



Design and Analysis of Steel Bridge Withstand Extreme Weather Conditions Using Midas Civil

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Abstract: With increasing extreme weather events, the structural integrity of bridges in vulnerable locations like the Dibang Hydroelectric Project (HEP) in India is crucial. This study focuses on designing a truss steel bridge that can endure the challenging terrain and weather patterns of the Dibang region. Using MIDAS software for structural analysis and design, the bridge's performance is simulated under heavy rainfall, strong winds, seismic activity, and temperature variations.

Keywords: Truss Steel Bridge, Extreme Weather, MIDAS, Dibang HEP, Structural Analysis, Resilient Infrastructure.

1. INTRODUCTION

Designing steel bridges to withstand extreme weather conditions is a crucial aspect of modern civil engineering. MIDAS, a powerful and comprehensive engineering software, offers advanced tools for the design and analysis of such structures. Utilizing MIDAS, engineers can simulate and evaluate the performance of steel bridges under various extreme weather scenarios, including high winds, heavy snowfall, and temperature fluctuations. This ensures that the bridges are not only structurally sound but also resilient to the impacts of climate change. By incorporating sophisticated modeling techniques and rigorous analysis, MIDAS helps in creating durable and reliable steel bridges that can endure the harshest environmental conditions.

2. OBJECTIVES

Design a truss steel bridge with optimized structural performance and resilience to extreme weather conditions. Analyse the proposed bridge using MIDAS software to evaluate its structural integrity and behaviour under various loading scenarios, including extreme wind, seismic events, and temperature fluctuations. Assess the environmental and economic benefits of implementing a resilient bridge design compared to conventional designs. Develop recommendations for construction practices and materials selection to enhance the resilience of the bridge. Produce comprehensive documentation detailing the design process, analysis results, and recommendations for stakeholders and regulatory bodies.

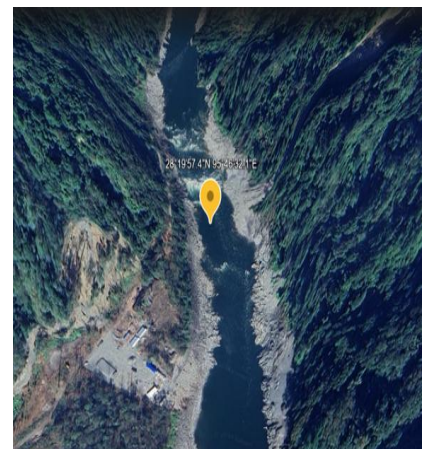


Figure No. 2.1 Proposing location



3. CLIMATIC CHANGE

3.1 IMPACTS OF CLIMATIC CHANGE

Identifying problems for a truss steel bridge in extreme weather conditions involves analyzing various factors that can compromise the bridge's structural integrity, safety, and functionality.

Temperature Increases: Rising global temperatures lead to more frequent and intense heatwaves, affecting human health, agriculture, and ecosystems.

Sea Level Rise: Melting polar ice caps and glaciers contribute to rising sea levels, threatening coastal communities and ecosystems with increased flooding and erosion.

Extreme Weather Events: Climate change intensifies the frequency and severity of extreme weather events such as hurricanes, typhoons, droughts, and heavy rainfall, causing widespread damage to infrastructure, agriculture, and livelihoods.

Ocean Acidification: Increased carbon dioxide levels result in more acidic oceans, affecting marine life, particularly coral reefs and shellfish, and disrupting marine ecosystems.

Biodiversity Loss: Altered habitats and changing climatic conditions lead to shifts in species distributions and increased extinction rates, reducing biodiversity and ecosystem resilience.

Agricultural Impacts: Changes in temperature and precipitation patterns affect crop yields, soil health, and water availability, posing risks to food security and agricultural livelihoods.

Human Health: Climate change exacerbates health issues through increased heat-related illnesses, the spread of vector-borne diseases, and reduced air quality.

Water Resources: Altered precipitation patterns and increased evaporation rates impact freshwater availability, leading to water shortages and affecting drinking water supplies, agriculture, and industry.

Economic Consequences: The costs of addressing climate-related damages, adaptation measures, and the loss of productivity due to extreme weather events impose significant economic burdens on communities and nations.

Social Displacement: Rising sea levels, extreme weather, and resource scarcity force populations to migrate, leading to increased displacement and potential conflicts over resources.

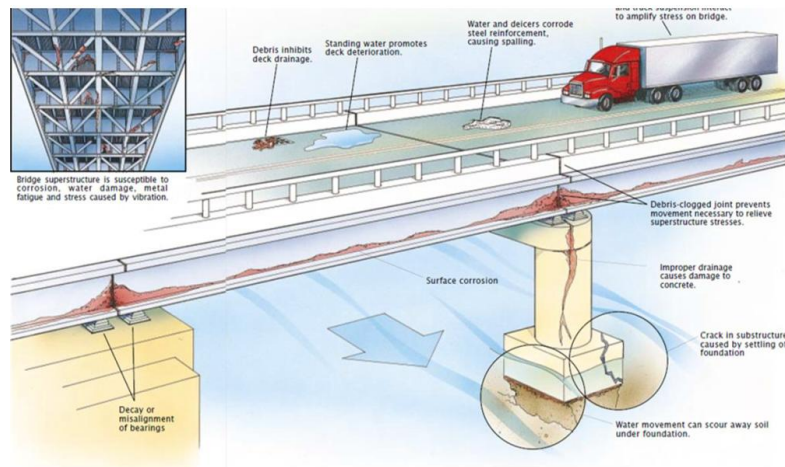
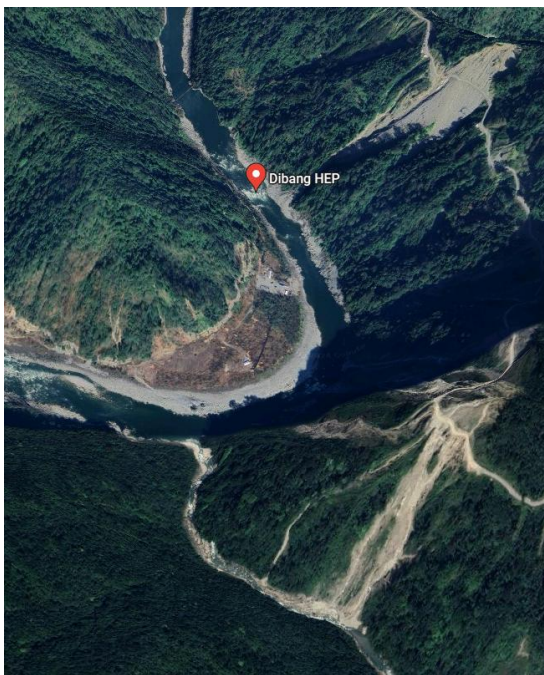


Figure No. 3.1 Affect Bridges

3.2 NEED FOR STUDY



With the increasing occurrences of extreme weather events, the structural integrity of bridges in vulnerable locations becomes paramount. Dibang Hydroelectric Project (HEP) in India, nestled amidst challenging terrain and weather patterns, necessitates the implementation of robust engineering solutions to ensure the longevity and safety of infrastructure. This paper presents a comprehensive study on the design and analysis of a truss steel bridge tailored to withstand extreme weather conditions prevalent in the Dibang HEP location.

The methodology employs MIDAS software, a powerful tool for structural analysis and design, allowing for accurate simulation and assessment of the bridge's performance under various environmental stresses. Factors such as heavy rainfall, strong winds, seismic activity, and temperature variations characteristic of the Dibang region are meticulously incorporated into the analysis. Bridge Location Between a Village



The design process begins with a detailed assessment of site-specific conditions and environmental loads. Utilizing advanced engineering principles and material science, the truss steel bridge is optimized for maximum strength, stability, and resilience. Special attention is given to the selection of materials, cross-sectional dimensions, and structural configurations to enhance durability and minimize maintenance requirements.

When the river is in space, parents don't send their wards to schools. They fear that the children might slip off the log bridge. It is also extremely difficult to take a patient to a hospital in the absence of a proper bridge, monsoon or not. "We have to carry patients on our back and cross the log bridge over the river to the Primary health centre or the General Hospital. The road connectivity issue is also affecting the area economically and socially, people of the villages feel.



3.3 EXPERIMENTAL INVESTIGATION

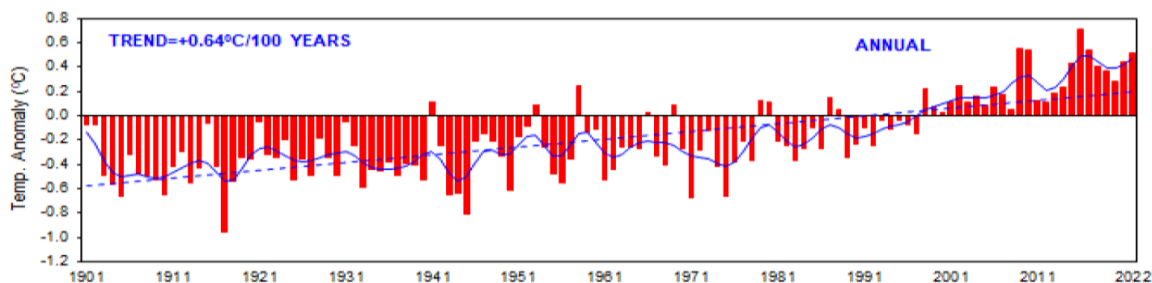


Fig.1: Annual mean land surface air temperature anomalies averaged over India for the period 1901-2022. The anomalies were computed with respect to the base period of 1981-2010. The dotted line indicates the linear trend in the time series. The solid blue curve represents the sub-decadal time scale variation smoothed with a binomial filter.

Figure No. 3.1 Annual Temperature Report

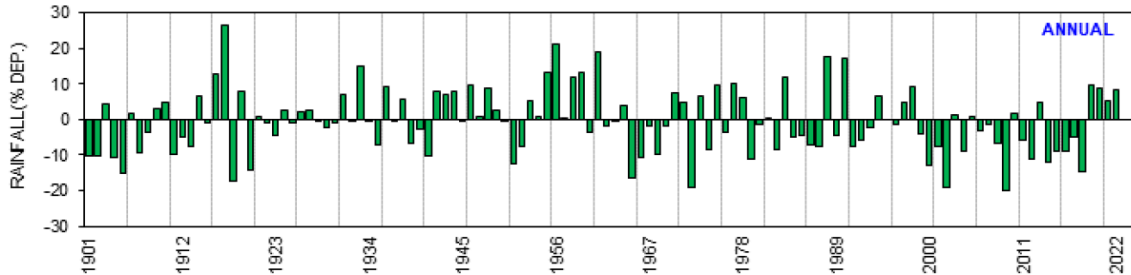


Fig. 2: Time Series of All India Annual Rainfall percentage Departure (1901-2022) from normal based on data of 1971-2020.

Figure No. 3.2 Annual Temperature Report

3.4 STUDY OF CLIMATIC CHANGE IN ARUNACHAL PRADESH

Arunachal Pradesh, being a northeastern state of India, typically experiences a humid subtropical climate in the lower elevations and an alpine climate in the higher elevations. Climate change impacts in such regions can vary but might include:

1. **Temperature Changes:** Overall, temperatures are expected to rise, leading to warmer average temperatures throughout the year. This could have significant impacts on ecosystems, agriculture, and water resources.
2. **Changing Precipitation Patterns:** While some regions might experience increased rainfall, others might face more frequent droughts or changes in the timing and distribution of rainfall. This can affect agriculture, water availability, and lead to increased risk of flooding or landslides.
3. **Glacial Retreat:** In high-altitude areas, glaciers may be melting at accelerated rates due to warmer temperatures. This can impact water availability downstream and also increase the risk of glacial lake outburst floods.
4. **Shifts in Ecosystems:** Changes in temperature and precipitation patterns can lead to shifts in vegetation zones and the distribution of wildlife. This can have implications for biodiversity and ecosystem services.
5. **Extreme Weather Events:** There may be an increase in the frequency or intensity of extreme weather events such as cyclones, storms, and heavy rainfall events. These events can cause significant damage to infrastructure, agriculture, and livelihoods.

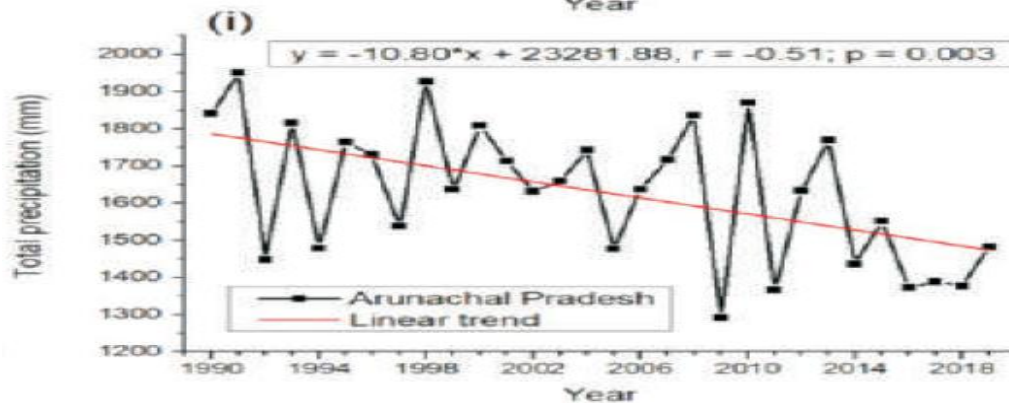
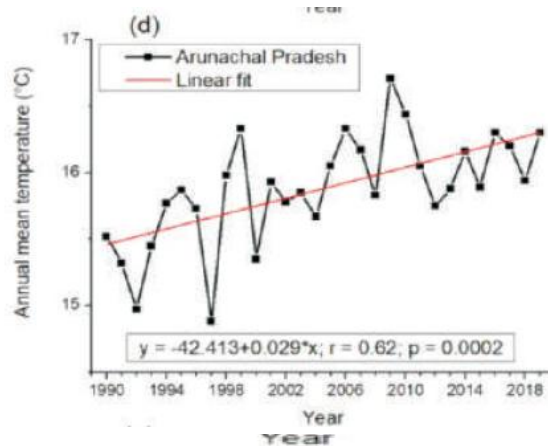


Fig: 3.3 Annual Temperature Report AP

Fig: 3.4 Annual Precipitation Report AP

- Steel expands about 0.0000065 meters per meter for every degree Celsius of temperature change. This means that a 100-meter-long steel beam can expand or contract by 0.65 meters when the temperature changes by 100 degrees Celsius
- Active work zones: 20 mph

3.4 PROPOSED SOLUTION OF TRUETT BRIDGE

1. **Regular Inspections and Monitoring:** Implement a rigorous inspection schedule to detect early signs of wear and damage.
2. **Protective Coatings:** Apply anti-corrosion coatings and sealants to steel components.
3. **Structural Reinforcements:** Reinforce critical areas to handle extreme loads and stresses.
4. **Thermal Expansion Joints:** Design and maintain expansion joints to accommodate temperature-induced movements.
5. **Scour Protection:** Use riprap, concrete aprons, or other methods to protect foundations from erosion.
6. **Wind Barriers and Aerodynamic Modifications:** Install wind barriers or modify the bridge design to reduce wind-induced stresses.



Seismic Upgrades: Retrofit older bridges with seismic-resistant designs and materials.

4. METHODOLOGY USED

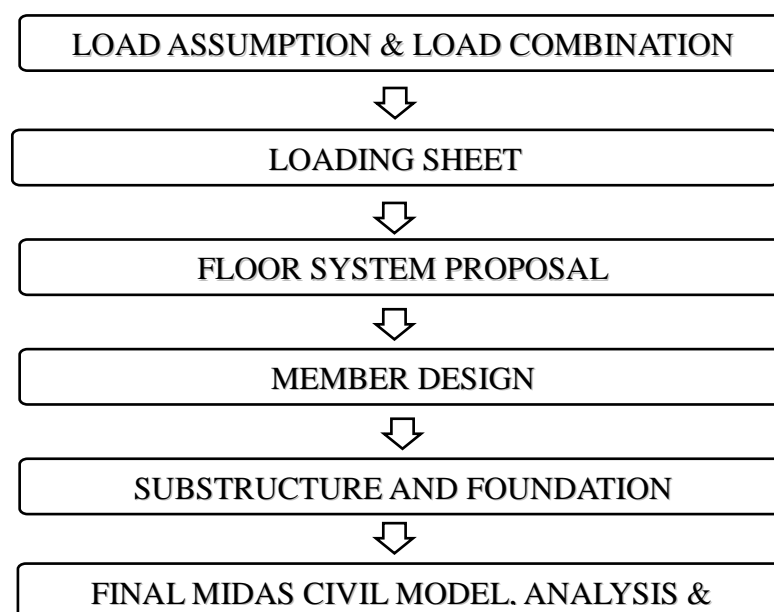


Figure No. 4.1 Flow Chart for design methodology

4.1 ANALYSIS METHOD OF MIDAS CIVIL SOFTWARE

The outline process of designing a sustainable steel bridge using MIDAS CIVIL software covers all the essential steps to ensure an efficient bridge design as follows:

Model Creation and Material Properties: Creating a detailed 3D model of the bridge allows engineers to accurately represent the geometry and components of the structure. Assigning material properties to each component ensures that the model accurately simulates the behavior of the bridge under various loading conditions. This step lays the foundation for the subsequent analysis and design phases.

Load Modelling and Analysis: Applying appropriate loading conditions, including static and dynamic loads such as vehicle weights, wind, and seismic loads, allows engineers to assess the structural response of the bridge. MIDAS CIVIL's advanced analysis capabilities, such as finite element analysis, enable engineers to predict how the bridge will behave under these loading conditions with a high level of accuracy.

Structural Design and Optimization: Based on the results of the load analysis, engineers



optimize the structural design of the bridge to ensure that it can safely withstand the required loads while adhering to specified limits for stress, deflection, and deformation. This may involve adjusting the size, spacing, or thickness of steel components to achieve the desired performance.

Results Interpretation and Verification: Once the design is optimized, engineers interpret and verify the results of the analysis to ensure that the bridge meets all required safety standards and regulations. This may involve conducting additional analyses, such as fatigue analysis or serviceability analysis, to assess the long-term durability and performance of the bridge.

5.EXPERIMENTAL WORK

5.1 STRUCTURE PARAMETERS

5.1.1 Truss Bridge – 200m (Typical 3 x 66.6 m span)

EJ – EJ	= 66.6m
Effective Span	= 198.5m
Height	= 5m
Width	= 7 m
Clear width (one side)	= 8 m
No. of segments	= 10 Nos.

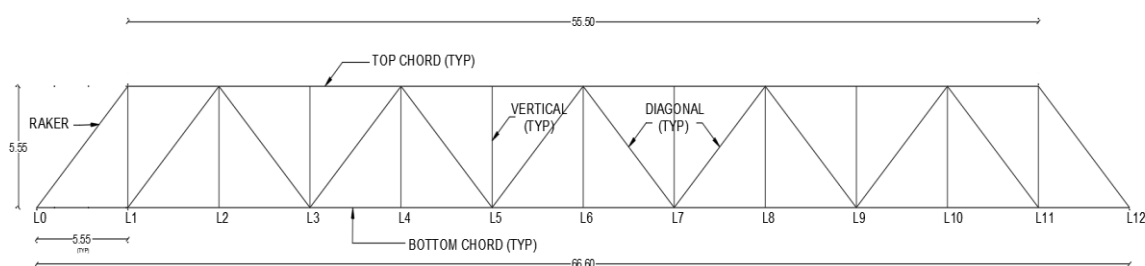


Figure No. 5.1 Structure detailing in Elevation View

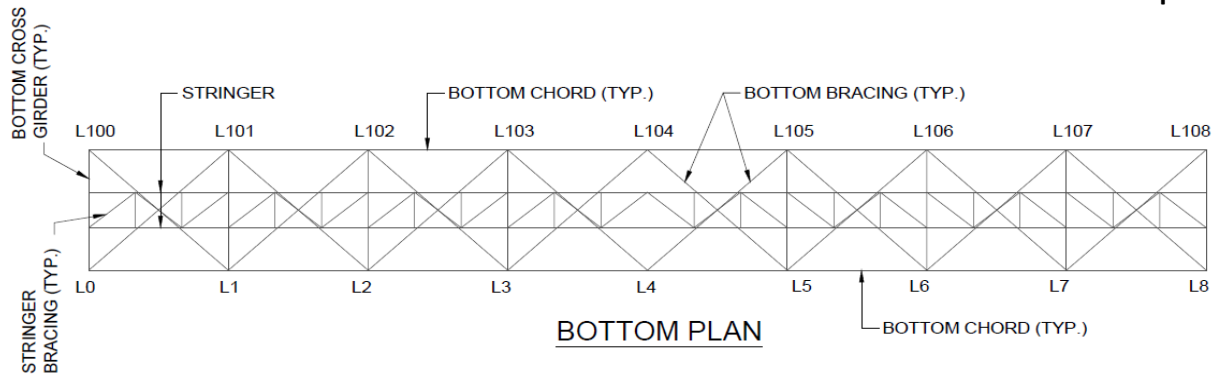


Figure No. 5.2 Structure detailing in Bottom View

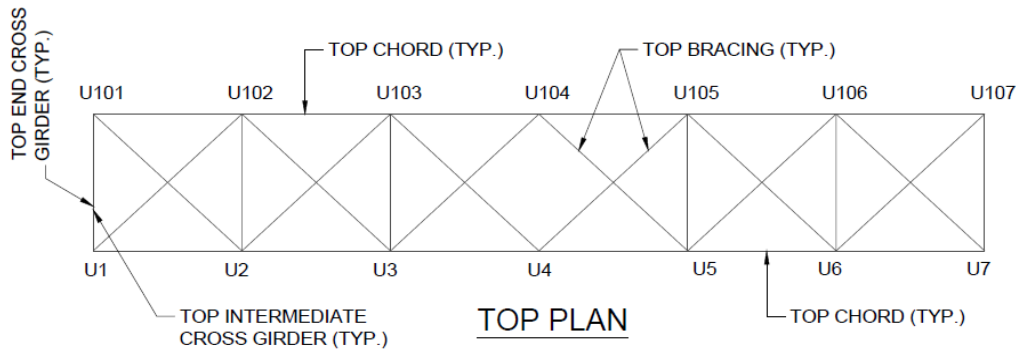


Figure No. 5.3 Structure detailing in Top View

5.2 DESIGN BASIS:

General:

Deck width	: 8m
Span	: 66.6m
Deck width	: 7.0 m

Levels:

Pile cap bottom level	: +9m R.L
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Loads:

Superimposed Dead load (SIDL):

Crash barrier	: Normal crash barrier (8 kN/m per crash barrier)
Utility load	: 2 kN/m per crash barrier (inclusive of noise barrier)
Wearing coat thickness	: 90 mm
Footpath	: 4.91 kN/m
Railing	: 1.5 kN/m

Live load:

Number of lanes	: 2
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Congestion factor	: Yes
Special vehicle	: Yes
Wind load:	
Wind speed	: 44 m/sec
Seismic load:	
Seismic zone	: V
Type of soil	: I
Importance factor	: 1.5
Barge impact load:	
Class of waterway	: I
Water velocity	: 2 m/sec

Important points:

Only 80% of concrete strength must be considered for design in case of underwater piling.
For PSC bridges, Provision shall be made in the design to replace at least 25% of the internal prestress tendons with structurally equivalent external pre-stress tendons.
Noise barrier of height 1.9m to be provided on top of crash barrier.

5.3 DESIGN INPUT

1. Total length of superstructure RHS Side	= 66.6m
2. Total length of superstructure LHS Side	= 66.6m
3. Deck Width	= 7m
4. Overall width	= 8 m
5. Carriageway Width one way	= 3.5 m
6. Carriageway Width two way	= 7 m
7. Thickness of wearing coat	= 0.09m
8. Depth of the box girder at Support	= 1m
9. Deck slab thickness	= 0.18m
10. Height of Crash Barrier (from FRL)	= 1.1m
11. Height of Hanger (maximum)	= 5.5m
12. Height of structure above ground (Soffit of girder to GL)	=14.75m
13. Low water level	
14. High flood level	
15. Design speed	= 100 km/h
16. Basic Wind Speed	= 44 m/s
17. Maximum mean velocity of water current	= 2 m/s
18. Seismic Zone	= V

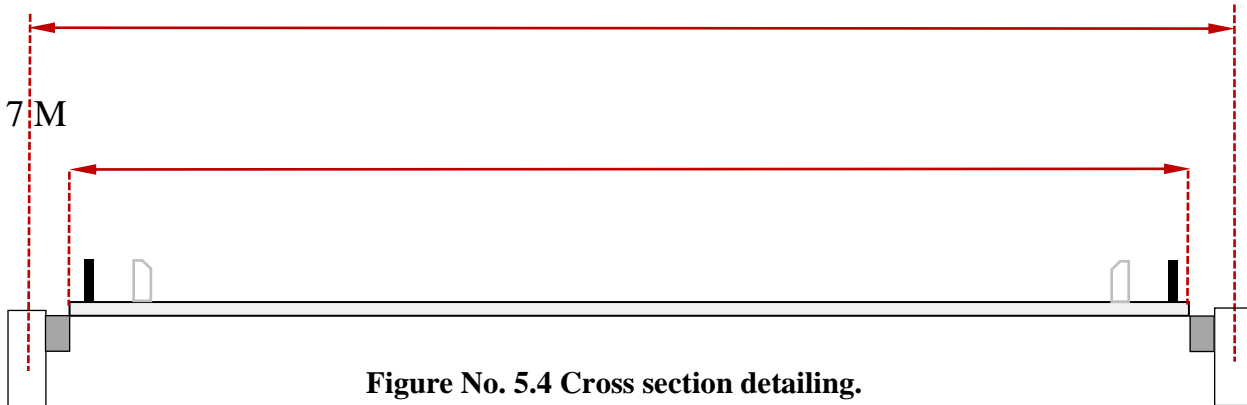


Figure No. 5.4 Cross section detailing.

5.4 DESIGN LOAD

5.4.1 Dead Load

In MIDAS CIVIL model command is used which accounts for the self weight of the steel members .To account for weights of connections to the steel members, the density of steel is increased by 28%.

5.4.2 Deck Slab Load

Total Deck slab Weight per running meter	=	101.50	kN/m
Weight per stringer	=	11.28	kN/m

Superimposed Dead Load (SIDL)

5.4.3 SIDL (Variable Load)

Weight of Wearing coat per running meter	=	26.73	kN/m
Total Weight of SIDL Variable Load per running meter	=	26.73	kN/m
Weight of SIDL Variable Load per stringer beam	=	2.97	kN/m

5.4.4 SIDL (Fixed)

Weight of Crash barrier	=	8.00	kN/m
Weight of Railing	=	0.00	kN/m
Weight of Utilities	=	2.00	kN/m
Total Weight of SIDL Fixed Load For 1 Crash Barrier	=	10.00	kN/m
Number of Crash Barriers	=	2.00	
Total Weight of SIDL Fixed Load	=	20.00	kN/m

5.4.5 Footpath load

Load Considered	=	500.00	kg/m ²
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Width of footpath = 0.00 m
 Footpath load = 0.00 kN/m

5.4.6 Live Load & Associated Loading

5.4.6.1 Vehicular Live Load

The carriageway live load combination with 4 lanes has been adopted in accordance with IRC: 6-2017 taking carriageway as 13.6 m.

Design live load consists of two standard vehicles:

1. Class 70R Vehicle (Wheeled or Tracked)
2. Class A Vehicle

Load combination considered for 4 lane loading is as below :

- 1) One lane of class A on each lane (with & without simultaneous loading on all lanes) 2) One lane of class A and one lane of class 70R for every two-lane placed at minimum distance from class A
- 2) In-Built Vehicular definition is available in MIDAS Civil for moving loads as per IRC: 6 - 2017 and the same is used for Analysis.

5.4.6.2 Congestion Factor

Congestion factor is considered in the design as per table 7 of IRC 6-2017.

Note: For Intermediate bridge spans, the value of congestion factor may be interpolated.

Table No: 5.1 Congestion Factor

Sl.NO.	Span Range	Congestion Factor
1	Above 10 m and upto 30m	1.15
2	30.0 m to 40.0 m	1.15 to 1.30
3	40.0 m to 50.0 m	1.30 to 1.45
4	50.0 to 60.0 m	1.45 to 1.60
5	60.0 m to 70.0 m	1.60 to 1.70
6	Beyond 70.0 m	1.70

5.4.6.3 Reduction in Longitudinal Effect

Reduction in longitudinal effect will be considered as per Clause 205 of IRC: 6-2017 depending on the number of lanes. This reduction is applicable for live load shear force, bending moment and torsion in longitudinal direction for superstructure, substructure and foundation design.

5.4.6.4 Impact Factor

As the span lengths are more than 45m, Impact factor will be considered as 8.8% for the concrete and 15.4% for steel.(Clause 208 of IRC 6-2017).

5.4.6.5 Special Vehicle

Special vehicle (multi axle hydraulic trailer of 385 t) loading shall be considered as per IRC: 6 2017 Clause 204.5. An eccentricity of 300 mm will be considered for the same from centreline of



carriageway.

5.4.6.6 Fatigue Loads

Fatigue load is specified as per Amendment No.8/IRC:6-2017/October, 2022 (Clause 204.6 of IRC: 6-2017). The truck defined in the figure below will be used for the fatigue life assessment of concrete bridge. 40% of the impact factors mentioned in Clause 208 of IRC:6-2017 will be applied to this fatigue load.

5.4.6.7 Wind Load

a) Overturning force on top chords (windward & leeward side)-P1		= 188.88 Kn
Lever arm (Z_1)	=5.5+0.62/2	= 5.810 M
Overturning moment (M_{O1})	=188.888×55.810	=1097.437 Kn/m
b) Overturning force on top chords (windward & leeward side)-P2		= 278.430 Kn
Lever arm (Z_2)	=0.62/2	= 0.310 M
Overturning moment (M_{O2})	=278.430×0.310	= 86.313 Kn/m
c) Overturning force on top chords (windward & leeward side)-P3		= 597.410 Kn
Lever arm (Z_3)	=6.5x66.6	= 0.600 M
Overturning moment (M_{O3})	=597.410×0.600	= 358.446 Kn/m
Total Overturning Moment, $M_O=M_{O1}+M_{O2}+M_{O3}$		= 10986.580 kNm

Restoring Moment (M_R):

SIDL	7*66.61	= 380.170 kN
Dead load(Ref Sec 3.1.5)	4*645.13	= 2580.520 kN
Total dead load & SIDL of superstructure , W	=380.170+2580.520	= 2960.690 kN
Lever arm (x)	=6.45/2	= 3.225 m
Restoring moment,		
$M_R=W.x$	=0.9×3046.720×3.225	= 8593.405 kNm
Factor of safety		= 5.572
		> 1.4
		Safe

5.4.6.9 Seismic Load

The horizontal seismic coefficient is calculated by the following equation.



$$A_h = \frac{\left(\frac{Z}{2}\right)\left(\frac{S_a}{g}\right)}{\left(\frac{R}{I}\right)}$$

Where, Zone factor $Z = 0.24$ (Zone V)
Importance Factor $I = 1.5$

S_a/g = Average response acceleration coefficient for 5 percent damping of load resisting elements depending upon the fundamental period of vibration T of structure. It shall be taken corresponding to 5 percent damping.

a) Overturning force on top chords (windward & leeward side)-P1 = 63.303 Kn
Lever arm (Z_1) = 5.5+0.62/2 = **6.500 m**
Overturning moment (MO_1) = 411.470 Knm

b) Overturning force on top chords (windward & leeward side)-P2 = 80.549 Kn
Lever arm (Z_2) = 0.62/2 = **0.310 M**
Overturning moment (MO_2) = 24.970 Knm

c) Overturning force on top chords (windward & leeward side)-P3 = 597.410 Kn
Lever arm (Z_3) = 6.5x66.6 = **0.600 M**
Overturning moment (MO_3) = 597.410x0.600 = 358.446 Knm

Total Overturning Moment, $MO=MO_1+MO_2+MO_3 = 794.886$ knm

Restoring Moment (M_R):

SIDL = 7*66.61 = **380.170** kN
Dead load(Ref Sec 3.1.5) = 4*645.13 = 2580.520 kN
Total dead load & SIDL of superstructure , $W = 380.170+2580.520 = 2960.690$ kN
Lever arm (x) = 6.45/2 = 3.225 m
Restoring moment,
 $M_R=W.x = 0.9 \times 2960.690 \times 3.225 = 8593.405$ kNm

Factor of safety = 10.81
> 1.4
Safe



Temperature Effects

(C.1 6.8 of Section 2 Volume 4 of ER)

5.4.6.9.1 Uniform Temperature

For Project site location:

Highest Maximum Bridge Temperature = 42.5 °C

Lowest Minimum Bridge Temperature = 5 °C

Total Variation of Temperature = 42.5 - 5 = 37.5 °C

Mean of Maximum and Minimum Air shade Temperature
= (42.5+5) / 2 = 23.75 °C

Bridge Temperature assumed when the structure is effectively restrained.

= Mean of Max. & Min. Air shade Temp. ±10°C

Effective Bridge Temperature = 23.75 + 10 = 33.8 °C

= 23.75 - 10 = 13.8 °C

Maximum Temperature rise accounted

= 42.5 - 13.75 = 28.75 °C

Maximum Temperature fall accounted

= 5 - 33.75 = -28.75 °C

Maximum Temperature rise and fall as calculated above has been applied in MIDAS using inbuilt element temperature load function, for superstructure.

For metallic structures (Steel composite) :

Highest Maximum Bridge Temperature = 57.5 °C

Lowest Minimum Bridge Temperature = -5 °C

Total Variation of Temperature = 57.5 - (-5) = 62.5 °C

Mean of Maximum and Minimum Air shade Temperature
= (57.5+-5) / 2 = 26.25 °C

Bridge Temperature assumed when the structure is effectively restrained.

= Mean of Max. & Min. Air shade Temp. ±10°C

Effective Bridge Temperature = 26.25 + 10 = 36.3 °C

= 26.25 - 10 = 16.3 °C

Maximum Temperature rise accounted = 57.5 - 16.25 = 41.25 °C

Maximum Temperature fall accounted = -5 - 36.25 = -41.25 °C

Maximum Temperature rise and fall as calculated above has been applied in MIDAS using inbuilt element temperature load function, for steel composite sections in superstructure.

Long term Elastic modulus for seasonal variation of temperature has been considered by adopting load factor of 0.5 for this case.

5.5.1 DESIGN OF STEEL ELEMENTS

IS Code	Description
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IS 800:2007	General construction in Steel — code of practice
IRC:6-2017	Section: II Loads and Load Combinations (7th Revision)
May 2021-Temperature IRC6 Amendment	For Temperature Loads
01-IH-JAN-2018-Amendment (Air shade temp)	For Temperature Loads
IS 456: 2000	Plain and Reinforced Concrete - Code of practice
SP 16	Structural use of concrete. Design reinforced beams, doubly reinforced beams and columns.
SP 34	Handbook on Concrete Reinforcement & Detailing
IS 2950	Indian Standard Code of Practice for Design and Construction of Raft Foundation (Part – 1)

5.5.2 DESIGN LOADS (OTHER THAN EARTHQUAKE LOADS)

IS Code	Description
IS 875(Part 1): 1987	Dead Loads -Unit Weight of Building Material and Stored Material
IS 875(Part 2): 1987	Imposed Loads
IS 875(Part 3): 2015	Wind Loads

5.5.3 DESIGN FOR EARTHQUAKE RESISTANCE

IS Code	Description
IS 1893:2016	Criteria for earthquake resistance design of structures.
IS 13920: 2016	Ductile Detailing of Reinforced Concrete Structures subjected to Seismic Forces - Code of Practice.
SP 22	Explanation to IS 1893 & IS 4326

6.RESULTS AND DISCUSSION

6.1 MIDAS MODEL

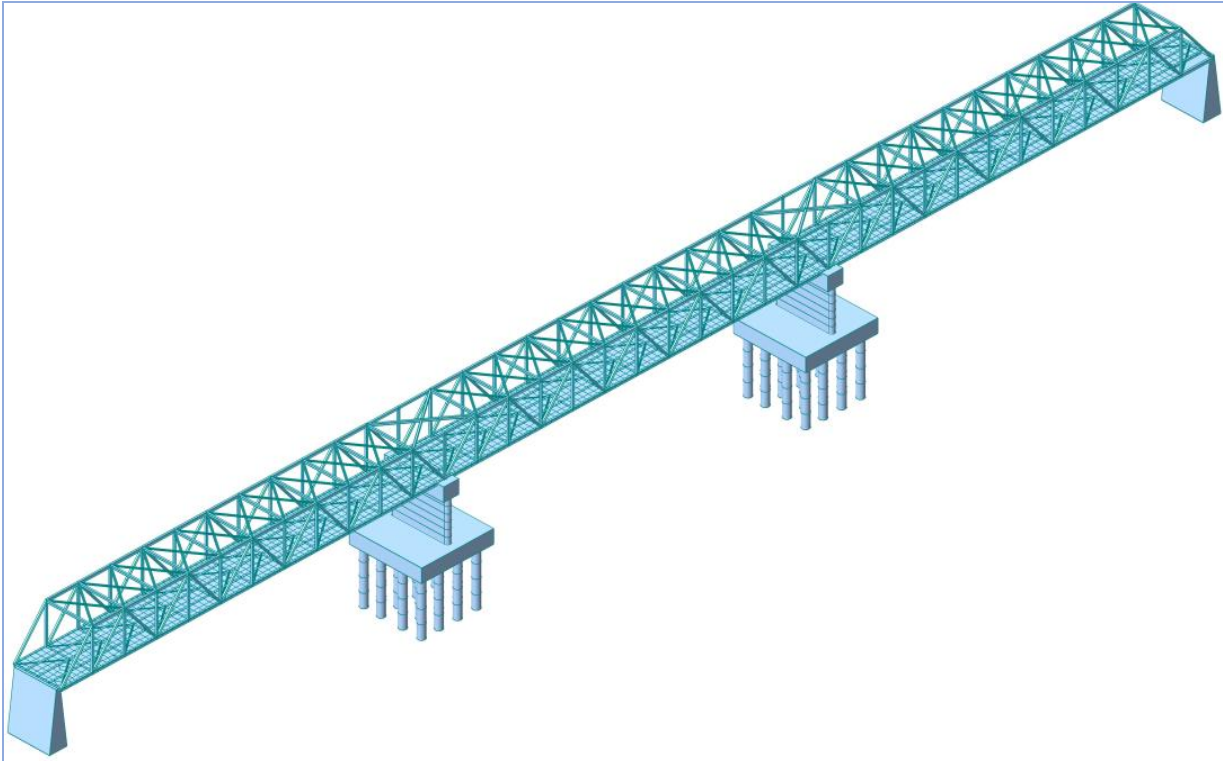


Figure No. 6.1 MIDAS –Detailed Model– Isometric View

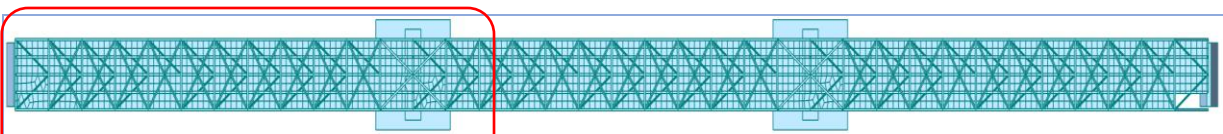


Figure No. 6.2 MIDAS –Detailed Model– Top View

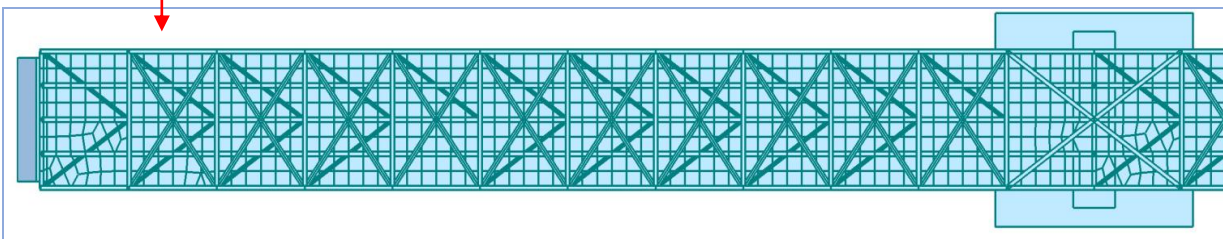


Figure No. 6.3 MIDAS –Detailed Model– Top View (blow up drawing)



DESIGN COMPONENTS:

1. Concrete Slab
2. Stringer
3. Cross Beam
4. Anchor Rod
5. Top Lateral & Bottom Chord.

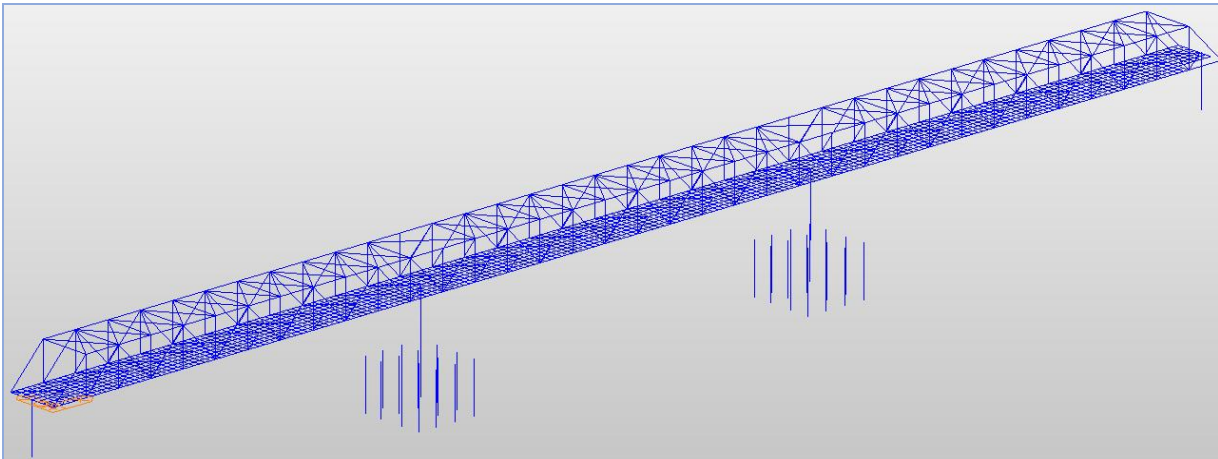


Figure No. 6.4 MIDAS – Truss Bridge - Nodal Representation

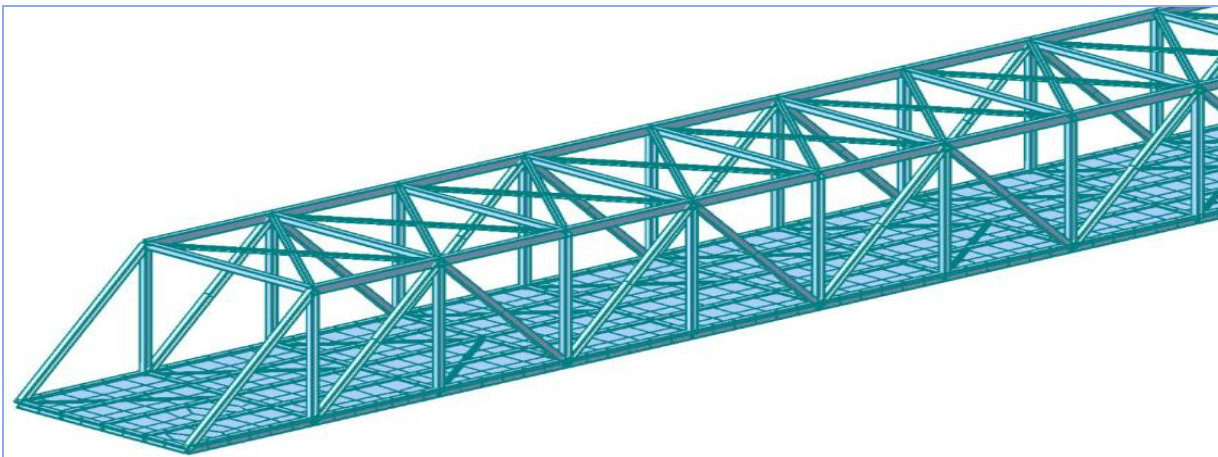


Fig. No. 6.5 MIDAS – Model Stage with Section, Material Property & Boundary Conditions

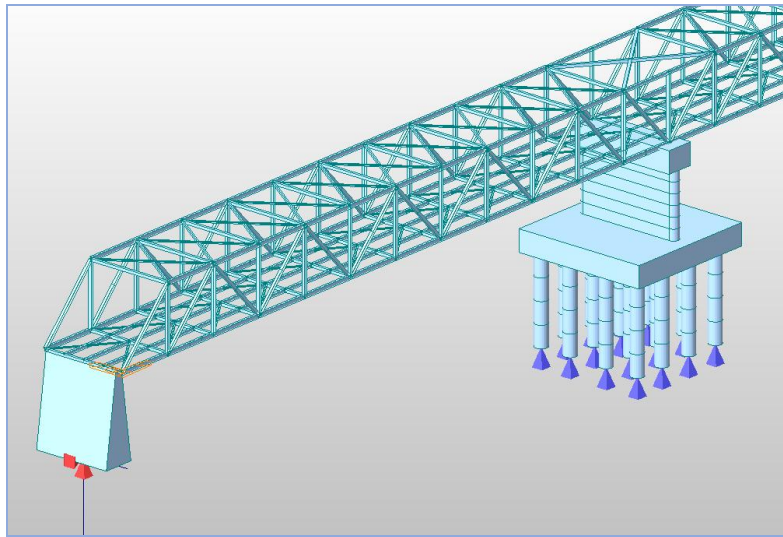


Figure No. 6.6 MIDAS – Model Stage with Support Reaction

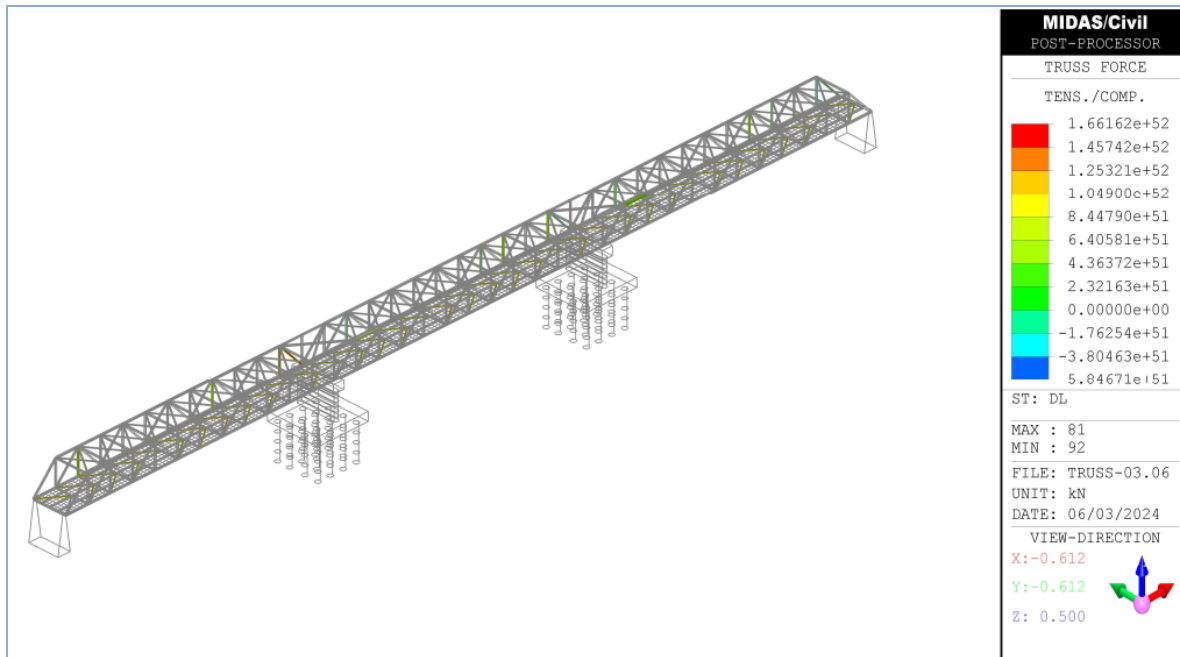


Figure No. 6.7 MIDAS – Force Transferring of Truss Bridge

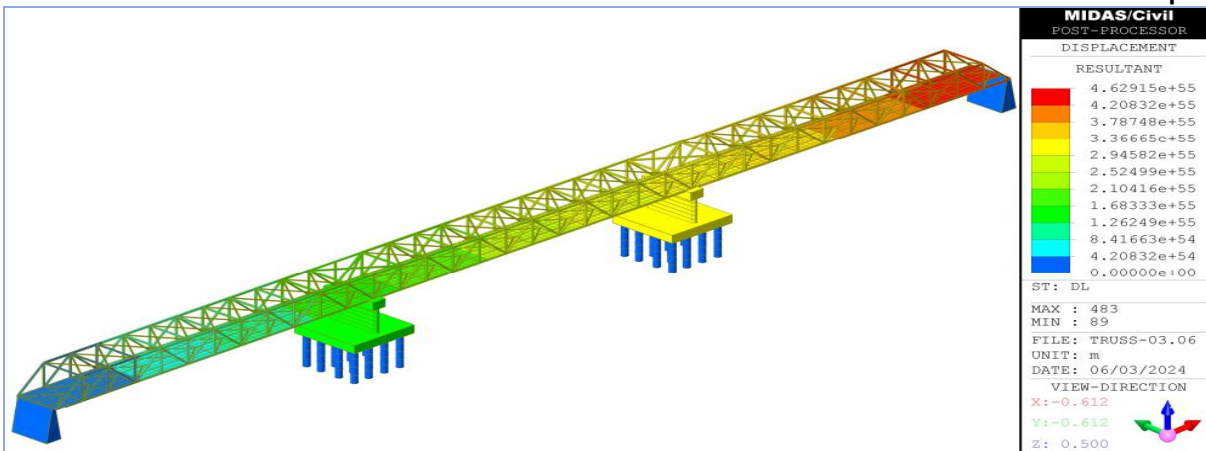


Figure No. 6.8 MIDAS – Beam Force & Moment Reactants

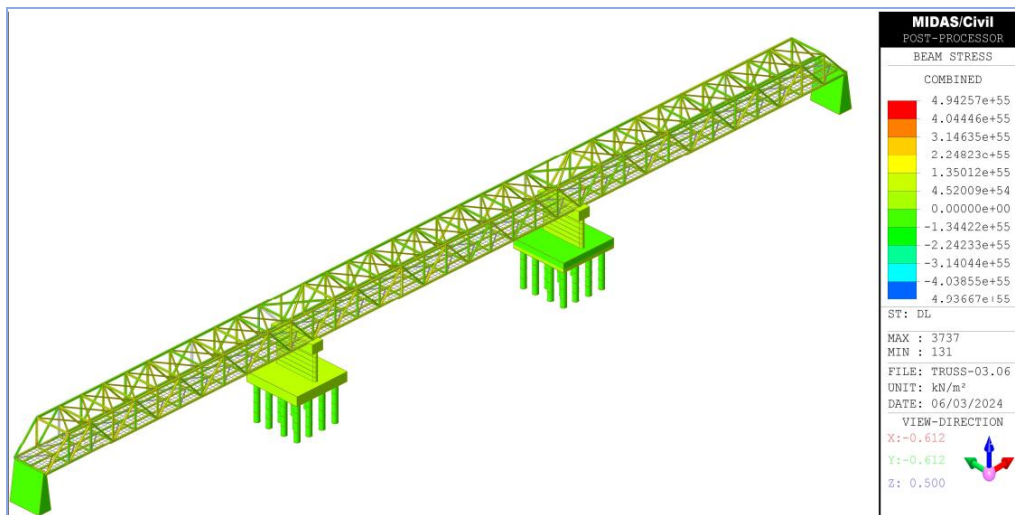


Figure No. 6.9 MIDAS – Beam Stress Reactants

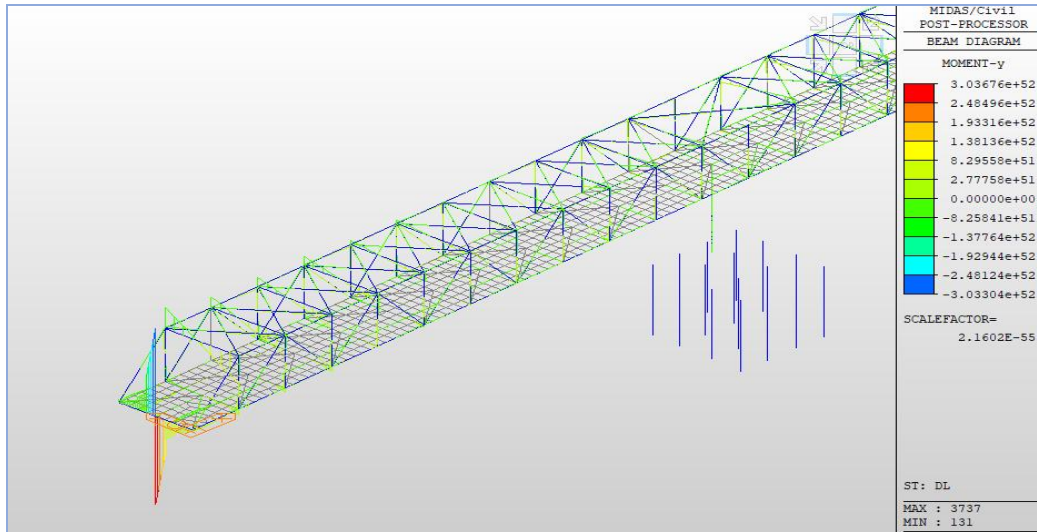


Figure No. 6.9.1 MIDAS – Beam Force & Moment Diagram

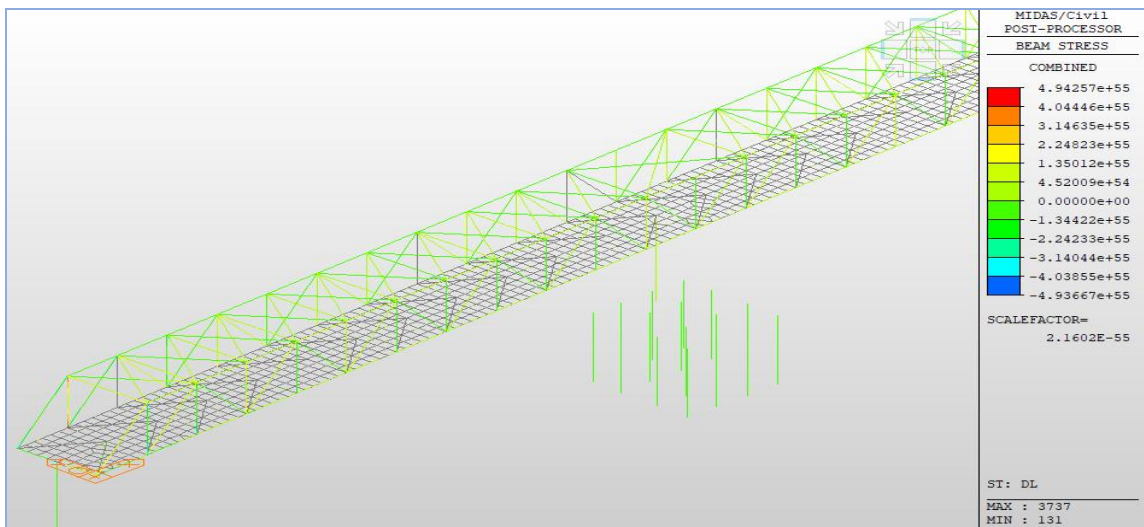
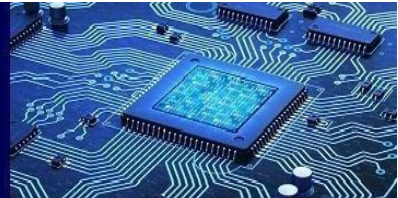


Figure No. 6.9.2 MIDAS – Beam Stress Diagram



Elem	Load	Part	Axial (kN/m)	Shear-y (kN/m)	Shear-z (kN/m)	Bend(+y) (kN/m)	Bend(-y) (kN/m)	Bend(+z) (kN/m)	Bend(-z) (kN/m)	Cb1(min/max) (kN/m)	Cb1(-y+z) (kN/m)	Cb2(+y+z) (kN/m)	Cb3(+y-z) (kN/m)	Cb4(-y-z) (kN/m)
709	ULS ENV(all)	J[1270]	2.92e+60	-1.62e+58	3.85e+58	-3.05e+59	3.05e+59	2.07e+59	-2.07e+59	3.43e+60	2.82e+60	2.41e+60	2.41e+60	3.02e+60
712	ULS ENV(all)	J[419]	-2.93e+60	-2.14e+58	-3.16e+58	3.40e+59	-3.40e+59	5.37e+59	-5.37e+59	-3.80e+60	-2.73e+60	-2.05e+60	-3.12e+60	-3.80e+60
712	ULS ENV(all)	J[2379]	-2.93e+60	-2.14e+58	-3.16e+58	2.29e+58	-2.29e+58	4.62e+59	-4.62e+59	-3.41e+60	-2.49e+60	-2.44e+60	-3.37e+60	-3.41e+60
715	ULS ENV(all)	J[426]	2.97e+60	-1.94e+58	3.63e+58	-4.00e+58	4.00e+58	6.45e+59	-6.45e+59	3.66e+60	3.66e+60	3.58e+60	2.29e+60	2.37e+60
715	ULS ENV(all)	J[1109]	2.97e+60	-1.94e+58	3.63e+58	-3.27e+59	3.27e+59	7.31e+59	-7.31e+59	4.03e+60	4.03e+60	3.38e+60	1.91e+60	2.57e+60
718	ULS ENV(all)	J[418]	-3.14e+60	-2.39e+58	4.86e+58	3.76e+59	-3.76e+59	4.34e+59	-4.34e+59	-3.95e+60	-3.08e+60	-2.33e+60	-3.20e+60	-3.95e+60
718	ULS ENV(all)	J[1516]	-3.14e+60	-2.39e+58	4.86e+58	2.32e+58	-2.32e+58	5.49e+59	-5.49e+59	-3.71e+60	-2.57e+60	-2.57e+60	-3.66e+60	-3.71e+60
721	ULS ENV(all)	J[417]	-3.21e+60	-7.55e+57	1.34e+59	2.62e+59	-2.62e+59	-3.99e+60	3.99e+60	-7.46e+60	-7.46e+60	-6.94e+60	1.05e+60	5.24e+60
721	ULS ENV(all)	J[1747]	-3.21e+60	-7.55e+57	1.34e+59	1.50e+59	-1.50e+59	-3.68e+60	3.68e+60	-7.03e+60	-7.03e+60	-6.73e+60	6.20e+59	3.19e+60
724	ULS ENV(all)	J[427]	2.90e+60	2.54e+58	6.94e+60	-3.94e+59	3.94e+59	-1.78e+61	1.78e+61	2.11e+61	-1.45e+61	-1.53e+61	2.03e+61	2.11e+61
724	ULS ENV(all)	J[1310]	2.90e+60	2.54e+58	6.94e+60	-1.75e+58	1.75e+58	-1.38e+60	1.38e+60	4.30e+60	4.30e+60	1.54e+60	4.27e+60	4.30e+60
727	ULS ENV(all)	J[416]	-3.03e+60	1.10e+58	-1.85e+58	1.09e+59	-1.09e+59	3.55e+59	-3.55e+59	-3.49e+60	-2.78e+60	-2.57e+60	-3.28e+60	-3.49e+60
727	ULS ENV(all)	J[2394]	-3.03e+60	1.10e+58	-1.85e+58	2.71e+59	-2.71e+59	3.12e+59	-3.12e+59	-3.61e+60	-2.99e+60	-2.45e+60	-3.07e+60	-3.61e+60
730	ULS ENV(all)	J[428]	3.01e+60	1.77e+58	1.63e+59	-3.20e+59	3.20e+59	-1.75e+59	1.75e+59	3.51e+60	3.16e+60	2.52e+60	2.87e+60	3.51e+60
730	ULS ENV(all)	J[1183]	3.01e+60	1.77e+58	1.63e+59	-5.79e+58	5.79e+58	2.11e+59	-2.11e+59	3.28e+60	3.17e+60	2.75e+60	2.75e+60	2.86e+60
733	ULS ENV(all)	J[415]	-2.88e+60	1.02e+58	4.50e+57	1.06e+59	-1.06e+59	6.53e+59	-6.53e+59	-3.64e+60	-2.33e+60	-2.12e+60	-3.42e+60	-3.64e+60
733	ULS ENV(all)	J[2623]	-2.88e+60	1.02e+58	4.50e+57	2.56e+59	-2.56e+59	6.64e+59	-6.64e+59	-3.80e+60	-2.47e+60	-1.96e+60	-3.28e+60	-3.80e+60
736	ULS ENV(all)	J[429]	2.87e+60	1.43e+58	-6.24e+58	-2.85e+59	2.85e+59	5.88e+59	-5.88e+59	3.74e+60	3.17e+60	2.00e+60	2.57e+60	5.88e+59
736	ULS ENV(all)	J[10177]	2.87e+60	1.43e+58	-6.24e+58	-7.41e+58	7.41e+58	4.41e+59	-4.41e+59	3.30e+60	3.30e+60	3.24e+60	2.35e+60	2.50e+60
739	ULS ENV(all)	J[414]	-2.86e+60	9.91e+57	1.58e+58	9.37e+58	-9.37e+58	1.82e+59	-1.82e+59	-2.93e+60	-2.57e+60	-2.39e+60	-2.75e+60	-2.93e+60
739	ULS ENV(all)	J[2255]	-2.86e+60	9.91e+57	1.58e+58	2.40e+59	-2.40e+59	2.19e+59	-2.19e+59	-3.12e+60	-2.68e+60	-2.23e+60	-2.64e+60	-3.12e+60
742	ULS ENV(all)	J[430]	2.84e+60	1.22e+58	1.13e+58	-2.55e+59	2.55e+59	4.54e+57	-4.54e+57	2.90e+60	2.90e+60	2.39e+60	2.39e+60	2.89e+60
742	ULS ENV(all)	J[1723]	2.84e+60	1.22e+58	1.13e+58	-7.44e+58	7.44e+58	3.12e+58	-3.12e+58	2.75e+60	2.75e+60	2.60e+60	2.54e+60	2.69e+60
745	ULS ENV(all)	J[413]	-2.45e+60	9.74e+57	-1.57e+58	8.14e+58	-8.14e+58	4.26e+58	-4.26e+58	-2.57e+60	-2.49e+60	-2.32e+60	-2.41e+60	-2.57e+60
745	ULS ENV(all)	J[2101]	-2.45e+60	9.74e+57	-1.57e+58	2.26e+59	-2.26e+59	5.45e+57	-5.45e+57	-2.68e+60	-2.67e+60	-2.22e+60	-2.23e+60	-2.68e+60
748	ULS ENV(all)	J[431]	2.43e+60	1.25e+58	-1.41e+58	-2.43e+59	2.43e+59	-5.69e+58	5.69e+58	2.73e+60	2.62e+60	2.13e+60	2.24e+60	2.73e+60
748	ULS ENV(all)	J[1912]	2.43e+60	1.25e+58	-1.41e+58	-5.90e+58	5.90e+58	-9.03e+58	9.03e+58	2.58e+60	2.40e+60	2.28e+60	2.46e+60	2.58e+60
751	ULS ENV(all)	J[412]	-2.19e+60	1.01e+58	2.07e+57	6.35e+58	-6.35e+58	1.06e+59	-1.06e+59	-2.36e+60	-2.15e+60	-2.02e+60	-2.23e+60	-2.36e+60
751	ULS ENV(all)	J[1956]	-2.19e+60	1.01e+58	2.07e+57	2.13e+59	-2.13e+59	1.10e+59	-1.10e+59	-2.52e+60	-2.29e+60	-1.87e+60	-2.09e+60	-2.52e+60
754	ULS ENV(all)	J[411]	-1.93e+60	1.63e+58	3.32e+57	-4.02e+57	4.02e+57	1.79e+58	-1.79e+58	-1.95e+60	-1.90e+60	-1.95e+60	-1.95e+60	-1.94e+60
754	ULS ENV(all)	J[1851]	-1.93e+60	1.63e+58	3.32e+57	2.37e+59	-2.37e+59	2.57e+58	-2.57e+58	-2.19e+60	-2.14e+60	-1.66e+60	-1.71e+60	-2.19e+60
757	ULS ENV(all)	J[432]	1.89e+60	2.71e+58	5.85e+57	-3.12e+59	3.12e+59	-1.07e+57	1.07e+57	2.21e+60	2.20e+60	1.58e+60	1.97e+60	2.21e+60
757	ULS ENV(all)	J[2204]	1.89e+60	2.71e+58	5.85e+57	8.92e+58	-8.92e+58	1.28e+58	-1.28e+58	2.00e+60	1.82e+60	2.00e+60	1.97e+60	1.79e+60
758	ULS ENV(all)	J[329]	1.88e+61	-3.52e+59	-1.91e+59	2.44e+61	-2.44e+61	1.83e+60	-1.83e+60	4.50e+61	-3.80e+60	4.50e+61	4.14e+61	-7.46e+60
758	ULS ENV(all)	J[450]	1.88e+61	-3.52e+59	-1.91e+59	1.40e+60	-1.40e+60	-1.67e+59	1.67e+59	2.03e+61	1.72e+61	2.00e+61	2.03e+61	1.76e+61
759	ULS ENV(all)	J[450]	1.88e+61	-3.52e+59	-1.91e+59	1.40e+60	-1.40e+60	-1.67e+59	1.67e+59	2.03e+61	1.72e+61	2.00e+61	2.03e+61	1.76e+61

Figure No. 6.9.3 MIDAS – Resultant Table

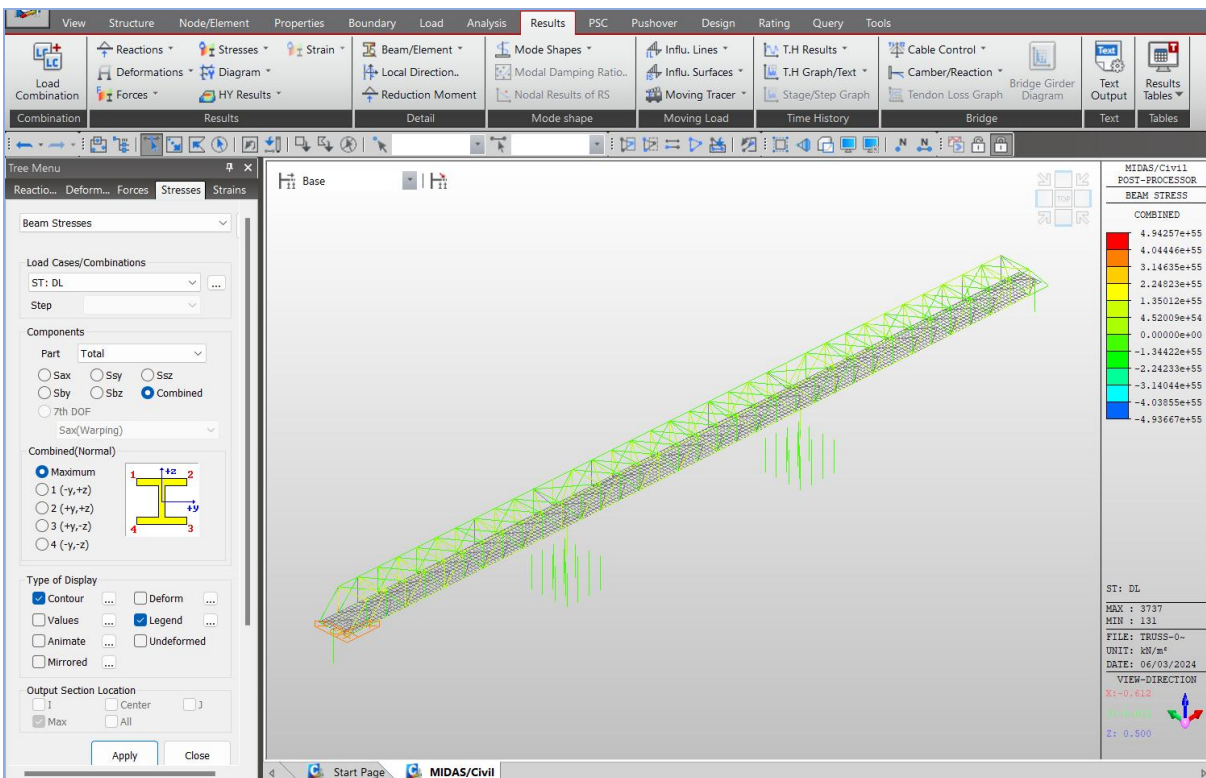


Figure No. 6.9.4 MIDAS – Resultant Diagram of Truss Bridge

6.2 STRUCTURAL ELEMENT SIZE

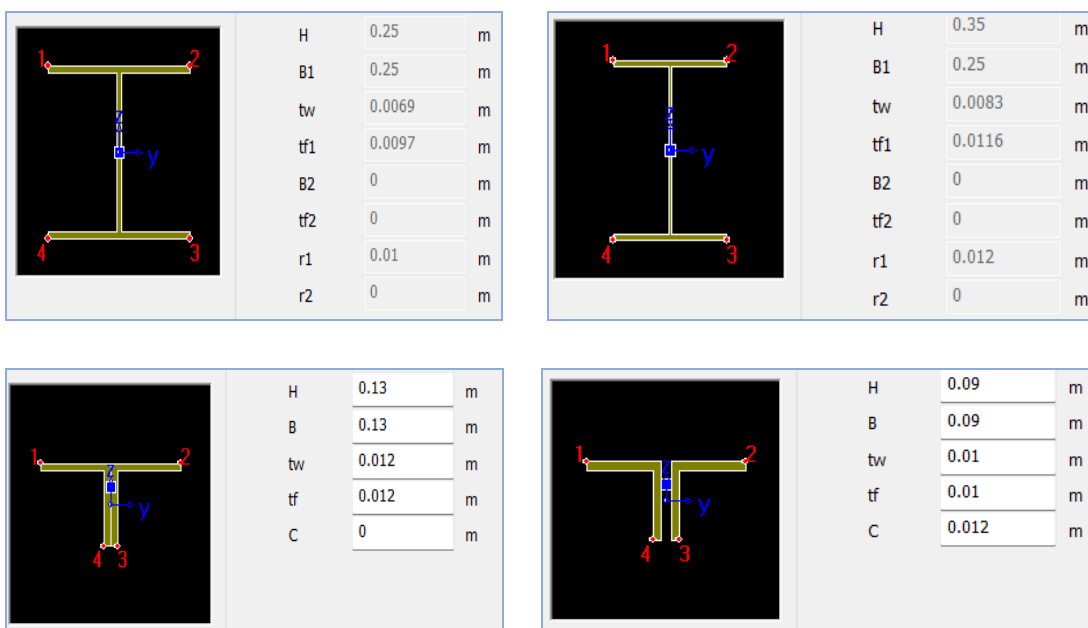


Figure No. 6.9.5 Structural Element Size

6.3 ELEMENT MATERIAL PROPERTY

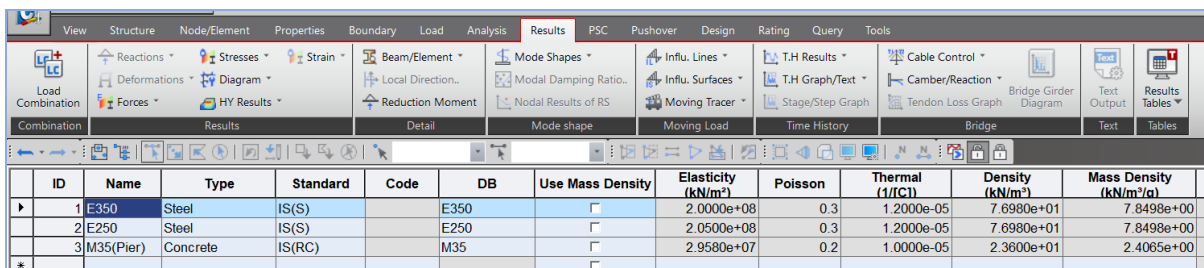


Figure No. 6.9.6 Material property Dialog box

6.4 ELEMENY SECTIONPROPERTY

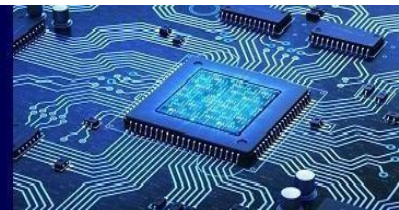
ID	Type	Shape	Name	Area (m ²)	Asy (m ²)	Asz (m ²)	Ixx (m ⁴)	Iyy (m ⁴)	Izz (m ⁴)	Cyp (m)	Cym (m)	Czp (m)	Czm (m)	Qyb (m ²)	Qzb (m ²)	Peri.(Out) (m)	Peri.(In) (m)
1	DB/User	I	End Raker	0.0065	0.0040	0.0017	0.0000	0.0001	0.0000	0.1250	0.1250	0.1250	0.1250	0.0489	0.0078	1.4862	0.0000
2	DB/User	I	Vertical	0.0065	0.0040	0.0017	0.0000	0.0001	0.0000	0.1250	0.1250	0.1250	0.1250	0.0489	0.0078	1.4862	0.0000
3	DB/User	I	Diagonal	0.0065	0.0040	0.0017	0.0000	0.0001	0.0000	0.1250	0.1250	0.1250	0.1250	0.0489	0.0078	1.4862	0.0000
4	DB/User	I	Top Cord	0.0086	0.0048	0.0029	0.0000	0.0002	0.0000	0.1250	0.1250	0.1750	0.1750	0.0725	0.0078	1.6834	0.0000
5	DB/User	I	Bottom Cord	0.0086	0.0048	0.0029	0.0000	0.0002	0.0000	0.1250	0.1250	0.1750	0.1750	0.0725	0.0078	1.6834	0.0000
6	DB/User	I	Stringers	0.0065	0.0040	0.0017	0.0000	0.0001	0.0000	0.1250	0.1250	0.1250	0.1250	0.0489	0.0078	1.4862	0.0000
7	DB/User	2L	Top Lateral Bracing	0.0060	0.0026	0.0026	0.0000	0.0000	0.0000	0.1300	0.1300	0.0369	0.0931	0.0043	0.0084	0.7800	0.0000
8	DB/User	2L	Bottom Lateral Bracing	0.0034	0.0015	0.0015	0.0000	0.0000	0.0000	0.0960	0.0960	0.0262	0.0638	0.0020	0.0040	0.7200	0.0000
9	DB/User	I	Floor Beam	0.0065	0.0040	0.0017	0.0000	0.0001	0.0000	0.1250	0.1250	0.1250	0.1250	0.0489	0.0078	1.4862	0.0000
10	DB/User	I	Strut	0.0065	0.0040	0.0017	0.0000	0.0001	0.0000	0.1250	0.1250	0.1250	0.1250	0.0489	0.0078	1.4862	0.0000
11	DB/User	SR	Pile	1.1310	1.0179	1.0179	0.2036	0.1018	0.1018	0.6000	0.6000	0.6000	0.6000	0.1200	0.1200	3.7699	0.0000
12	DB/User	SB	Pile Cap	156.2500	130.2083	130.20	3433.2	2034.5	2034.5	6.2500	6.2500	6.2500	6.2500	19.5313	19.5313	50.0000	0.0000
13	Tapered	SB	Abutment	5.0820	4.2350	4.2350	0.7796	0.2075	22.321	3.6300	3.6300	0.3500	0.3500	0.0612	6.5884	15.9200	0.0000
14	DB/User	SB	Cap	26.9598	22.4665	22.466	51.795	15.421	237.88	5.1450	5.1450	1.3100	1.3100	0.8580	13.2355	25.8200	0.0000
15	DB/User	STRK	Pier	9.7854	9.7069	8.2069	3.0518	0.7991	78.203	5.0000	5.0000	0.5000	0.5000	0.1208	11.9755	21.1416	0.0000

Figure No. 6.9.7 Section property Dialogue box

6.5 LOAD CASES

No	Name	Type	Description
1	DL	Dead Load (D)	
2	DS	Dead Load (D)	
3	SIDL Fixe	Dead Load of Compon	
4	SIDL Vari	Dead Load of Wearing	
5	TU+	Temperature (T)	
6	TU-	Temperature (T)	
7	BREAKIN	Braking Load (BRK)	
8	WDL-SUP	Wind Load on Structur	
9	WDT-SUP	Wind Load on Structur	
10	WDL-SU	Wind Load on Structur	
11	WDL-SUP	Wind Load on Structur	
12	WDT-SUP	Wind Load on Structur	
13	WDL-SU	Wind Load on Structur	
14	WDL-LL	Wind Load on Live Lo	
15	WDT-LL	Wind Load on Live Lo	

Figure No. 6.9.8 Load Combination



6.6 ULS-SLS Checks Equations

Material Properties

Grade of Steel used for girders	=	E350	
Ultimate tensile stress of steel	=	490.00 MPa	
Yield strength of steel used for girders	=	350.00 MPa	For Plate Sizes <20mm
	=	330.00 MPa	For Plate Sizes 20 to 40mm
	=	320.00 MPa	For Plate Sizes > 40mm
Concrete grade for deck slab	=	45	MPa

6.6.1 Deflections Span (Typical 3x66.6m) = 200 m

A Serviceability Limit State check involves evaluating various factors to ensure that the structure meets acceptable criteria for performance, appearance, and user comfort. Here are some common considerations for SLS checks in bridge design:

Deflection: Excessive deflection can lead to discomfort for users and affect the appearance of the structure. SLS checks typically involve evaluating deflection limits for different components of the bridge, such as the deck, beams, and girders, under various load conditions.

- **Vibration:** Excessive vibration can also impact user comfort and safety. SLS checks may involve assessing natural frequencies and damping ratios to ensure that vibrations caused by traffic, wind, or other loads remain within acceptable limits.
- **Cracking:** Cracks in concrete elements can affect the appearance and durability of the structure. SLS checks may involve evaluating crack widths and spacing to ensure that they remain within acceptable limits under service loads.
- **Fatigue:** Fatigue considerations are important for steel bridges, where cyclic loading can lead to fatigue failure over time. SLS checks may involve assessing fatigue life and ensuring that the structure can withstand repeated loading cycles without experiencing excessive deterioration.
- **Comfort:** SLS checks may also consider factors such as ride comfort for vehicles, pedestrian comfort, and aesthetics to ensure that the bridge meets the needs and expectations of its users.

SLS checks are typically performed alongside ULS checks during the design process to ensure that the structure meets both safety and performance requirements. Design codes and standards provide guidance on acceptable criteria for serviceability limits, and engineers use analytical methods, numerical simulations, and empirical data to assess and verify the performance of the structure under service loads.

Table No. 6.1 Deflection check



Deck width	Load Case	DZ (mm)	Limit	UR	Check
7.5m	Live Load	-55.0	125.00	0.44	OK
	Dead Load	-57.0	166.67	0.34	OK

6.6.2 Stress Levels SLS

6.6.2.1 Bottom Chord Members

The forces for normal load case(DL+SIDL+LL+LF+BF), Wind load case & Seismic load case are extracted from MIDAS Civil analysis result and summarised for each member in table. Load combinations are made using these load cases. Members are grouped together and each group has same member properties. Permissible stress is found out using Table IV & Table II of IRS steel bridge code. Each member is checked against its permissible stress . Later connection design is carried out for each joint locations.

Permissible increase in Stress for Normal case = No increase

Permissible increase in Stress for Wind/Seismic stresses = 16.67%

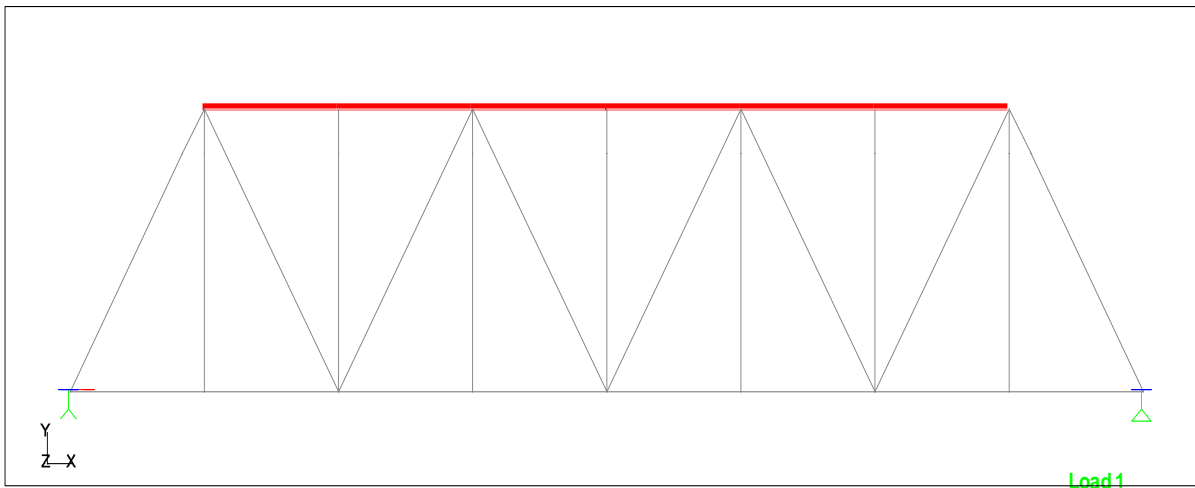
Table No. 6.2 Stress Level check at Bottom Chord Member

Bottom Chord	Developed Stress (MPa)		Allowable Stress (MPa)		UR		Check	
	Max	Min	Max	Min	Max	Min	Max	Min
L0-L1	-110.038	-95.585	241	206.5	-0.45659	-0.46288	ok	ok
L1-L2	-118.405	-92.5819	241	206.5	-0.49131	-0.44834	ok	ok
L2-L3	-177.26	-144.599	241	206.5	-0.73552	-0.70024	ok	ok
L3-L4	-177.956	-141.997	241	206.5	-0.73841	-0.68764	ok	ok
L5-L6	-195.572	-168.625	241	206.5	-0.74234	-0.88764	ok	ok

6.6.2.2 Top Chord



Top chord designed for the following loads Member forces in the Top chord due to Normal load condition and overturning effect are extracted from Midas model (Ref Midas model-Truss-66.6m) and these forces are shown in the below Table.



Horizontal bending of Top laterals

Additional axial forces are considered in the top chord due to horizontal bending of Top lateral system due to wind/Seismic forces. These forces are extracted from separate Midas model and same are also shown in the below table. For wind load & Seismic calculation.

Table No. 6.3 Stress Level check at Top Chord

Top Chord	Developed Stress (MPa)		Allowable Stress (MPa)		UR		Check	
	Max	Min	Max	Min	Max	Min	Max	Min
U1-U2	128.2	117.400	206.5	196.1	0.620823	0.598674	ok	ok
U2-U3	128.2	117.400	206.5	196.1	0.620823	0.598674	ok	ok
U3-U4	113.2	102.700	206.5	196.1	0.548184	0.523712	ok	ok
U5-U6	102.2	102.700	206.5	196.1	0.548184	0.523712	ok	ok



6.6.2.3 Vertical Cross Beams

Member forces are extracted for Normal load combination and overturning effect due wind/Seismic from Midas model (Ref Midas model- Truss-66.6m) and these forces are shown in below table

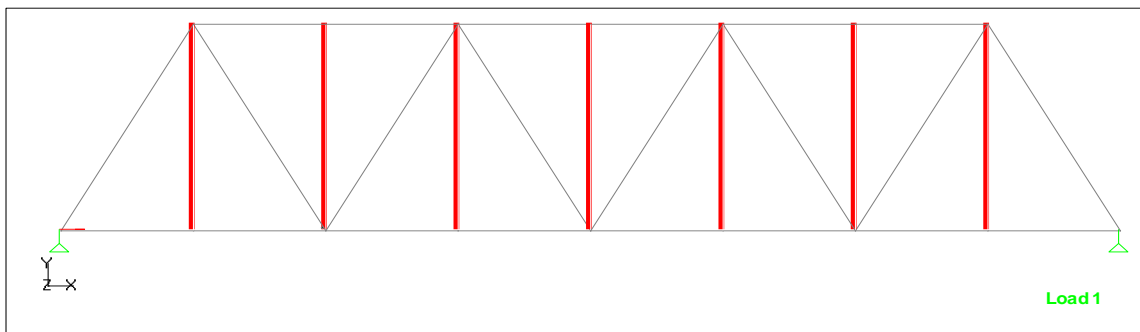


Table No. 6.4 Stress Level check at Vertical Cross Beams

Vertical	Developed Stress (MPa)		Allowable Stress (MPa)		UR		Check	
	Max	Min	Max	Min	Max	Min	Max	Min
L1-U1	-54.1511	54.151	172.1	147.5	-0.31465	-0.36713	ok	ok
L2-U2	64.430	2.842	182	64.43	0.354011	0.04411	ok	ok

6.6.2.4 Diagonal Cross Beams

Member forces in the Diagonal members due to Normal load combination and overturning effect due wind load/Seismic are extracted from Midas and the same are shown in the below Table.

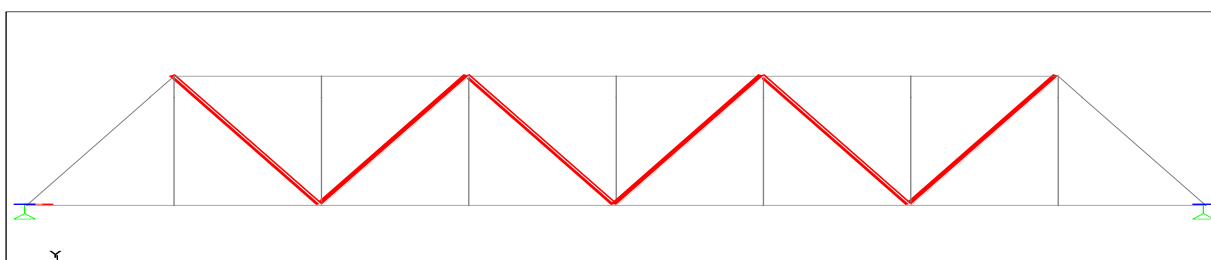


Table No. 6.5 Stress Level check at Diagonal Cross Beams



Diagonal	Developed Stress (MPa)		Allowable Stress (MPa)		UR		Check	
	Max	Min	Max	Min	Max	Min	Max	Min
U1-L2	-89.7861	-85.207	165.3	141.6	-0.54317	-0.60174	ok	ok
L2-U3	112.369	94.92728	147.5	121.1	0.761823	0.783875	ok	ok
U3-L4	-38.7222	-37.7136	165.3	141.6	-0.23425	-0.26634	ok	ok

6.6.2.4 ULS Capacities

Ultimate Limit State (ULS) capacities are crucial parameters in structural engineering and are determined through rigorous analysis and testing to ensure the safety and reliability of a bridge under extreme loading conditions. These capacities are typically expressed in terms of various factors, including:

- **Ultimate Strength:** The maximum load-carrying capacity of a structural element before failure occurs. This could be in terms of compression, tension, shear, or bending, depending on the type of load and the specific structural component.
- **Material Properties:** The properties of the materials used in the construction of the bridge, such as the yield strength of steel or the compressive strength of concrete. These properties influence the ULS capacities of individual components and the overall bridge structure.
- **Geometric Considerations:** The size, shape, and configuration of structural elements play a significant role in determining their ULS capacities. For example, larger cross-sectional areas generally result in higher load-carrying capacities.
- **Load Combinations:** ULS capacities are typically evaluated based on the most critical load combinations, considering factors such as dead loads, live loads, wind loads, seismic loads, and temperature effects. These combinations are determined according to relevant design codes and standards.
- **Safety Factors:** Design codes and standards typically incorporate safety factors to account for uncertainties in material properties, construction tolerances, and load assumptions. These safety factors ensure that the structure remains safe and reliable under uncertain conditions.

Table No. 6.6 Design ULS check

Member	UR	Check
Bottom Chord Beam	0.86	OK



Top Chord Beam	0.82	OK
Vertical Cross Beam	0.81	OK
Diagonal Cross Beam	0.80	OK

6.7 SUBSTRUCTURE AND FOUNDATION

The substructure and foundation of a building are critical components that support the entire structure, ensuring its stability and longevity. The substructure generally refers to all parts of the building below the ground level, including the foundation, which directly transfers the load of the building to the ground. Foundations can be shallow, such as spread footings and mat foundations, or deep, like pile foundations and drilled shafts, depending on soil conditions and load requirements. Proper design and construction of the substructure are essential to prevent settlement, provide adequate support, and ensure the structural integrity of the building. Factors such as soil type, load distribution, water table levels, and environmental conditions must be thoroughly evaluated to determine the most suitable foundation system. Effective substructure and foundation work not only guarantee safety but also contribute to the building's overall performance and durability.

6.7.1 LOADS CONSIDERED

1. Bearing type is Elastomeric for initial assessment with bearing stiffness of 4550kN/m
2. SIDL, WL ,LL are considered as per employee requirement
3. Type 2 soil with FB models
4. 0.75I considered for pier and piles in the model.
5. Seismic zone III and wind speed of 44 m/s
6. Concrete grade-M60 grade for pile. For design 80% of concrete strength is used as per ER.
7. Fe550 grade of steel for pile
8. HFL=3.3mRL
Pile cap top level= 4.7mRL
9. Midas model with -Depth of fixity of 14m
10. All the results provided below are for EJ pier
11. Congestion factor of 1.7 is considered.

Table No. 6.7 Substructure detailing



Pier ID	Pier + Peircap height (m)	Pier type	No of bearings
P1	10	Rectangular	4
P2	10	Rectangular	4

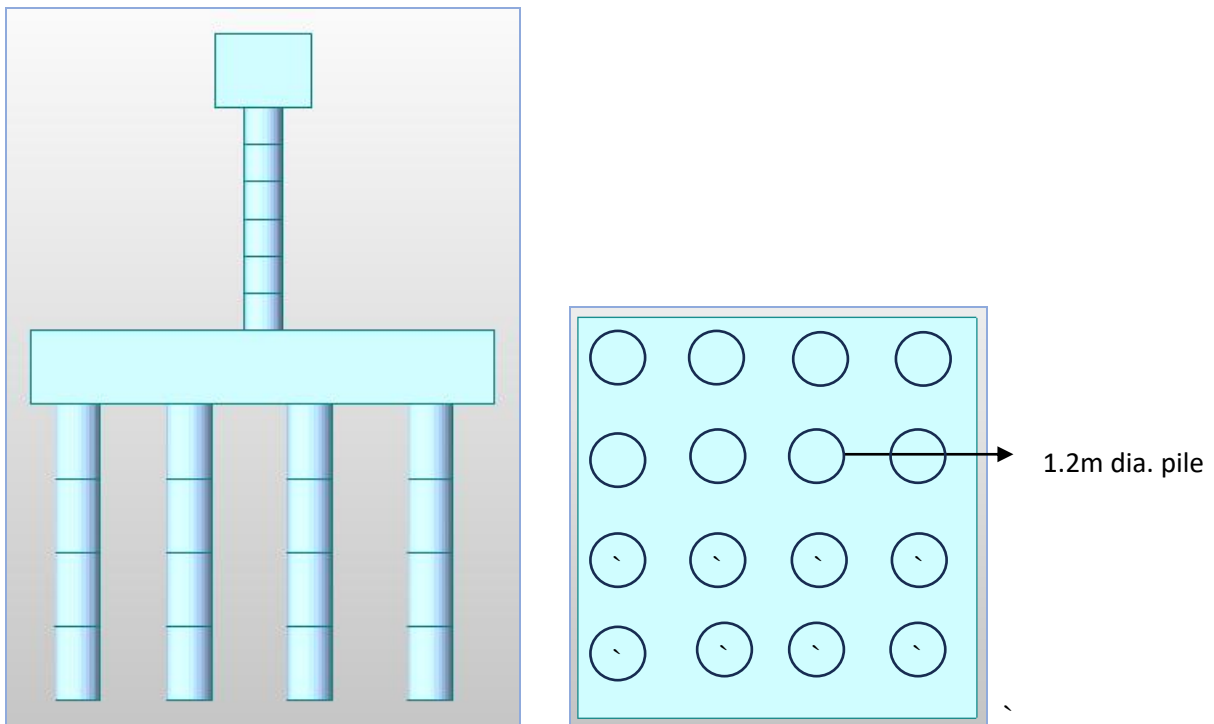


Figure No. 6.9.10 Substructure detailing

Table No. 6.8 Maximum Moment on Substructure

	Trans Shear (kn)	Long Shear (kn)	Axial (kn)	Long MT (knm)	MTTran MT(KNm)	Torsion (KNm)
SEISMIC Max longitudinal moment	3525	898	26993	7744	-19155	818
ULS Basic Max transverse moment	2823	1460	28107	18804	-29602	845

Table No. 6.9 Design ULS check



P(kN)	MY (kNm)	MZ(kNm)	M/MU	
-5724	1522	4919	0.75	seismic
-6916	2020	4093	0.66	basic

Table No. 6.9.1 Pile cap SLS check

SLS	P (kN)	MY (kNm)	MZ (kNm)	conc stress (Mpa)	UR
Forces from Pile cap bottom	-5859	2151	2755	19.03	0.88

Table No. 6.9.2 Substructure quality take-off

ELEMENT	Concrete (m3)	Steel (MT)
PIER	134	58
TIE BEAM	632	63
PILE	4	1
PILE CAP	8	4
Sum	1697	288

The design considerations for a steel truss bridge with a 200m span.

- Pier Size: Each pier has dimensions of 2 meters by 2.5 meters.
- Pile Arrangement: The bridge is supported by 6 piles with a diameter of 1.2 m each.
- The decision to use 6 piles instead of 4 is likely based on structural analysis, specifically concerning the wind load. Wind can exert significant lateral forces on a bridge, creating transverse moments that must be resisted by the piers and piles. With only 4 piles, the transverse moment induced by the wind load might exceed the structural capacity of the bridge, making it unfeasible.
- By increasing the number of piles to 16, the load can be more evenly distributed, reducing the transverse moment on each pile and ensuring the bridge's stability and safety under wind loading conditions. This configuration likely provides a more robust and stable bridge structure for the given span and pier size.



7. CONCLUSION

The design and analysis of steel bridges to withstand extreme weather conditions are critical to ensuring their safety, durability, and functionality. The use of advanced software like MIDAS Civil facilitates this process by providing precise and comprehensive analysis capabilities. Here are the key conclusions drawn from the study:

1. Enhanced Structural Integrity:

- The use of MIDAS Civil allowed for an in-depth analysis of the structural integrity of the steel bridge under various extreme weather conditions, such as heavy snow loads, high winds, and extreme temperatures.
- The software's ability to simulate different scenarios and loads helped identify potential weak points in the design, allowing for modifications and reinforcements that ensure the bridge can withstand these conditions.

2. Optimized Material Usage:

- Through the analysis, it was possible to optimize the use of steel, ensuring that the right grades and quantities were used in different parts of the bridge to enhance performance without unnecessary expenditure.
- MIDAS Civil's material library and design tools facilitated the selection of appropriate steel grades that offer better resistance to corrosion and fatigue, which are critical in extreme weather.

3. Efficient Load Distribution:

- The study demonstrated that the software could accurately predict how loads would be distributed across the bridge structure under various extreme weather conditions.
- This capability ensured that the bridge design accounted for uneven loading patterns, which can occur due to heavy winds or asymmetric ice accumulation, thereby preventing structural failure.

4. Safety and Compliance:

- MIDAS Civil enabled the design to meet stringent safety standards and regulatory requirements.



- By simulating extreme weather conditions and performing dynamic analysis, the software ensured that the bridge design adhered to national and international codes, providing confidence in its safety and compliance.

5. **Economic Efficiency:**

- The precision in design and analysis provided by MIDAS Civil led to cost savings by avoiding over-design and ensuring that resources were allocated efficiently.
- The ability to foresee and mitigate potential issues before construction began saved on potential future repair and maintenance costs.

6. **Innovative Design Solutions:**

- The advanced capabilities of MIDAS Civil allowed for the exploration of innovative design solutions, such as the use of windbreaks, aerodynamic shapes, and ice-phobic coatings, which further enhanced the bridge's resilience to extreme weather.
- The software facilitated the incorporation of these features into the design seamlessly, ensuring their effectiveness and integration into the overall structural system.

7. **Long-Term Durability:**

- The analysis confirmed that the design modifications made to address extreme weather conditions significantly increased the bridge's long-term durability.
- Factors such as fatigue life under cyclic loading due to temperature variations and resistance to corrosion in humid or saline environments were effectively addressed.

Recommendations for Future Work

1. **Continuous Monitoring:**

- Implement continuous monitoring systems on the bridge to gather real-time data on its performance under extreme weather conditions. This data can be used to refine future designs and validate the accuracy of simulations.

2. **Regular Maintenance:**

- Develop a comprehensive maintenance plan that includes regular inspections and timely repairs, especially in components that are more susceptible to weather-related wear and tear.

3. **Advanced Materials Research:**



- Invest in research on advanced materials that offer better performance in extreme weather conditions, such as high-strength low-alloy (HSLA) steels or composite materials.

4. Climate Change Adaptation:

- Consider the potential impacts of climate change in future designs, ensuring that bridges remain safe and functional under changing weather patterns and more frequent extreme weather events.

By leveraging the capabilities of MIDAS Civil, the design and analysis of steel bridges can be significantly enhanced to ensure they withstand the challenges posed by extreme weather conditions, ultimately leading to safer and more durable infrastructure.

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