Analysis of Piers and Foundation of the newly built Nagampadam Rail Over Bridge

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Abstract - *Modern-day construction loves the long span bridge construction. This report deals with the design and analysis of a newly built railway overbridge in Nagampadam, Kottayam, Kerala, India. The bridge is a part of the main central road that runs through Kottayam district. The rail overpass is designed to allow road traffic to pass over the railway line. The main purpose of rail overpass is to reduce the travel time of road traffic. Frequent closing of the level crossings can cause heavy traffic congestion, and therefore impacts the traffic on the main central road. The main purpose of this project is to validate and recommend details for the design of durable and buildable details to achieve the structural continuity of this bridge. Mainly the bridge piers and the foundation is analysed in this project. The softwares used in this project are STAAD.Pro, BEAVA and STAAD foundation.*

***Key Words*: Bridge piers, foundation, STAAD.Pro. BEAVA, STAAD foundation, underlying pavements.**

1. INTRODUCTION

When people feel the need for a bridge, they communicate it to government through public representatives or by prominence. As traffic increases demand for bridge due to various reasons like main road, tourist site, pilgrimage center and industry increases, thus the government decides to build a bridge at a particular location. Bridge is any structure that overcomes water, traffic or other objects, this barrier allows for a smooth and safe passage of vehicles. The term "bridge" in highway transportation systems is generally reserved for aquatic structures. However, many other structures are considered in general highway bridges. Overhead is a bearing structure similar to the highway above a railway; an underpass is a structure similar to a national highway passing under a railway. . Highway bridges can be made of steel, concrete, wood, stone, metal alloys or innovative composite materials and may have different structural systems such as girder (beam), truss, arch, cable stay, suspension. The Road Project division is required to carry out surveys for the location of the bridge and collect the necessary preliminary survey data for bridge planning and design. Usually it takes 2-3 cross sections of oncoming sites and determines the length of the bridge. The purpose of the preparation of the Stage-1 estimate required is to obtain administrative approval. The functions of the designed bridge structure totally depend upon the geography of the site, the topography, nature of terrain, materials and resources used for construction and the funds facilitated to it. Design of a bridge construction varies with these above factors. A bridge has three important structural components. First part is the substructure also called the foundation. They are the ones that transfer complete load to the ground. Columns also known as the piers and abutments are included. Abutments are used to get the connection between the endpoints of the bridge and road. This helps in giving support to the end conditions of the bridge. Second part is the superstructure of the bridge. A horizontal platform is placed over the space between the columns and finally the third part of the bridge is the deck of the bridge.

The rail over bridge is designed for road transport above a railway line. The main objective of the construction of the rail over bridge is to reduce travel time and cost of road traffic and trains and increase speed of traffic by avoiding delay in road traffic as trains passes by. By using STAAD.Pro. BEAVA software, modelling, designing and structural analysis of the bridge is to be done.

2. METHODOLOGY

STAAD.Pro is comprehensive structural engineering software that addresses all aspects of structural engineering including model development, verification, analysis, design and review of results. It includes advanced dynamic analysis and push over analysis for wind load and earthquake load. The commercial version, STAAD.Pro, is one of the most widely used structural analysis and design software products worldwide. It supports several steel, concrete and timber design codes. STAAD. Pro is a widely used structural analysis and design software for analyzing and designing structures for bridges, towers, buildings, transport, industrial and utility structures. The software with its new and improved features now has its latest version, STAAD.Pro V8i. STAAD.Pro V8i can now analyze and design any engineering structure.

The general philosophy governing the design of bridges is that, subject to a set of loading rules and constraints, the worst effects due to load application should be established and designed against. The process of load application can be

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complex as governing rules can impose interdependent parameters such as loaded length on a lane, lane factors, and load intensity. To obtain the maximum design effects, engineers have to try many loading situations on a trial and error basis. This leads to the generation of many live load application instances (and a large volume of output data) that then must be combined with dead load and other effects, as well. Bridge Deck is used to minimize the load application process while complying with national code requirements.

The program is based on the use of influence surfaces, which are generated by STAAD.Pro as part of the loading process. An influence surface for a given effect on a bridge deck relates its value to movement of a unit load over the point of interest. The influence surface is a three-dimensional form of an influence line for a single member (or, in other words, it is a 2D influence function). STAAD.Pro will automatically generate influence surfaces for effects such as bending moments for elements, deflection in all the degrees of freedom of nodes, and support reactions. The user then instruct the program to utilize the relevant influence surfaces and, with due regards to code requirements, optimize load positions to obtain the maximum desired effective values.
Dimensions of Path Over Bridge:

Overall Span of the bridge = 69.67m
Width of the bridge deck =2m
Details of Road

- Function: Freeway
- Live load: Due to the real-time loading of vehicle loading of all the codes, bending moments, shear forces, distortions, that is IRC codes were calculated and graphically presented

Bridge Details

- Dead load: -1.05 kN/m, inclusive of additional load of arches etc
- Length of first span: 40 m
- Length of second span: 18.76 m
- Type of Carriage way: one lane two way
- Clear carriage way width: 7.5 m

Details of Pier

- Type of Material used in Pier: Reinforced Concrete
- Type of Pier used in bridge: Multi-Column Type Pier
- C/s of pier: 1.5 m dia
- Height of Pier: 5.195 m
- No of Pier: 5

Type of Loading: IRC Class A loading
Code Used: For Live load -IRC Chapter 3
For Dead load - IS 875:2007(Part 1)
For Design – IS 456:2000
Analyse and design the transverse-deck-slab and its cantilever portions, unless the superstructure is purely longitudinally reinforced solid slab with no cantilevering portions. This is necessitated so as to decide the top flange thickness of the deck section which is essential to work out the deck section properties for the subsequent longitudinal design. Compute the dead load and live load bending moments at each critical section. In order to determine the maximum and minimum live load effects that a particular longitudinal can receive, carry out the transverse load distribution for live load placed in various lanes. This may be done by Courbon's method, Little and Morice's method, Hendry and Jaeger methods. Alternatively, use may be made to the Plane-Grid method which involves using one of the many standard computer programs (. e.g. STAAD program). The Plan Grid method is basically a finite element method. Though time consuming in writing the input data, it is nevertheless very useful for the purpose of analysis. For wide and multi-cell box and transverse live load distribution may be studied by the finite element method but it is time consuming. Design against bending of critical sections, in reinforced or in prestressed concrete as the case may be. Work out dead load and live load shear forces at each critical section in the longitudinal of the deck and design the sections and reinforcements for effects of torsion and shear, if required.

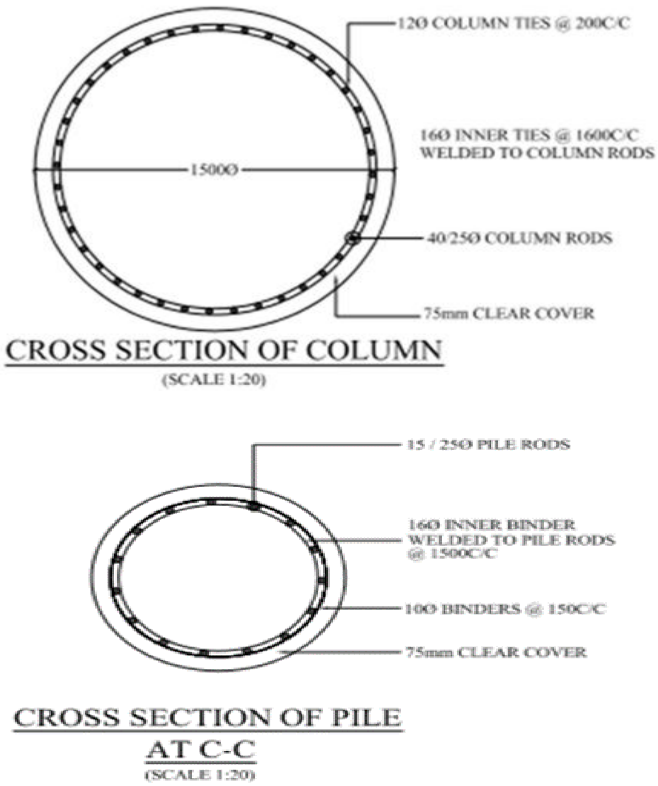

Fig -1: Cross section details of column and pile

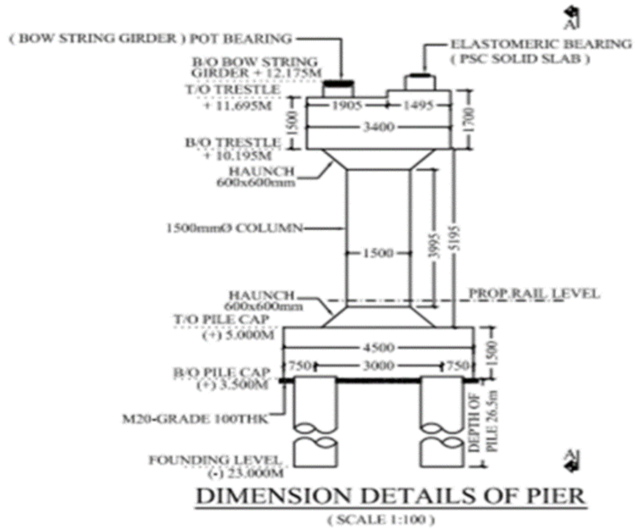

Fig -2: Details of pier

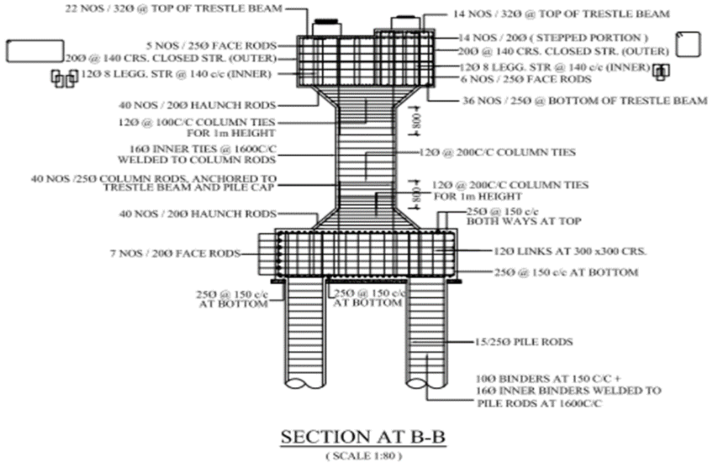

Fig -5: Reinforcement of pier

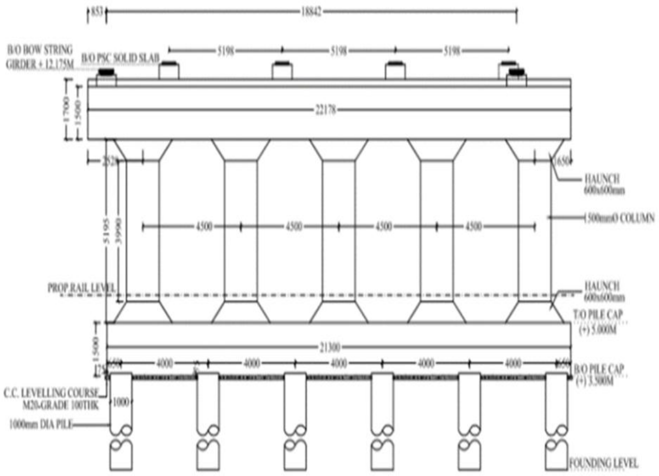

Fig -3: Front view of piers

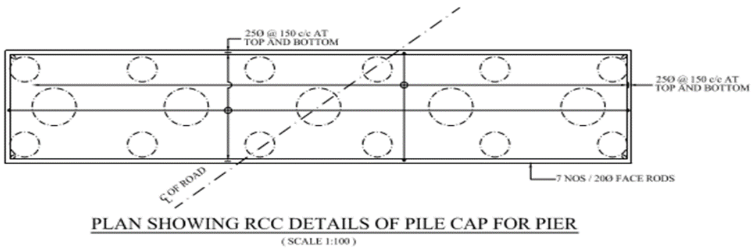

Fig -6: RCC details of pile cap for pier

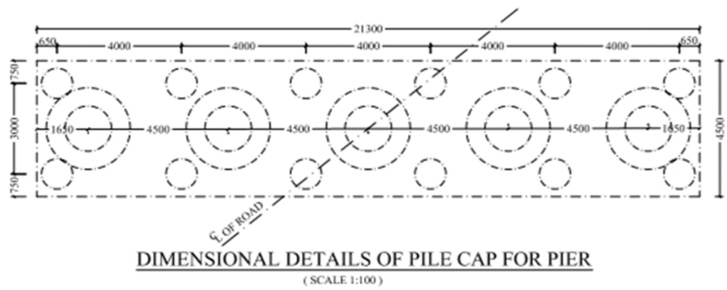

Fig -7: Dimensional details of pile cap for pier

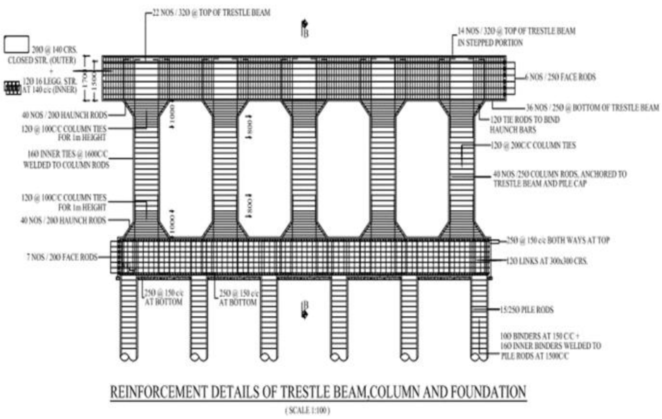

Fig -4: Reinforcement details of beam, column and foundation

3. MODELLING AND ANALYSIS

3.1 Modelling and Analysis of the Bridge using STAAD Pro

Table -1: Maximum shear force and maximum moment on critical pier

Load combination	Shear Fy (KN)	Shear Fz (KN)	Moment My (KNm)	Moment Mz (KNm)
Self weight	-0.001	-0.000	0.000	-0.002
IRC: Class A	45.611	-16.503	33.464	136.009
Self weight	0.001	0.000	-0.000	-0.002
IRC: Class A	-45.611	16.503	52.268	-345.755

Table -2: Maximum displacement at the end piers due to self weight

Pier	Node	Deflection (mm)
Pier 5	10	0.029
Pier 14	990	0.029

Table -3: Maximum displacement values on the piers

Piers	Node	Load combinations	Deflection (mm)
Pier 1	2	Self weight	2.329
		IRC: Class A	0.466
Pier 2	4	Self weight	0.448
		IRC: Class A	0.118
Pier 3	6	Self weight	0.417
		IRC: Class A	0.189
Pier 4	8	Self weight	0.449
		IRC: Class A	0.204
Pier 5	10	Self weight	0.029
		IRC: Class A	0.228
Pier 6	12	Self weight	0.018
		IRC: Class A	0.154
Pier 7	14	Self weight	0.000
		IRC: Class A	0.151
Pier 8	16	Self weight	0.018
		IRC: Class A	0.153
Pier 9	506	Self weight	2.327
		IRC: Class A	0.443
Pier 10	508	Self weight	0.447
		IRC: Class A	0.194
Pier 11	510	Self weight	0.419
		IRC: Class A	0.202
Pier 12	512	Self weight	0.447
		IRC: Class A	0.214
Pier 13	989	Self weight	2.329
		IRC: Class A	0.693
Pier 14	990	Self weight	0.029
		IRC: Class A	0.339
Pier 15	1144	Self weight	2.327
		IRC: Class A	0.680

Table -4: Maximum shear force and maximum moment values

Piers	Node	Load Combination	Shear Fy (kN)	Shear Fz (kN)	Moment My kNm	Moment Mz kNm
Pier 1	2	Self weight	-2.35E+3	-79.162	161.635	-9.6E+3
		IRC: Class A	-408.3	-14.9	26.099	-851.376

			66	01		
	1	Self weight	2.35E+3	79.162	249.623	-2.61E+3
		IRC: Class A	408.366	14.901	51.311	-566.421
Pier 2	4	Self weight	18.422	-33.573	50.580	-668.732
		IRC: Class A	60.137	-10.304	-18.881	-135.760
	3	Self weight	-18.422	33.573	123.833	764.434
		IRC: Class A	-60.137	10.304	35.750	448.175
Pier 3	6	Self weight	5.993	-0.000	0.000	-651.111
		IRC: Class A	-55.834	13.070	-26.605	-162.370
	5	Self weight	-5.993	0.000	0.000	682.246
		IRC: Class A	55.834	-13.070	-41.292	265.617
Pier 4	8	Self weight	18.422	33.573	-50.580	-668.732
		IRC: Class A	-54.973	19.654	-35.366	-173.150
	7	Self weight	-18.422	-33.573	-123.833	764.434
		IRC: Class A	-59.003	-19.654	-66.737	479.670
Pier 5	10	Self weight	0.002	-51.6	171.335	0.008

				53		
		IRC: Class A	-99.783	-20.855	50.043	614.254
	9	Self weight	-0.002	51.653	97.001	0.003
		IRC: Class A	99.783	20.855	61.579	-145.256
Pier 6	12	Self weight	-0.001	16.498	-69.635	-0.003
		IRC: Class A	-51.427	-16.182	33.495	94.216
	11	Self weight	0.001	16.182	-16.073	-0.002
		IRC: Class A	51.427	16.182	50.569	-361.380
Pier 7	14	Self weight	-0.001	-0.000	0.000	-0.002
		IRC: Class A	45.611	-16.503	33.464	136.009
	13	Self weight	0.001	0.000	-0.000	-0.002
		IRC: Class A	-45.611	16.503	52.268	-345.755
Pier 8	16	Self weight	-0.001	-16.498	69.635	-0.003
		IRC: Class A	44.923	-20.428	49.931	126.825
	15	Self weight	0.001	16.498	16.072	-0.002
		IRC: Class A	-44.923	20.428	56.193	338.608
Pier 9	506	Self	2.35E	-79.1	161.63	9.6E+3

		weight	+3	64	5	
		IRC: Class A	388.026	-8.600	22.645	1.62E+3
	505	Self weight	-2.35E+3	79.164	249.623	2.61E+3
		IRC: Class A	-388.026	8.600	33.068	564.364
Pier 10	508	Self weight	-18.422	-33.573	50.579	668.732
		IRC: Class A	-61.642	7.266	-18.288	143.212
	507	Self weight	18.422	33.573	123.833	-764.434
		IRC: Class A	61.642	-7.266	23.349	-463.442
Pier 11	510	Self weight	-5.995	0.000	0.000	651.111
		IRC: Class A	54.413	12.736	-25.642	184.479
	509	Self weight	5.995	0.000	0.000	-682.247
		IRC: Class A	-54.413	-12.736	-40.523	-452.322
Pier 12	512	Self weight	-18.422	33.673	-50.580	668.732
		IRC: Class A	-58.314	19.578	-35.527	188.128
	511	Self weight	18.422	-33.673	-123.833	-764.434
		IRC: Class A	58.314	-19.5	-66.183	-491.068

				78		
Pier 13	989	Self weight	-2.35E+3	79.164	-161.655	-9.6E+3
		IRC: Class A	-555.629	27.155	-50.491	-2.5E+3
	1294	Self weight	2.35E+3	-79.164	-249.623	-2.61E+3
		IRC: Class A	555.629	-27.155	-90.580	-731.673
Pier 14	990	Self weight	0.002	51.653	-71.335	0.008
		IRC: Class A	216.689	10.960	-26.573	1.09E+3
	1295	Self weight	-0.002	-51.653	-97.001	0.003
		IRC: Class A	-216.689	-10.960	39.129	-46.628
Pier 15	1144	Self weight	2.35E+3	79.164	-161.635	9.6E+3
		IRC: Class A	602.016	27.662	-54.112	2.58E+3
	1296	Self weight	-2.35E+3	-79.164	-299.623	2.61E+3
		IRC: Class A	-602.016	-27.662	-89.593	699.980

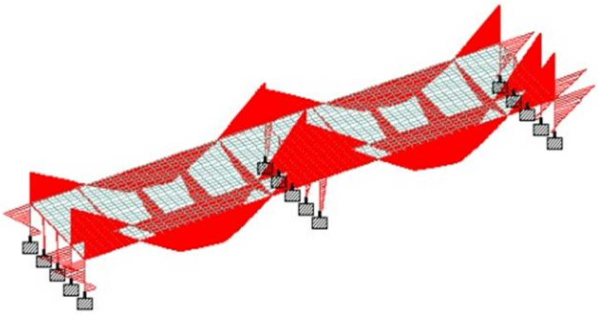

Fig -8: Bending moment diagram in Z direction

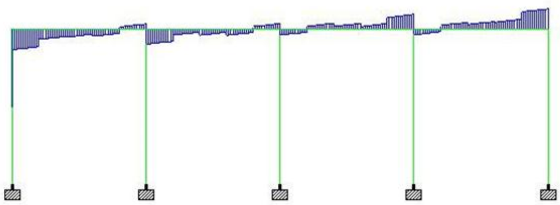

Fig -9: Shear force diagram in Y direction

3.2 Design of piers using STAAD

Member 1 - Detailed IS456 Design Requirements

Design of Column is done as per IS:456-2000

Section Property: 1500 Dia

Storey height = 5.195 m

Circular section: Diameter = 1500 mm

Cover = 40 mm

Unsupported Length of column = 5.20 m

Slenderness checks:

Effective length Major, l_{ex} =5.195 m

Effective length Minor, l_{ey} = 5.195 m

Slenderness ratio Major, (l_{ex}/H) = 3.463

Slenderness ratio Minor, (l_{ey}/B) = 3.463

Slenderness Limit = 12.000

\NOT SLENDER

Critical Loadcase: LOADCASE 1

Axial Load P, = 2189.01 kN

Major M, End 1, = 0.01 kNm

End 2, = -0.00 kNm

Minor M, End 1, = 14.01 kNm

End 2, = -13.93 kNm

Minimum eccentricity about major axis = 60.39 mm

Minimum eccentricity about minor axis = 60.39 mm

Moment Due to Min Ecc Major =132.19 kNm

Moment Due to Min Ecc Minor =132.19 kNm

Min. Eccentricity moment about major axis ignored as per Cl 39.3

Min. Eccentricity moment about minor axis ignored as per Cl 39.3

Design Moment Major = 0.01 kNm

Design Moment Minor = 14.01 kNm

Steel area required= 14451mm^2 (46 No. 20 dia. bars)

Total steel area provided = 14451mm^2

Pure Axial Capacity P_u= 20272.222 KN

Axial Capacity Ratio P/P_u=0.108

Axial Capacity ^{3} Axial Load
OK for axial resistance

Major Axis Capacity M_{ux1} =4286.251 KNm

Major Axis Capacity Ratio M_{ux} / M_{ux1}=0.000

Major Axis Capacity ^{3} Major Axis Moment
OK for moment resistance

Minor Axis Capacity M_{uy1} =4286.251 KNm

Minor Axis Capacity Ratio M_{uy} / M_{uy1} =0.003

Minor Axis Capacity ^{3} Minor Axis Moment
OK for moment resistance

Biaxial Interaction equation= $[(M_x/M_{ux1})]^{an} + [(M_y/M_{uy1})]^{an}$ £ 1,0 Cl. 39.6

where exponent, a_n = 1.000

Biaxial Interaction equation= $[(0.01/4286.25)]^{1.00} + [(14.01/4286.25)]^{1.00}$ = 0.11

Biaxial Interaction Result < 1.0

OK for biaxial resistance

Diameter of lateral ties 8 mm

Spacing of lateral ties = 300 mm

4. DESCRIPTIVE STUDY ON THE BRIDGE PAVEMENT

Problems with bridge approach pavements are widespread. A study is needed, including the approach walkway. That is, the pavement layer, joints, backfill and drainage systems. Solving this problem requires better solutions. Improve maintenance costs, ride quality, and eliminate accidents. "Bump at the end of the bridge" is the problem which gained national attention and recognized many important causes of bridge approach settlement in the United States. The study estimates that 25% of bridges nationwide suffer from bridge access settlement with annual maintenance costs of100 million at least. The bridge approach solution was previously investigated by many researchers who focus on both superstructure and substructure components. According to the Studies, lateral movement of the bridge, and settlement of embankment are considered. The result of lateral movement of the abutment is occurred by the bridge superstructure which develops and shrinks over time due to fluctuations in temperature. This lateral motion affects the integral Abutment bridges which are tougher than non-integral abutment bridges. In the case of integral bridges, as the temperature increases bridge superstructure moves the abutments towards the soils that cause high lateral pressures, which can reach stress levels as high as the idle pressure limit. As temperature decreases, the abutments shift away from soil.

It creates a void between the soil, the abutment and the backfill material. The presence of vacuum increases soil erosion, which increases the size of the void under the approach slab reported as lateral movement of the bridge which occurs at the integral abutment bridges which will reduce the pile pressure and reduce vertical load bearing capacity of piles.

Embankment settlement is a major issue in the approach settlement:
(1) Time-dependent consolidation of the basic soil and the approach slab basin.
(2) poor drainage conditions and soil erosion around the abutment.
(3) poor compaction of embankment fill near to the abutment.

One of the challenges of the bridge approach solution problem is knowing that there are limited resources to address it which determines when repairing the "bump" at the end of the bridge. To start a maintenance training (e.g., asphalt overlay), a tolerable differential settlement between bridge and approach slab must be exceeded. Therefore, it is necessary to be capable of measurement of behaviour of differential settlement and evaluate riding quality.

Differential settlement of greater than 63 mm results in poor riding quality, while tolerable differential settlements could be ashigh as 100 mm. The use of a settlement gradient along the pavement of 1/200 as the basis for beginning a alternative action is recommended. Settlement gradients and International Roughness Index (IRI) measurements used for portrayal of riding quality with IRI values in the bridge approach of 3.9 or less specifies very good riding quality and 10 or more indicating very poor riding quality.

Previous studies reported various solutions for reducing the differential approach slab pavement including the following:

(1) Basic foundation soil improvement various methods such as preloading, in situ densification and soil strengthening.
(2) the use of well graded backfill material.
(3) Strengthening of backfill material used in geosynthetics.
(4) Use of abutments supported by shallow foundations.
(5) The use of breakage incorporation or expandable material behind the bridge end.
(6) Set up a more efficient drainage system.
(7) Usage of the filter wrap to prevent erosion.
(8) Approach slabs are made with a slight inclination to introduce a pre-camber on the bridge ends. Although these solutions have been suggested, many of them have not been fully executed or assessed.

5. CONCLUSIONS

The main purpose of rail overbridge is to reduce the travel time and avoid road traffic stops as trains pass by. In this report, the analysis of Nagambadam Rail overbridge is done using IS 456:2000, IRC Chapter 3 and the type of loading is class A loading and code for dead load used is IS 875:2007(Part 1). The design and analysis of the bridge is done in piers, abutments and foundations. The analysis of piers and abutments is done using STAAD.Pro . STAAD Pro shows accurate and efficient results in the measurement of shear force, bending moment and displacement. It saves time and increases efficiency. It is possible to analyze and design the bridge substrate with the help of the software and save time by eliminating the long calculations required for the analysis and design of the bridge substrate. The settlement of approach roads is due to lateral movements in the abutments and due to the embankment settlement. A detailed description about the problems and their solutions of the approach pavement settlement is explained.

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