SAFETY AUDIT OF THREE RAILWAY BRIDGES IN MADURAI DIVISION OF SOUTHERN RAILWAY

A Report on

FIELD INSPECTION AND STRUCTURAL DESIGN CHECK OF 1377A PRESTRESSED CONCRETE GIRDER BRIDGE, AT KODAI ROAD

for

MADURAI DIVISION

SOUTHERN RAILWAY

by

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EXECUTIVE SUMMARY

IIT Madras along with EPMCR is assessing the condition of existing bridges in Madurai Division as third party consultant for Southern Railway. IITM has agreed to execute the safety auditing of the bridges in two stages:

Stage I – Preliminary condition assessment by field inspection and structural design check.

Stage II – Advanced condition assessment by sample collection and testing, instrumentation, and detailed design checks.

This report consists of the Stage 1 assessment of 1377A Prestressed concrete box girder bridge in Dindigul- Madurai section. The Bridge 1377A has 5 spans of 20 m with 4 intermediate piers and 2 abutments at both ends. In this report, the findings from the field inspection (walk through only) and the structural design checks are presented. During the field inspection, piers, abutments, girders, deck slab, inspection platform, trolley refuge and bearings were assessed. However, the structural safety of foundation and piers could not be assessed due to lack of drawings and the geotechnical data. The general observations on most of the elements are related to vegetation growth, corrosion, eccentricity of rail and missing drainage spout.

Limit state method was used for the structural design check, as per IS: 1343. (2012). Indian standard - code of practice for pre-stressed concrete. The effective live load on girder has been considered as per IRS Bridge Rule - 25t Loading – 2008. For the given sections as per drawings, with the 25t loading condition without accounting for any possible defects, the structure satisfies safety and stability conditions according to IS: 1343 (2012) (Indian standard - code of practice for pre-stressed concrete). Deflection of girder is within allowable limits.

1 INTRODUCTION

Figure 1 shows the photograph of the Prestressed concrete girder bridge 1377A on Dindigul-Madurai section. The Bridge is a Prestressed concrete girder structure, completed in year 2015. The Prestressed concrete girder has 5 spans of length 20 m each and width of 6.1 m. Figures 2 and 3 shows elevation and plan views of the Prestressed concrete girder bridge. The height of bridge from rail top of railway line at ground to bottom of girder is 7.675 m. The structural system consists of piers, abutments, box girder, and deck slab. The type of foundation structure is unknown from the given drawing. The superstructure is a simply supported PSC box girder sections over reinforced concrete (RC) pier.

Figure 1 Photograph of PSC Girder Bridge 1377A at Kodai road.

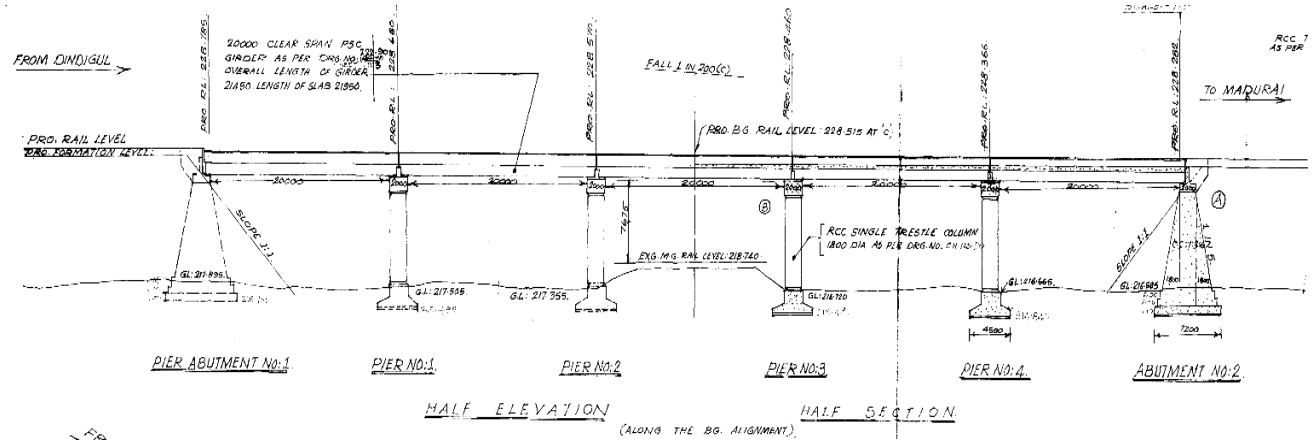

Figure 2 Elevation of PSC Girder Bridge 1377A

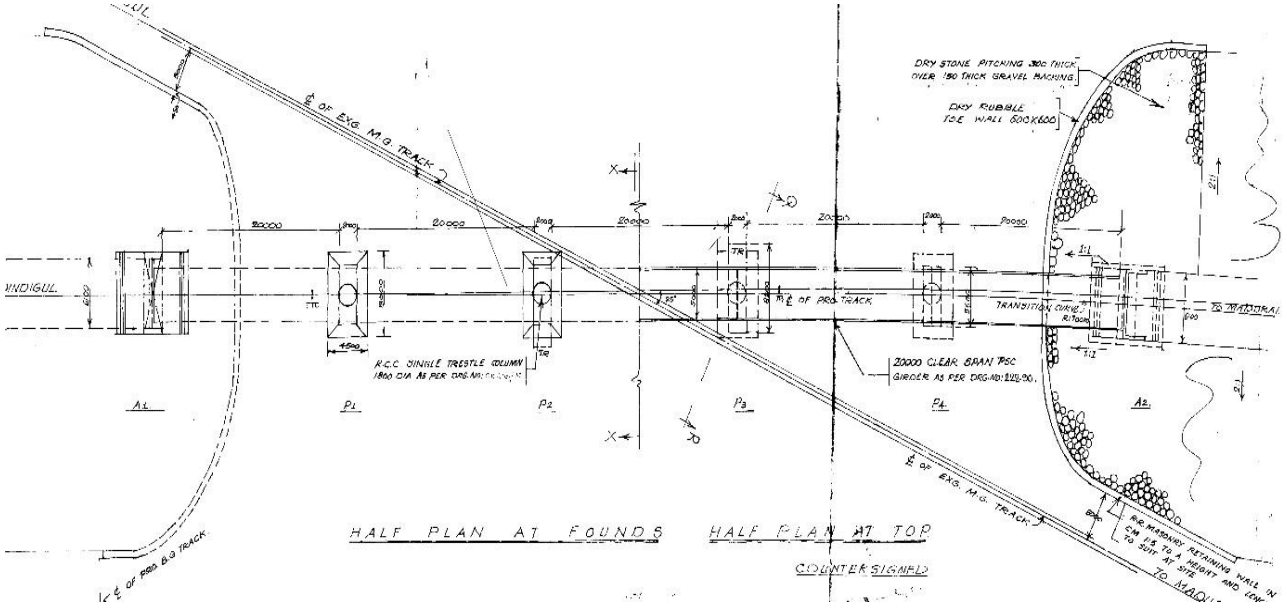

Figure 3 Top view plan of PSC Girder Bridge 1377A

1.1 GENERAL APPROACH

The general approach followed in the project is as follows:

- The current condition of the bridge is assessed with available data. All the uncertainties considered and assumptions made involved are stated.
- Suggestions for repair are made, if required.

1.2 SCOPE

Stage I covers the following scope:

i. Detailed inspection, checking of physical condition, collection of necessary data for analyzing;

ii. Checking of adequacy of bridges to carry 25t axle load/ present day loading condition.

iii. Submission of detailed report on current state with replacement/rehabilitation strategy and design details.

1.3 CONDITION ASSESSMENT

The condition assessment is defined as the process, where a set of indicators are obtained from the results of a field inspection of an existing structure, which are used to develop a definition or to arrive at a calculation of the so-called condition state. The condition state indicates the state of conservation of the structure.

1.4 METHODOLOGY

The assessment started with the review of the available documents, followed by the field inspection of the bridge. The data acquired from the field inspection was analyzed and a condition state was provided for different elements of the bridge. The structural design check was done to assess the load carrying capacity of the bridge and the report is drafted with the necessary findings and recommendations. The methodology was executed in the following sequence:

- Review of the bridge information sheet and available drawings;
- Field inspection of the bridge to identify any physical deterioration, structural damage and the surrounding environment;
- Analysis of the data from the field inspection to assign a 'condition state' for different elements;
- Detailed checking of structural design. Design parameters are verified to be within limits given in IS codes under the current loading conditions; and
- Drafting a report with all the details, findings and recommendations.

2 FIELD INSPECTION

The bridge was inspected to assess its current conditions, which are expressed as **Structural, Non-Structural and Preventive Maintenance** condition states. "Structural" means that the defect has an implication on structural safety and stability and may need detailed analysis with the recommendation for repair. "Non-Structural" means that there is no structural implication on stability and safety, but it may lead to deterioration; this shall be addressed with minimal repairs. "Preventive maintenance" requires routine maintenance procedures to be adopted to avoid further deterioration. The details of the field inspection are given in Appendix - A. The details of the defects observed in different elements of the bridge are given in decreasing order of extent of defect in Table 1, where IP, DS, A and PW represents inspection platform, deck slab, abutment and protection works. The details of defects observed from the visual inspection on 06-02-2020 are summarized below.

Table 1 Field inspection observations

		Structural Elements								Count
Components		IP1	IP3	IP4	DS	A1	A2	PW1	PW2	
Defects	Vegetation growth					✓	✓	✓	✓	4
	Corrosion	✓	✓	✓						3
	Wide gap				✓					1
	Drainage spout missing				✓					1
	Rail eccentricity				✓					1

Legend

A - Abutment
DS - Deck Slab
IP - Inspection platform
PW - Protection works

From Table 1, the prominent defect in the structural elements of the bridge structure are vegetation growth, corrosion, missing drainage spout and rail eccentricity.

3 STRUCTURAL DESIGN CHECK

This bridge is made up of Prestressed concrete box girder.

General data

Effective span of the box girder = 20.80 m c/c

Overall depth of the girder = 1.35m

Assumptions

The assumptions are made from a similar bridge of chennai division

1) f_{ck} is assumed as 55 N/mm^2

2) It is assumed that the transfer is after 28 days and the strength is 85% of f_{ck} (f_{ci}=46.75N/mm^2)

3) Loss of post tension is assumed as 30% (η=0.70)

4) Ultimate tensile strength (f_p) has been assumed as 1480 N/mm^2

5) Depth of the ballast fill is assumed to be 0.55m

6) Diameter, CG of the cables, No. of cables & No. of strands are assumed. As follows, maximum possible eccentricity at midspan and support section is also assumed since it depends on CG.

7) Shear reinforcement and additional longitudinal reinforcement is assumed.

8) Structural drawings of cable profiles are not available. Hence values of pre-stressing force and eccentricity are assumed.

Load calculations

Self-weight of super structure	=	6.64 T/m
Live load (EUDL)	=	15.06 T/m
Total superimposed dead load	=	5.70 T/m

Bending moment & shear force calculation per girder

Maximum bending moment at mid span	=	14,621 kN.m
Maximum shear force at supports	=	2,812 kN

(i) Check for minimum section modulus

Section modulus Z_b required	=	57,40,52,571mm^3
Section modulus Z_b provided	=	67,33,48,937mm^3

Section modulus provided is more than the section modulus required.

(ii) Pre-stressing force = 22,978 kN

(iii) Check for stresses

At transfer stage,

σ_t	=	2.84 N/mm^2
σ_b	=	21.17 N/mm^2

At working load stage,

σ_t	=	13.43 N/mm^2
σ_b	=	2.71 N/mm^2

Stresses are within allowable limits.

(iv) Check for ultimate flexural strength

Moment capacity of the section (M_u) = 43,778 kNm

Moment capacity of the section is greater than the moment due to imposed loads.

(v) Check for ultimate shear strength

Shear resistance required (V_{cw})	=	2,705 kN
Shear resistance of the assumed section	=	2,812 kN

(vi) Supplementary reinforcements

Minimum area of steel to be provided	=	3,184 mm^2
Area of steel assumed to be present	=	11,021 mm^2

(vii) Check for deflection

Short term deflection

Allowable deflection	=	35 mm
Estimated deflection due to design loads	=	11 mm

Long term deflection

Allowable deflection	=	84 mm
Estimated deflection due to design loads	=	34 mm

(viii) Check for Torsion

Torsion due to dead load (0.100 m ecc.)	=	58 kNm
Torsion due to live load (0.238 m ecc.)	=	366 kNm
Area of reinforcement required	=	529 mm^2
Area of reinforcement assumed to be present	=	804 mm^2

3.1 CONCLUSIONS FROM THE DESIGN CHECK

With the 25t loading condition (IRS Bridge Rule - 25t Loading – 2008) and above-mentioned assumptions, without accounting for any defects, the structure satisfies safety and stability conditions according to IS: 1343 (2012) Indian standard - code of practice for prestressed concrete.

4 FINDINGS AND RECOMMENDATIONS

The findings and recommendations from the field inspection and structural design check are given as follows:

i. Field measurements taken manually for ascertaining the track alignment are given below:

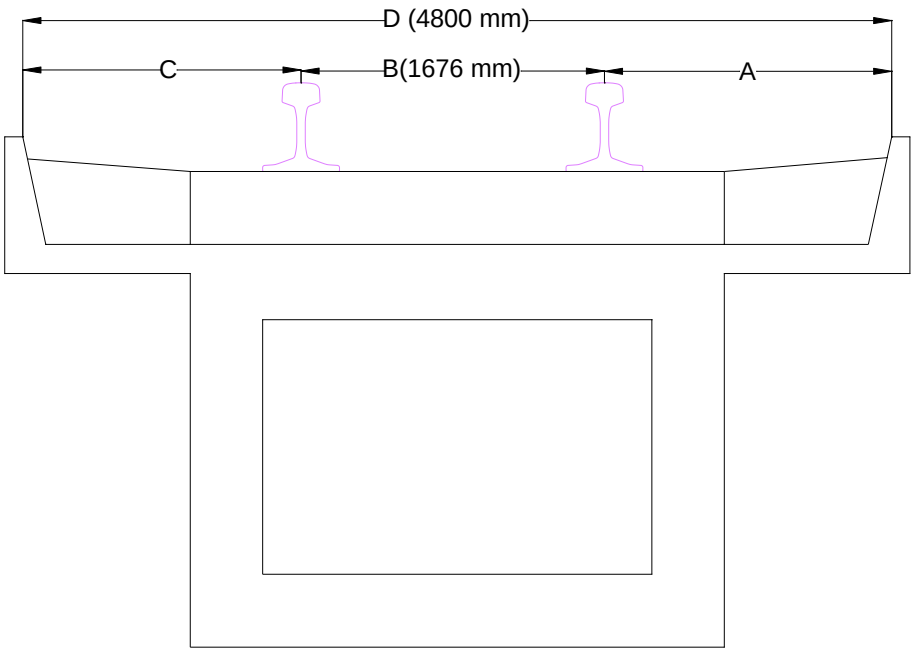

Figure 4 Cross section of rails for PSC Girder Bridge 1377A

The below eccentricity shift values are provided by railway engineers from Madurai division.

Table 2 Details of rail eccentric shift

Location	A (in mm)	C= D-(A+B) (in mm)	Eccentricity E= (A-C)/2
A1	1475	1649	-87
P1	1370	1754	-192
P1	1367	1757	-195
P2	1487	1637	-75
P2	1520	1604	-42
P3	1555	1569	-7
P3	1560	1564	-2
P4	1685	1439	123
P4	1682	1442	120
A2	1800	1324	238

Legend	
A	Abutment
P	Pier

From the above, Table 2, it is evident that Center line of rails are eccentrically shifted along the transition curve during the movement of trains. Movement of rails along the transition curve causing eccentricity in the loading is a serious issue. In addition to the data provided by the railway engineers, independent measurements were taken during site visit to the bridge. The shift in rail center line was measured at random locations and the eccentricity was found to be less than 100mm which is within the limits specified in railway manual. However, the high values of eccentricity reported by railway engineers indicate potential problems that could arise and this needs to be investigated thoroughly. It is recommended to study this issue in greater detail through instrumentation in Phase-2 of the project.

ii. Moderate corrosion is found on steel inspection platform members, which needs anti corrosion treatment and frequent maintenance.

iii. Drainage spouts under the deck slabs were missing. Missing drainage spouts needs to be reinstalled before next rainy season.

iv. No severe defect is observed in the bridge components.

v. Stress values are within limit for the 25t loading condition given in the Bridge Rule;

vi. Deflection for the PSC girder is within the allowable deflection;

vii. For the given sections and 25t loading condition without considering the defects, the structure is safe and stable;

viii. The assumptions made in the design due to non-availability of data need to be verified.

The following aspects have not been considered in the present study:

- The structural safety of foundation could not be assessed due to lack of drawings and the geotechnical data.

5 FURTHER TESTING REQUIREMENTS

Further measurements are required for ascertaining the safety and stability of the bridge. In particular strain gauges should be installed along various sections along the bridge in order to evaluate the torsional effects of eccentric loading. Since the loss of prestress is unknown, deflection measurements are also recommended.

REFERENCES:

RDSO. (2014). *Rules specifying the loads for design of super-structure and sub-structure of bridges and for assessment of the existing bridges*. Research design and standards organisation (RDSO), 102.

IS: 456. (2000). *Indian standard plain and reinforced concrete - code of practice*. Bureau of Indian Standards, New Delhi, 1–114.

IS: 1343. (2012). *Indian standard - code of practice for prestressed cocnrete*. Bureau of Indian Standards, New Delhi.

IRS Concrete Bridge Code. *Indian Railway standard - code of practice for plain, reinforced & prestressed cocnrete for general bridge construction*. Research design and standards organisation (RDSO).

IRS Bridge Rule. *Rules specifying the loads for design of super structure and sub structure of bridges and for assesmemnt of the strength of existing bridges.* Research design and standards organisation (RDSO).

IS: 432(part 2) – 1982: Specification for mild steel and medium tensile steel bars and hard-drawn steel wire for concrete reinforcement.

IS: 1786-1985: Specification for high strength deformed steel bars and wires for concrete Reinforcement

APPENDIX - A

Name of the bridge : 1377A Prestressed concrete girder bridge

Location of the bridge : Kodai road, Madurai

Inspection date and time : 06-02-2020; 10:00AM

Classification of condition state :

Condition state	Description
Structural	The defect has an implication on structural safety and stability and may need detailed analysis with the recommendation for repair
Non – Structural	The defect has no structural implication on stability and safety, but it may lead to deterioration; this shall be addressed with minimal repairs
Preventive Maintenance	The defect requires routine maintenance procedures to be adopted to avoid further deterioration

IMAGE NO.	A.1
BRIDGE ID	1377A
SPAN NO	5
COMPONENT	Inspection platform
COMPONENT ID	IP4
DEFECT	Corrosion
OBSERVATION	Corrosion observed in inspection platform floor beam
CONDITION STATE	Preventive maintenance

IMAGE NO.	A.2
BRIDGE ID	1377A
SPAN NO	4
COMPONENT	Inspection platform
COMPONENT ID	IP4
DEFECT	Corrosion
OBSERVATION	Corrosion observed in inspection platform floor beam & bracings
CONDITION STATE	Preventive maintenance

IMAGE NO.	A.3
BRIDGE ID	1377A
SPAN NO	4
COMPONENT	Inspection platform
COMPONENT ID	IP3
DEFECT	Corrosion
OBSERVATION	Corrosion observed in inspection platform floor beam & bracings
CONDITION STATE	Preventive maintenance

IMAGE NO.	A.4
BRIDGE ID	1377A
SPAN NO	1
COMPONENT	Inspection platform
COMPONENT ID	IP1
DEFECT	Corrosion
OBSERVATION	Corrosion observed in inspection platform floor beam & bracings
CONDITION STATE	Preventive maintenance

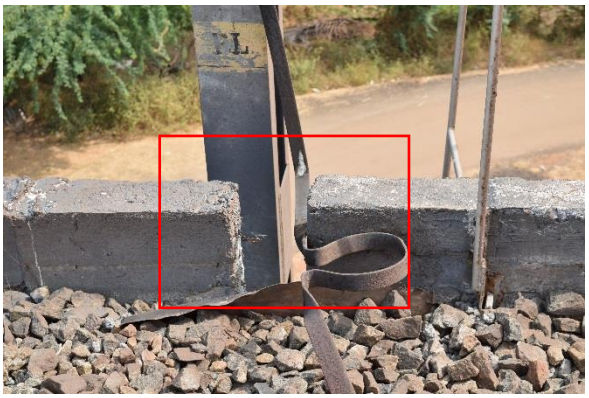

IMAGE NO.	A.5
BRIDGE ID	1377A
SPAN NO	2
COMPONENT	Deck slab
COMPONENT ID	D
DEFECT	Wide gap
OBSERVATION	Wide gap at expansion joint location
CONDITION STATE	Preventive maintenance

IMAGE NO.	A.6
BRIDGE ID	1377A
SPAN NO	3
COMPONENT	Deck slab
COMPONENT ID	D
DEFECT	No drainage spout
OBSERVATION	Drainage spout not available below the deck slab
CONDITION STATE	Preventive maintenance

IMAGE NO.	A.7
BRIDGE ID	1377A
SPAN NO	3
COMPONENT	Deck slab
COMPONENT ID	D
DEFECT	Rail eccentricity
OBSERVATION	The center line of the rail was eccentric
CONDITION STATE	Structural

IMAGE NO.	A.8
BRIDGE ID	1377A
SPAN NO	1
COMPONENT	Protection works/Abutment
COMPONENT ID	PW1/A2
DEFECT	Vegetation growth
OBSERVATION	Growth of vegetation found on protection works and near abutment
CONDITION STATE	Preventive maintenance

IMAGE NO.	A.9
BRIDGE ID	1377A
SPAN NO	1
COMPONENT	Protection works/Abutment
COMPONENT ID	PW1/A1
DEFECT	Vegetation growth
OBSERVATION	Growth of vegetation found on protection works and near abutment
CONDITION STATE	Preventive maintenance