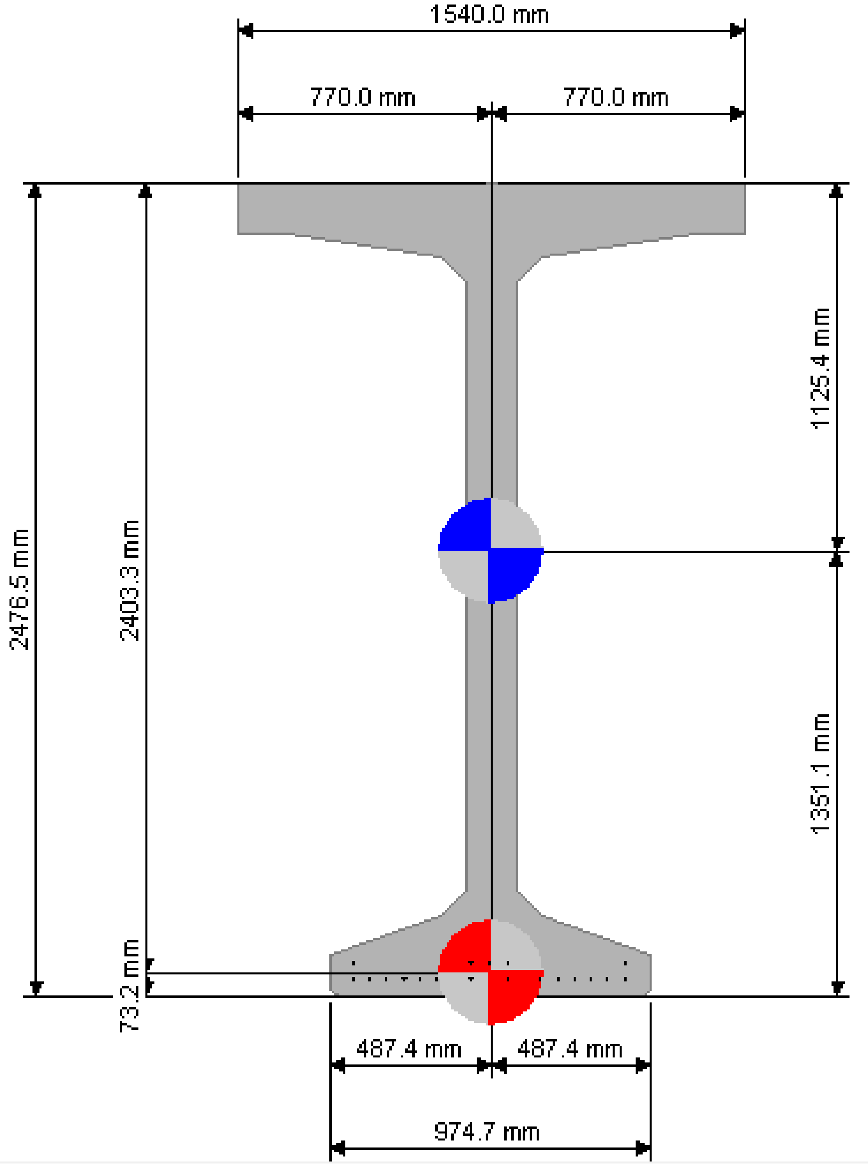

Figure 9. Typical Deck Bulb Tee WF98DG girder type dimensions

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	Value
C1 (mm)	25.4
D1 (mm)	152.4
D2 (mm)	76.2
D3 (mm)	76.2
D4 (mm)	130.175
D5 (mm)	114.3
D6 (mm)	76.2
D7 (mm)	1851.025
T1 (mm)	155.575
T2 (mm)	155.575
W1 (mm)	468.3125
W2 (mm)	76.2
W3 (mm)	333.375
W4 (mm)	76.2
Wmax (m)	2.4384
Wmin (m)	1.247775

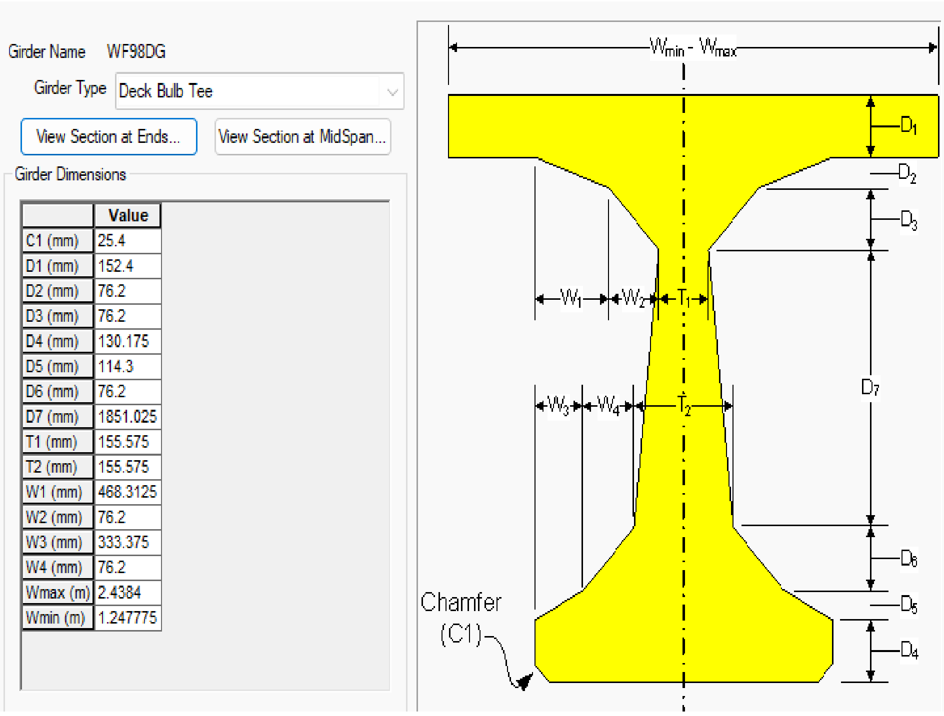

Figure 10. Section of Deck Bulb Tee WF98DG girder

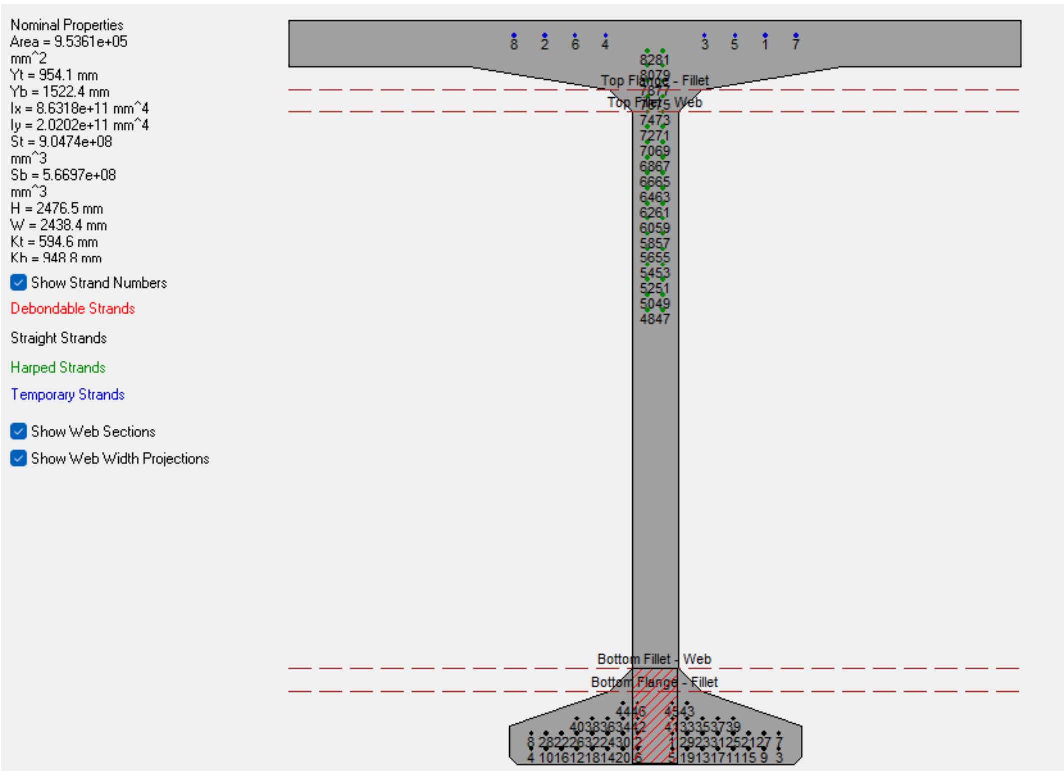

Figure 11. End Section of Deck Bulb Tee WF98DG girder

The strand arrangement formation on the girder used for the girder end position is as shown in Figure 11 and the position at the middle of the girder is as shown in Figure 12.

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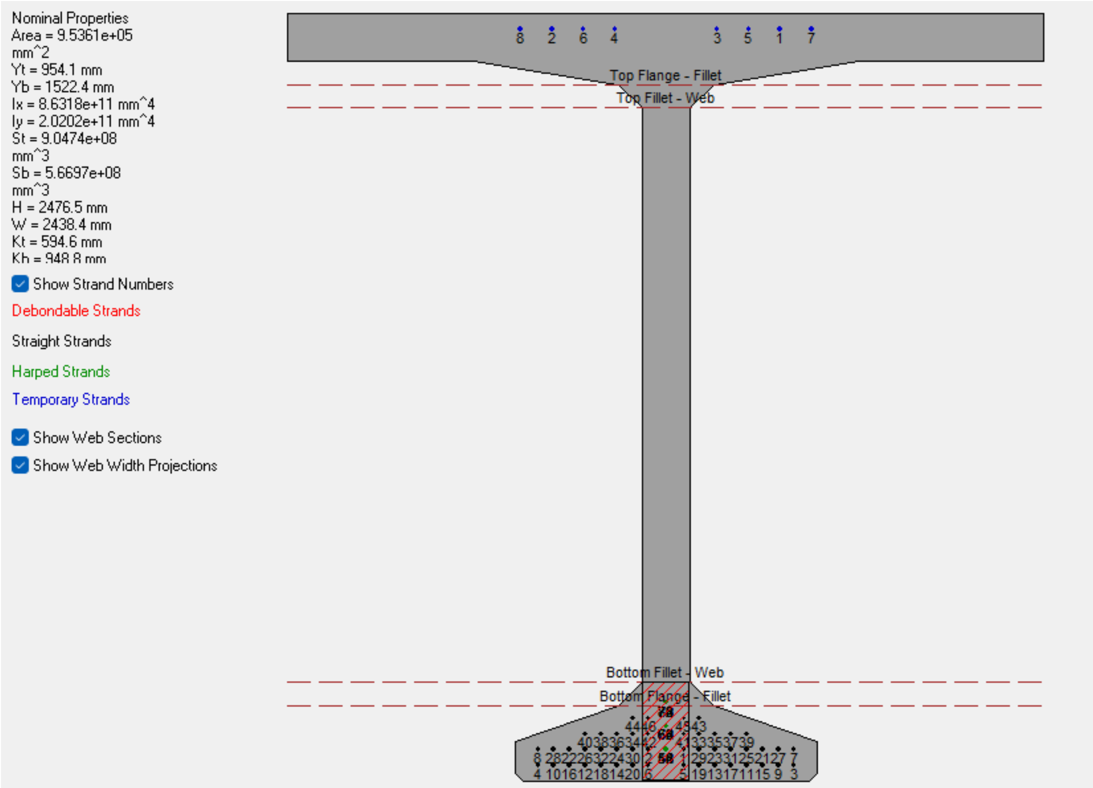

Figure 12. Mid Section of Deck Bulb Tee WF98DG girder

Figure 13 provides a visualization of the shape of the strand formation on the girders from the longitudinal side of the bridge to match Figures 11 and 12.

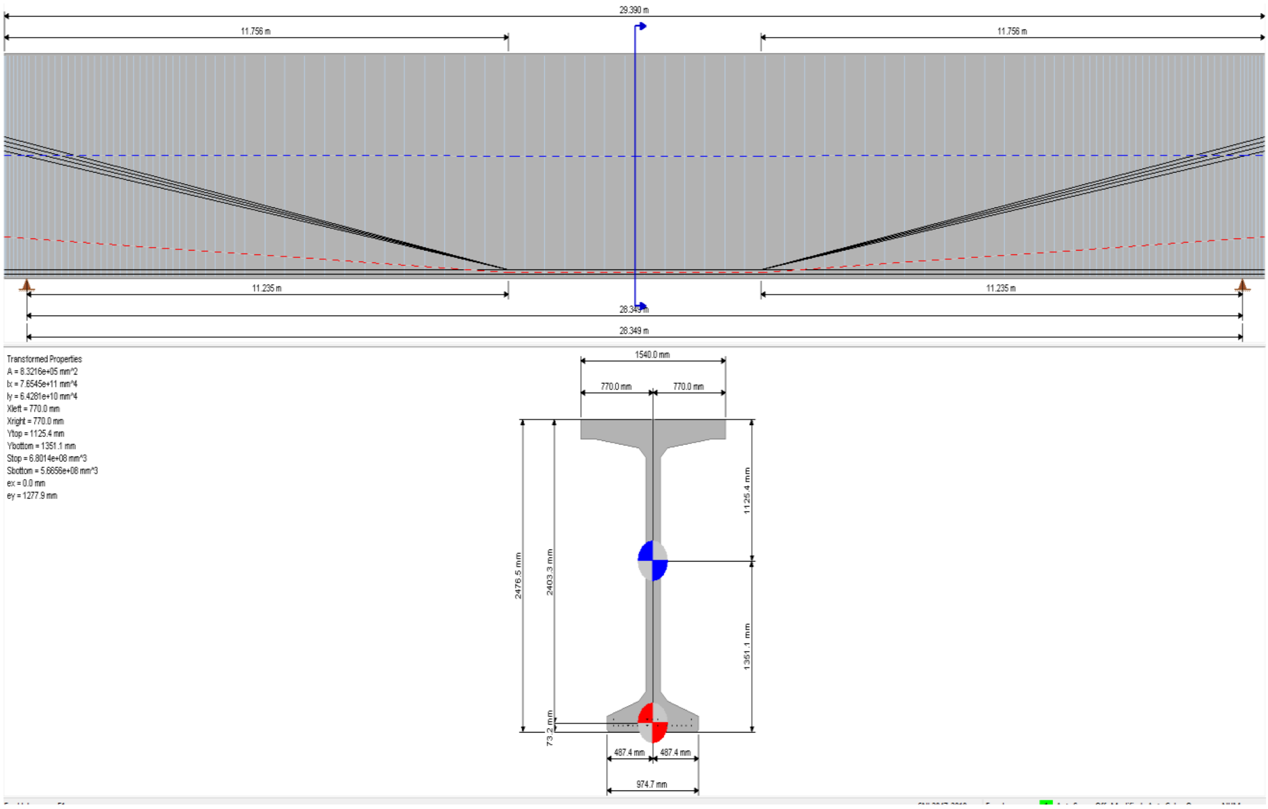

Figure 13. Longitudinal view of strand formation on bridge girders

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3.2. Bridgelink Design Analysis

One of the results issued by the analysis using Bridgelink is the moment capacity, shown in Figure 14, where the moment capacity of the girder used is the light green line marked with a yellow arrow, indicating the ability of the girder is still greater than the forces that occur due to several conditions that have been described in Figure 7, which confirms that these conditions are still below the condition of the girder element capabilities that have been designed and used as research parameters.

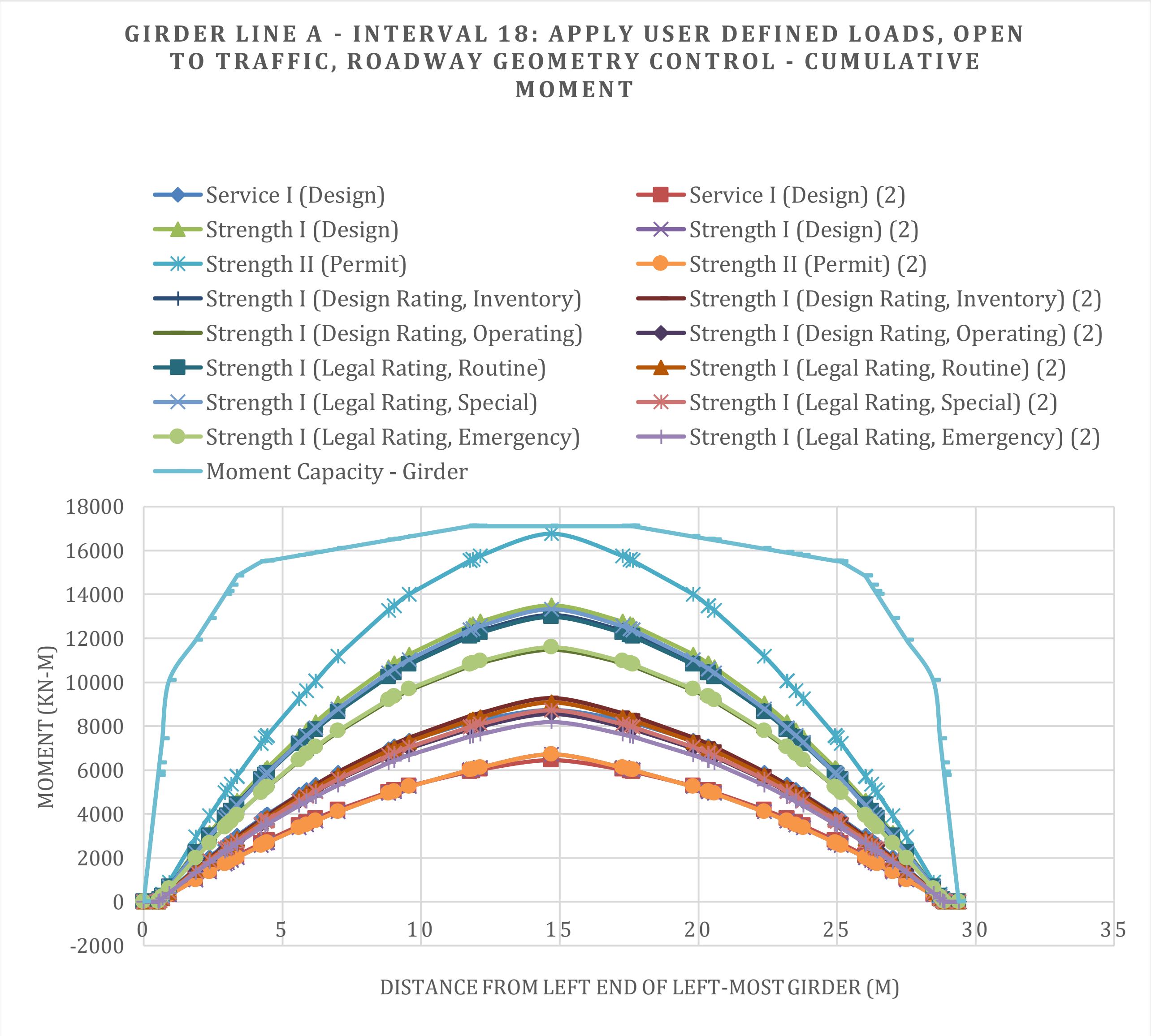

Figure 14. Moments that occur along the span and some conditions due to the forces that occur

Table 4 describes the output results and recommendations from Bridgelink in analyzing the capabilities of the elements when first entered, Bridgelink provides ideal recommendations in planning by providing options for adding strands, strand positions, and providing options for increasing the quality of concrete used ideally, Figure 18 provides information from the initial design results, namely the current value and recommendations given according to the proposed design column.

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Table 4. Analysis output table and design recommendations by bridge link

Parameter	Proposed Design	Current Value
Number of Straight Strands	18	18
Number of Harped Strands	7	7
Number of Temporary Strands	0	0
Straight Strand Jacking Force	3518.39	3518.39
Harped Strand Jacking Force	1368.26	1368.26
Temporary Strand Jacking Force	0.00 Kn	0.00 Kn
Distance from bottom of girder to bottom of harped strand group at start of girder	1409.7 mm	1409.7 mm
Distance from bottom of the girder to bottom of harped strand group at end of the girder	1409.7 mm	1409.7 mm
Distance from bottom of girder to bottom of harped strand group at left of girder	101.6 mm	101.6 mm
Distance from bottom of girder to bottom of harped strand group at right of girder	101.6 mm	101.6 mm
Eccentricity of Permanent Strands at Midspan	1276.9 mm	1276.9 mm
f'_{ci}	31.72 MPa	31.72 MPa
f'_{c}	35.16 MPa	35.16 MPa
Slab Offset ("A" Dimension)	365.4 mm	365.4 mm

Concrete release strength was controlled by flexural stress in Interval 2 Prestress Release, Service I, Compression, at the Bottom of the Girder. Concrete final strength was controlled by flexural stress in Interval 18 Apply User Defined Loads, Open to Traffic, Roadway Geometry Control, Service I, Compression, at the Bottom of Girder.

4. Conclusion

From the results of the analysis of this study, it is known that with a bridge cross-section of 3.124 m wide according to the needs of the width of the cross-section of a one-lane railway, which is a minimum of 3 m with a span length of 30 m using a single axle load of 20 tons requires a girder cross-section type Deck Bulb Tee WF98DG with the number of straight strand recommendations from bridge link is 18 pieces and Harped Strand as many as 7 pieces using fc' 35.16 MPa. This research needs to be continued because in this study using girders with types that already exist in Bridgelink's design criteria, further research should design with other cross-sectional dimensions according to local needs, to provide information and facilitate work and finding girder dimensions and some very broad options to be reviewed.

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References

[1] A. W. Efendi, "Behavior of Railroad Bridge Girders Due to Brake Loads with LISA V. 8 FEA," *… Conference on Railway and Transportation (ICORT …*, 2023, [Online]. Available: https://www.atlantis-press.com/proceedings/icort-22/125985594

[2] M. Su, Y. Yang, and R. Pan, "A comprehensively overall track-bridge interaction study on multi-span simply supported beam bridges with longitudinal continuous ballastless slab track," … Engineering and Mechanics, An Int'l Journal, 2021, [Online]. Available: https://www.dbpia.co.kr/Journal/articleDetail?nodeId=NODE10696911

[3] A. W. Efendi, "Behavior of Railroad Bridge Girders Due to Brake Loads with LISA V. 8 FEA," … Conference on Railway and Transportation (ICORT …, 2023, [Online]. Available: https://www.atlantis-press.com/proceedings/icort-22/125985594

[4] M. Su, Y. Yang, and R. Pan, "A comprehensively overall track-bridge interaction study on multi-span simply supported beam bridges with longitudinal continuous ballastless slab track," … Engineering and Mechanics, An Int'l Journal, 2021, [Online]. Available: https://www.dbpia.co.kr/Journal/articleDetail?nodeId=NODE10696911

[5] X. Chen, L. Pan, L. Xu, and C. Shi, "Three-Dimensional Vehicle–Curved Track Dynamic Model Based on FEM and DEM," … Journal of Structural Stability and …, 2021, doi: 10.1142/S0219455421501790.

[6] A. W. Efendi, "Behavior Analysis of Building Structures After a Fire with FEA LISA V. 8," Kurva S: Jurnal Keilmuan dan Aplikasi Teknik …, 2022, [Online]. Available: http://ejurnal.untag-smd.ac.id/index.php/TEKNIKD/article/view/6413

[7] P. M. Gullett, M. M. Dickey, and I. L. Howard, "Finite Element Analysis of Highway Bridges Subjected to Hurricane Storm Surge via the AMBUSH Framework," Journal of Bridge Engineering, 2020, doi: 10.1061/%28ASCE%29BE.1943-5592.0001602.

[8] J. M. Carbonell, L. Monforte, M. O. Ciantia, M. Arroyo, and …, "Geotechnical particle finite element method for modeling of soil-structure interaction under large deformation conditions," … and Geotechnical …. Elsevier, 2022. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S1674775521001943

[9] S. A. Meftah, "Formulation of Two Nodes Finite Element Model for Geometric Nonlinear Analysis of RHS Beams Accounting for Distortion and Shear Deformations," International Journal of Steel Structures. 2022. doi: 10.1007/s13296-022-00617-y.

[10] A. Recep and S. Sedat, "Investigation of the Consolidation Behavior of Soft Soil Improved with Vertical Drains by Finite Element Method," International Journal of Engineering and Applied …, 2021, [Online]. Available: https://dergipark.org.tr/en/pub/ijeas/issue/66141/1002115

[11] X. Tong, Q. Ma, and X. Yang, "The finite element analysis of magnetic storm geoelectric field based on the three-dimensional electrical structure," 2017 IEEE Conference on Energy Internet and Energy System Integration (EI2). IEEE, 2017. doi: 10.1109/ei2.2017.8245386.

[12] T. Albahkali, N. Alsanabani, and …, "A Concept to Estimate the Life Cycle of the Railway Track Using Finite Element Modeling," … International Journal …, 2021, [Online]. Available: http://journal.multiphysics.org/index.php/IJM/article/view/762

[13] P. Singh and S. P. Harsha, "Finite Element Analysis of Cartridge Tapered Roller Bearing of Freight Wagon," International Journal of Vehicle Structures and …, 2018, [Online]. Available: http://ischolar.info/index.php/IJVSS/article/view/185330

[14] A. W. Efendi, Y. Do, and N. F. Rachman, "Behavior of Rail Ballast Layer Using Mortar Foam with LISA-FEA," Journal of Railway Transportation and …, 2022, [Online]. Available: https://www.jrtt.org/index.php/jrtt/article/view/8

DOI: https://doi.org/10.71225/jstn.v1i2.52

[15] T. M. Gondhalekar and S. K. Panigrahi, "Transient Analysis of Railway Sleeper using Three-Dimensional Finite Element Method," Journal of The Institution of Engineers …, 2021, doi: 10.1007/s40030-021-00582-5.
[16] H. M. Elsanadedy, Y. A. Al-Salloum, M. A. Alrubaidi, and …, "Finite element analysis for progressive collapse potential of precast concrete beam-to-column connections strengthened with steel plates," Journal of Building …, 2021, [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2352710220335087
[17] T. M. Lenkovskiy, V. V. Kulyk, Z. A. Duriagina, L. V. Dzyubyk, and …, "Finite elements analysis of the side grooved I-beam specimen for mode II fatigue crack growth rates determination," Journal of Achievements in …. 2018.
[18] S. Zhu, Y. X. Zhang, and C. K. Lee, "Finite element analysis of hybrid fiber reinforced engineered cementitious composite link slabs," … Journal of Computational Methods, 2023, doi: 10.1142/S0219876221430222.
[19] V. C. Chavan and S. Mikkili, "Repositioning of series-parallel, total-cross-tide, bridge-link, and honey-comb PV array configurations for maximum power extraction," IETE Journal of Research, 2023, doi: 10.1080/03772063.2021.1986151.
[20] S. Harada, "Canonical components of character varieties of arithmetic two-bridge link complements," European Journal of Mathematics, 2023, doi: 10.1007/s40879-023-00640-1.
[21] H. Goda, C. Hayashi, and H. J. Song, "Dehn surgeries on 2-bridge links which yield reducible 3-manifolds," Journal of Knot Theory and Its …, 2009, doi: 10.1142/S0218216509007233.

DOI: https://doi.org/10.71225/jstn.v1i2.52