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Integrated Investigation and FEM Analysis of Long Span Steel Bridges for Incremental Launching Method

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Abstract: This study conducts an integrated investigation and FEM analysis of long span steel bridges employing the incremental launching method (ILM). Long span steel bridges are crucial for modern transportation, and ILM offers notable advantages in terms of construction efficiency and cost-effectiveness. The research analyses various bridge components and construction techniques to identify key design considerations and challenges. Structural stability and durability aspects are also assessed to ensure sustained bridge performance. FEM analysis, utilizing advanced numerical modelling, simulates the incremental launching process. The models incorporate bridge geometry, material properties, construction sequence, and external loads for accurate prediction of structural response. This analysis evaluates critical parameters, highlighting potential construction issues. Results offer insights into incremental launching's impact on long span steel bridge behaviour and performance, optimizing design and construction for improved safety and efficiency. This study enriches knowledge about long span steel bridges, supporting reliable and cost-effective construction methods for such structures.

Keywords: FEM analysis of long span steel bridge, Incremental launching method, Launching behaviour & structural performance, Steel bridge design considerations.

1 Introduction

Long-span steel bridges play a vital role in modern transportation infrastructure, providing efficient and reliable connectivity across vast distances. The incremental launching method involves the gradual advancement of the bridge structure from one end of the span to the other. This technique offers several advantages, including improved construction speed, reduced environmental impact, and enhanced safety during construction. However, the successful implementation of the incremental launching method necessitates a comprehensive understanding of the structural behaviour and performance of the bridge throughout the construction process. In this context, an integrated investigation and finite element method (FEM) analysis can provide valuable insights into the various aspects of long-span steel bridges constructed using the incremental launching method. This investigation involves a detailed examination of the components and factors influencing the construction process, including temporary supports, launching noses, launching equipment, and construction sequences. By studying these elements, it is Possible to identify critical challenges and limitations associated with the incremental launching method for long span steel bridges.

Complementing the investigation, FEM analysis enables a thorough assessment of the structural performance of long-span steel bridges during incremental launching. The FEM model incorporates accurate geometrical details, material properties, and construction sequences to simulate the behaviour of the bridge accurately. By analysing factors such as temporary support forces, stress distribution, and deformation characteristics, the FEM analysis provides quantitative data to evaluate the structural integrity and performance of the bridge. The findings from this investigation and FEM analysis contribute to advancing the understanding of the incremental launching method for long-span steel bridges. The insights gained from this research can inform the development of improved construction strategies and guide the design considerations for future projects. Bridge engineers and researchers can utilize this knowledge to optimize the construction process, enhance structural safety, and minimize potential risks associated with long-span steel bridges. This paper presents the results of an integrated investigation and FEM analysis of long-span steel bridges constructed using the incremental launching method. The subsequent sections detail the methodology employed, the analysis conducted, and the key findings obtained. The study aims to provide valuable insights and practical guidance for professionals involved in the design and construction of large-scale steel bridges, further advancing the state of the art in bridge construction techniques.

2. **Aim and Objectives:**

The Incremental Launching Method (ILM) for bridge constructions may offer advantages over conventional construction practice, including creating minimal disturbance to surroundings, providing a more concentrated work area for superstructure assembly and possibly increased worker safety given the improved erection environment. It is proposed to carry out analysis of structural behaviour of Long Span Steel Bridge by Incremental Launching Method by using STAAD pro Software. Furthermore, it is imperative to devise an economic ratio that encapsulates the relationship between the weight of the steel span and the launching nose span.

2.1. Objectives:

Following are the objectives for proposed research work –

- To analyse Long Span Steel Bridge for IRC loading by using software.
- To investigate the Structural behavior of Long Span Steel bridge by using FEM.
- To assess the cost-effectiveness of Launching Nose by studying various span of Launching Nose.
- To compute the economical ratio of Launching Span Weight with Launching Nose Span.
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2.1. Methodology:

In this Project Simply supported steel superstructure for rail cum Road Bridge is considered. The span arrangement of superstructure shall be 82.46m (c/c distance between bearings). In this particular arrangement, Top level of the truss type bridge span is accommodating deck slab for vehicular movements known as Road Bridge and Bottom level will accommodate two tracks for railway movements, known as Rail Bridge. Hence the main span will accommodate both Road and Rail, known as Rail cum Road Bridge.

The steel superstructure has been designed using “Indian Railway Standard Code of Practice for the Design of Steel or Wrought Iron Bridges carrying Rail, Road or Pedestrian Traffic”, (IRS Steel Bridge Code) which allows for “Working Load Method of Design” only. The Design has been carried out based on relevant clauses of Indian Railway Bridge Rules wherever necessary.

2.2. General arrangement of span and Loading Details:

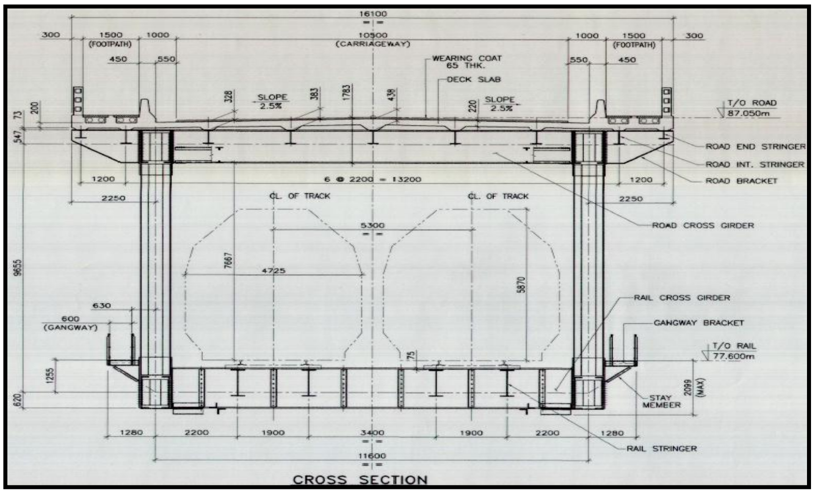

Figure 1. c/s of Main Span in Transverse Direction

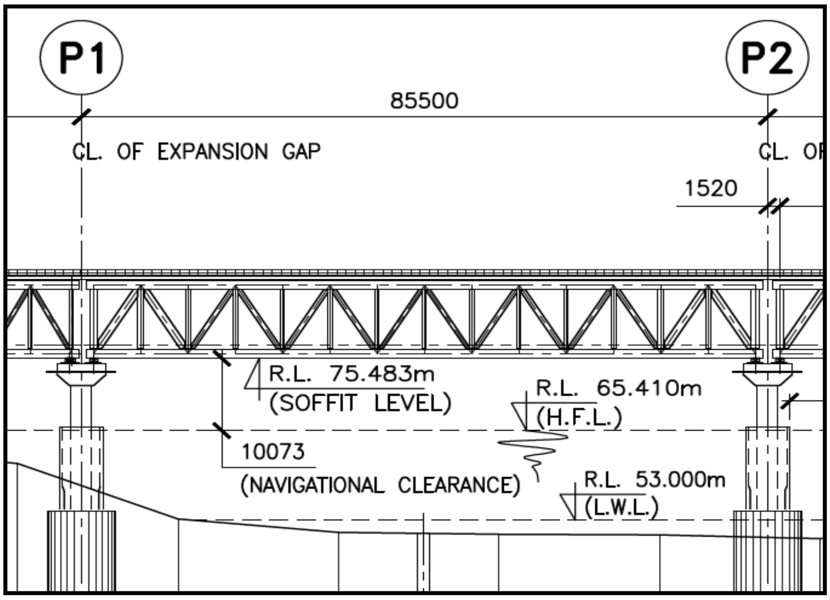

Figure 2. Side Elevation of Main Span in Longitudinal Direction

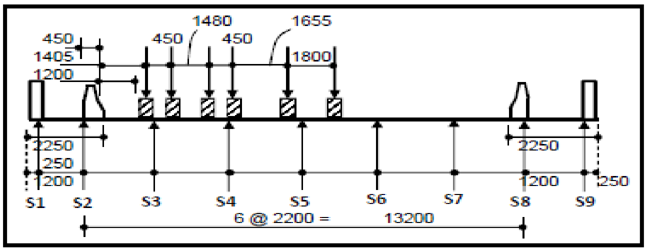

Figure 3. 1 Lane 70R wheel: "L-Type" + 1 lane class – A (Load left eccentric)

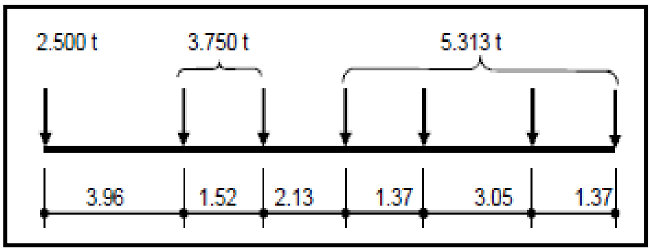

Figure 4. 1 Lane 70R wheel: "L-Type"

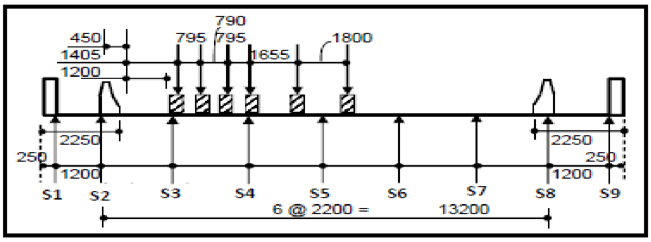

Figure 5. 1 Lane 70R wheel: "M-Type" + 1 lane class – A (Load left eccentric)

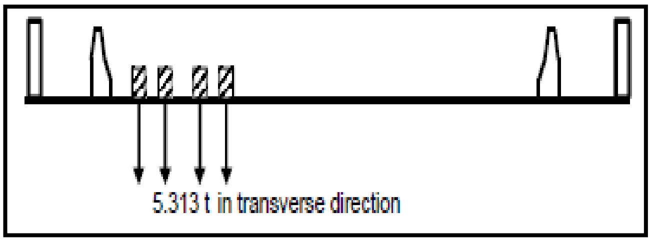

Figure 6. 1 Lane 70R wheel: "M-Type"

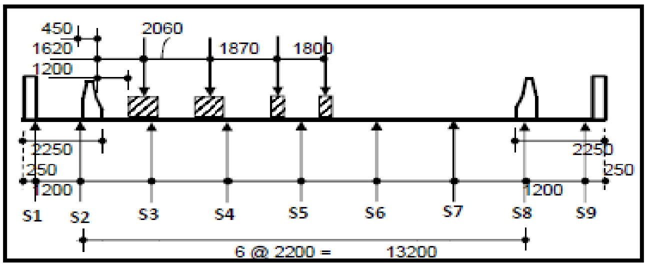

Figure 7. 1 Lane 70R Tracked + 1 lane class – A (Load left eccentric)

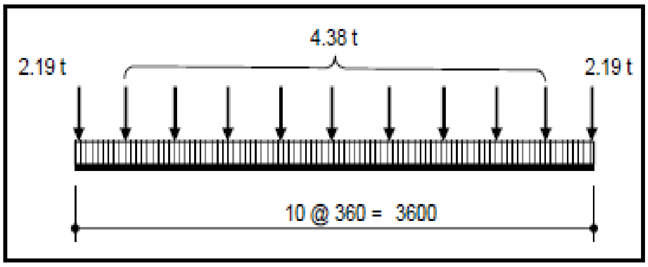

Figure 8. 1 70R Tracked Loading

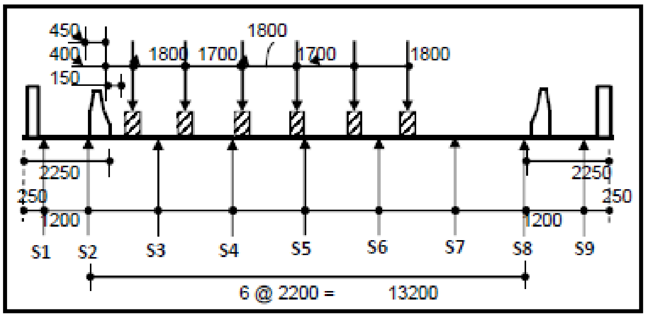

Figure 9. 3 Lane Class-A: Load left eccentric

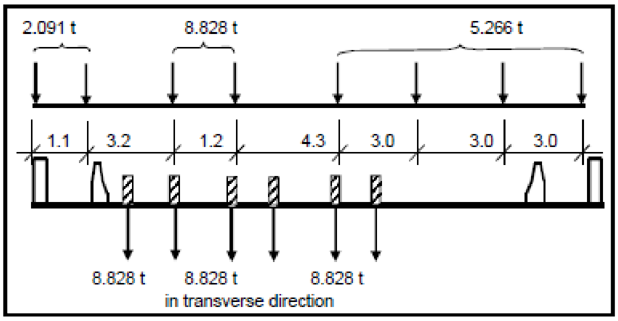

Figure 10. 1 Lane Class-A

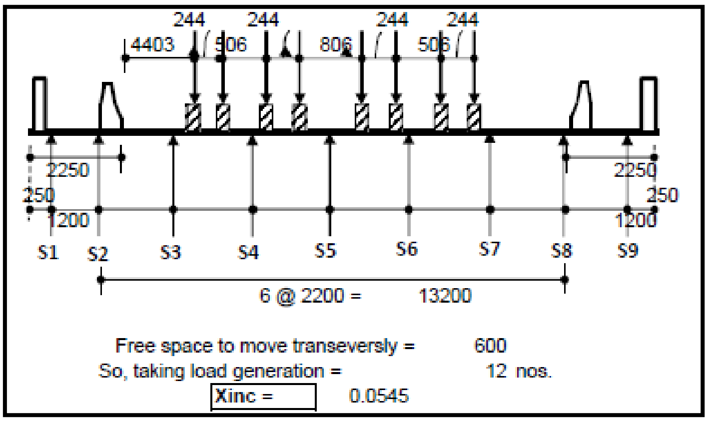

Figure 11. Special Vehicle: Load left eccentric

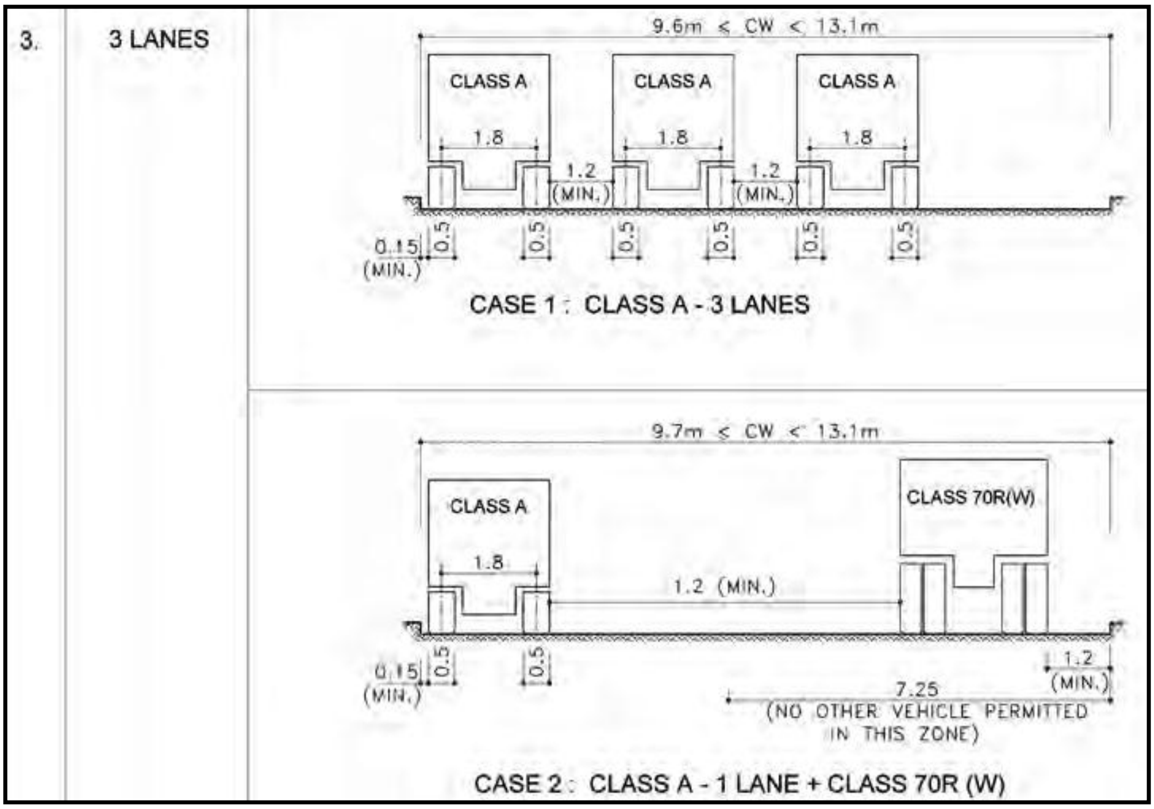

Figure 22. Class A: 3 Lane Loading & Class A – 1 Lane + Class 70R (W)

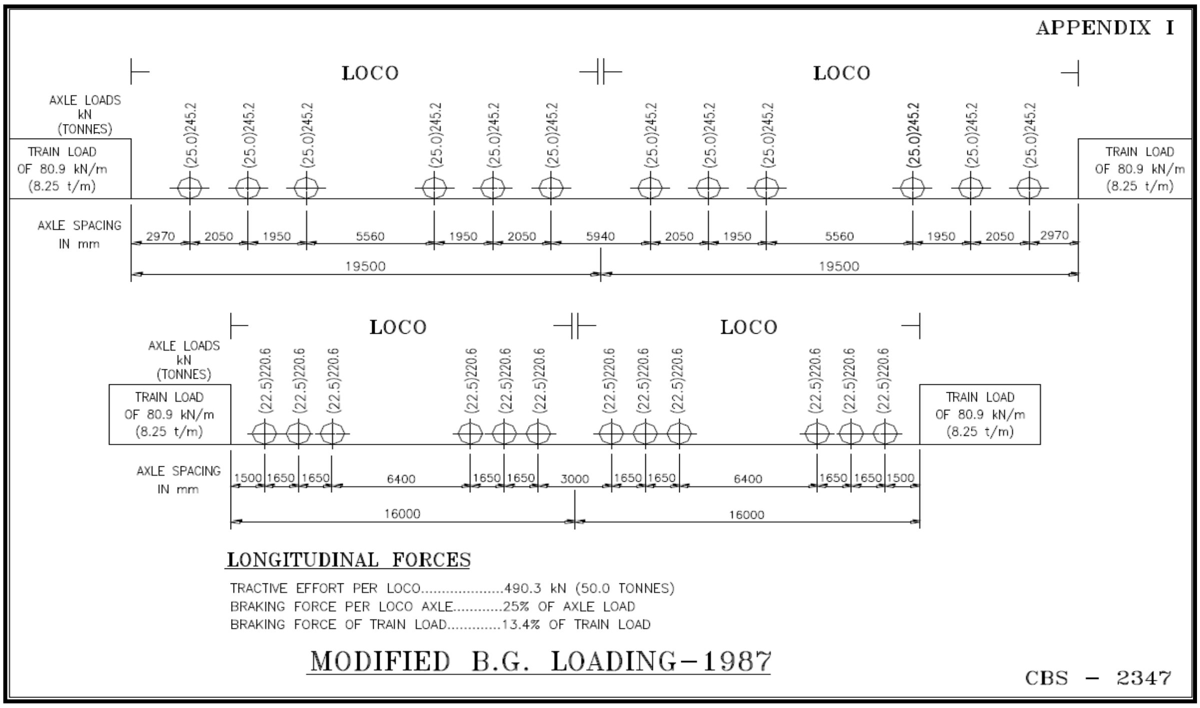

Figure 33. IRS Loading

2.3. STAAD Modelling of Main Span:

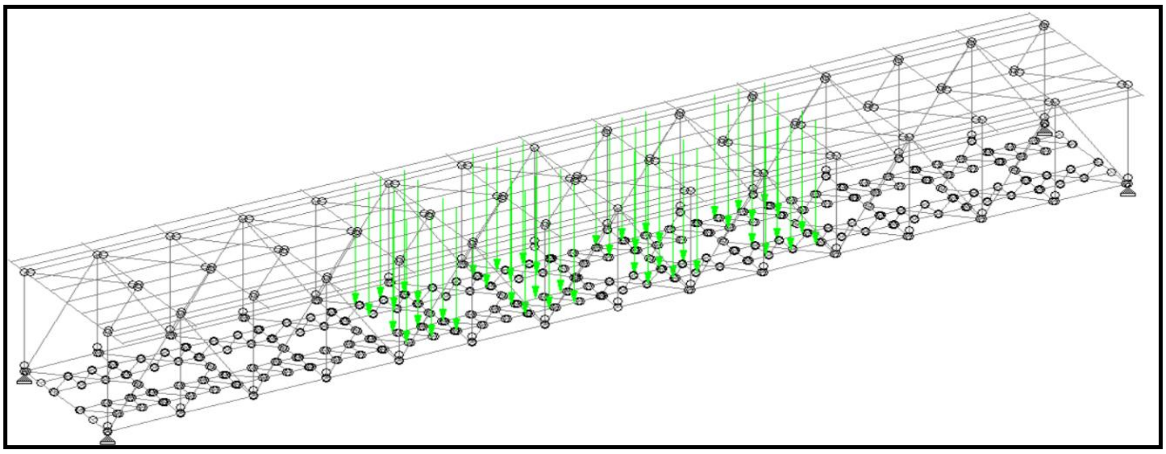

Figure 44. IRS Loading at Rail Level @ Bottom Chord Location

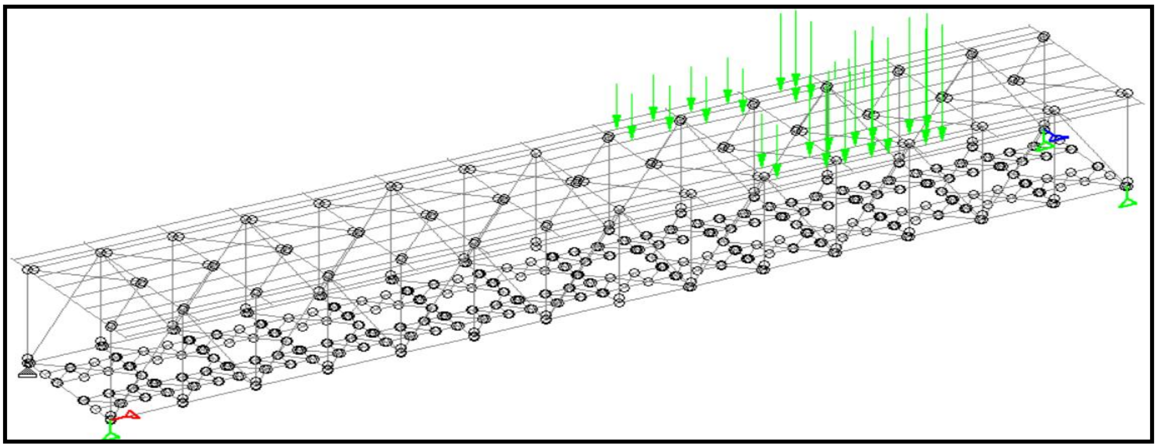

Figure 55. IRC Loading at Road Level @ Top Chord Location

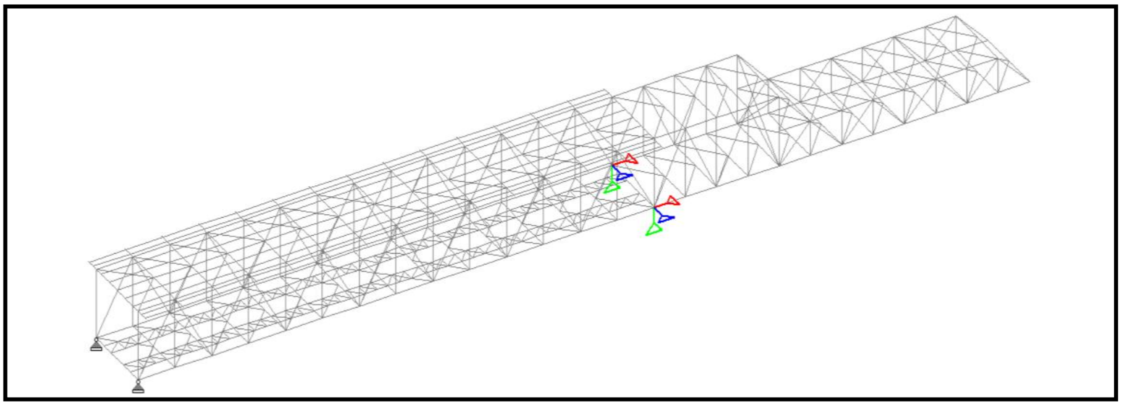

Figure 66. Main Span with Launching Nose (60m Cantilever)

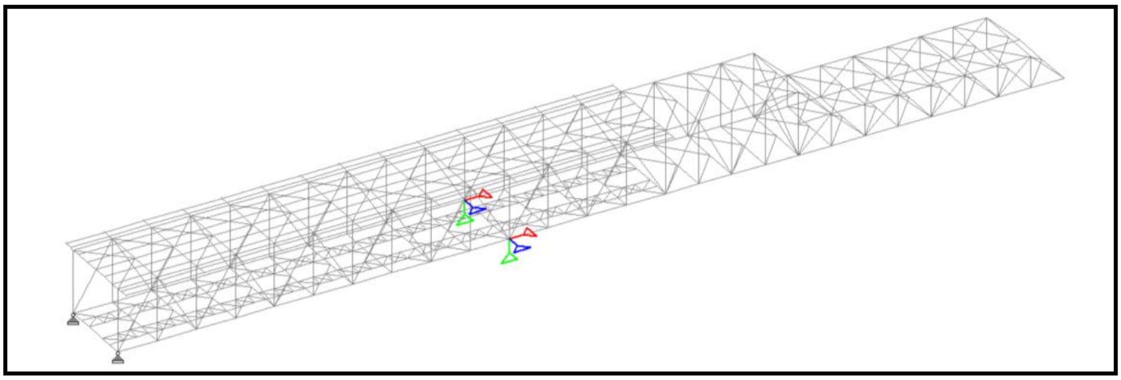

Figure 77. Main Span with Launching Nose (Max. Cantilever Condition)

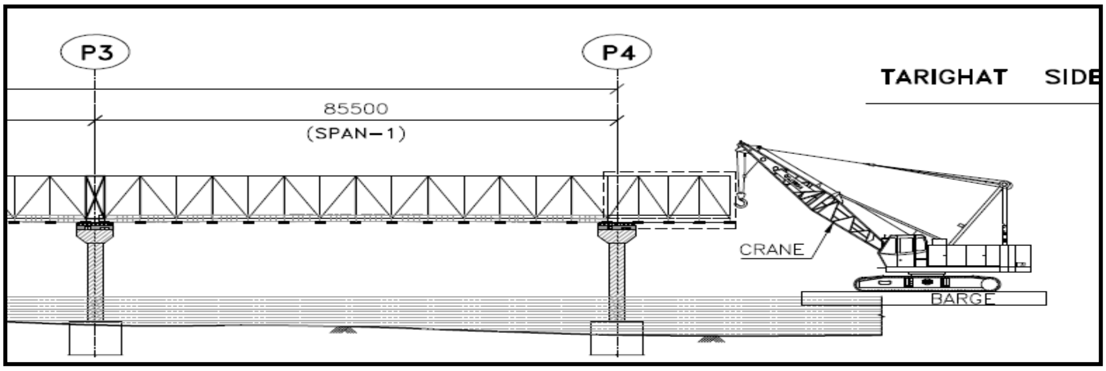

Figure 88. Launching Nose with Main Span @ Final Position

2.4. STAAD Analysis Results of Main Span:

Ref. STAAD Files - Main Span Moving Load-Road Level Only

Road Level Beams for Max. BM			
Max. BM (T-m)	**SF (T)**	**Load Case**	**Beam No.**
17.889	15.38	300	812
17.889	12.39	300	816
15.839	14.74	324	820
15.839	11.28	324	824
15.76	13.52	347	828

15.76	12.16	347	832
15.724	14.49	371	836
15.724	11.44	371	840
15.712	13.28	394	844
15.712	12.32	394	848
15.891	14.25	418	852
15.891	11.64	418	856
17.189	15.48	442	860
17.189	12	442	862
17.889	**15.38**	**300**	**812**

Table 9

Road Level Beams for Max. SF			
Max. SF(T)	**BM (T-m)**	**Load Case**	**Beam No.**
19.486	15.72	302	812
18.167	12.42	314	816
18.906	12.7	326	820
18.173	10.66	329	824
17.783	13.98	349	828
17.948	12.47	361	832
18.671	12.87	373	836
18.831	11.3	385	840
17.633	9.72	388	844
17.734	12.91	408	848
18.458	13.33	420	852
18.653	12.04	432	856
17.976	9.87	435	860
18.61	12.2	447	862
19.486	**15.72**	**302**	**812**

Table 2

Ref. STAAD Files - Main Span Moving Load-Rail Level Only

Rail Level Beams				
Beam No.	**Critical Beam**	**Load Case**	**Max. BM (T-m)**	**SF (T)**
115-117	116	517	81.668	13.7
118-120	119	81	53.687	13
121-123	122	557	59.275	15.35
124-126	125	568	59.051	14.69
127-129	128	561	59.809	12.93
130-132	131	592	60.152	13.22
133-135	134	604	59.124	14.63
136-138	137	557	59.315	14.89
139-141	140	569	59.884	13.48

142-144	143	600	59.582	12.67
145-147	146	593	59.33	14.43
148-150	149	604	58.972	15.61
151-153	152	635	58.94	14.37
154-156	155	667	59.916	12.86

Table 3

Rail Level Beams				
Beam No.	**Critical Beam**	**Load Case**	**Max. SF (T)**	**BM (T-m)**
115-117	115	493	54.358	76.59
118-120	118	40	44.126	40.627
121-123	123	539	47.015	42.25
124-126	125	551	48.477	51.04
127-129	129	582	49.663	42.82
130-132	130	107	48.855	48.905
133-135	133	99	47.829	51.4
136-138	138	134	47.575	51.833
139-141	141	146	48.967	49.62
142-144	144	582	43.97	52.38
145-147	145	610	48.735	41.97
148-150	148	622	47.313	42.26
151-153	153	193	47.839	49.922
154-156	156	649	49.056	47.89

Table 4

3. Results and Discussion:

The results of this integrated Investigation and FEM Analysis of Long Span Steel Bridges for Incremental Launching Method is presented here,

Case 1 entails the design and analysis of a significant steel bridge intended to serve as a rail-cum-road bridge. Notably, the Main Span incorporates a launching nose specifically designed for incremental launching.

And

Case 2 involves the design of the launching nose for the main span of a lightweight, long-span bridge, with the intention of launching it incrementally.

This study helps to understand the launching nose behaviour for both the cases viz. light weight and heavy weighted bridge.

3.1. Discussion:

The above extensive analysis and design of heavy long bridge which is intended to serve as Rail-cum-Road bridge.

Conclusion

The study in this research paper helps to understand the reversal stress effect of Main span for its serving period and its launching period. As in serving period the Compression Member undergoes in tensile stresses due to its incremental launching phenomenon. Hence we can conclude that incremental launching method is extensively useful in steel structures as steel structure possess same structural properties throughout its upper most fiber till its lower most fiber.

Studying Case–1 as previously indicated, in the case of substantial bridges such as a combined Rail and Road Bridge, a Finite Element Method (FEM) analysis of the primary span is essential to assess its performance under both operational conditions and the pivotal launching scenario. The conclusive effective weight to span ratio is (1400/82.46 =

16.98 M.T./m.) And effective safe launching nose for its critical cantilever condition along with main span. The conclusive effective weight to span ratio is (235/60 = 3.92 M.T./m.) While studying Case–2 as mentioned above; light weight bridge only Rail accessibility which is having long span, the conclusive effective weight to span ratio is (350/85) = 4.12 M.T./m.)

And the analysis of launching nose for its critical cantilever condition along with main span. The conclusive effective weight to span ratio is (100/55 = 1.82 M.T./m.) The integrated investigation and FEM analysis of Long span steel bridge for incremental launching method helps to conclude that economical span of launching nose is depend on the total weight and span length of main span. While heavy bridges such as rail cum road bridge as mentioned in Case –1, the span of launching nose will be approximately 3/4th span of Main Bridge Span, due to its safe launching span. And in light weight, long span bridge as mentioned in Case –2, the span of launching nose will be approximately 2/3rd span of Main Bridge Span.

Outcome of this research paper is have preliminary as well as detailed knowledge of long span steel bridges with respect to its incremental launching method. Hence this study will help to decide the selection of construction method for erection and launching of long span bridges. This will help to decide the appropriate budget of the project to both the agencies viz. authority department and contractor.

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