

Full-Scale Service Load Test of 40m span FSLM 434P08-09 Girder in the Mumbai–Ahmedabad High-Speed Rail Project

K. SHANMUGA SUNDARAM

M.Tech (Transportation)

P.E, Chartered Engineer, FIE, FIV, SCE, A.M.ASCE, M.ICE, M.IRC, M.ICI

General Manager-Rail Division

Aarvee Associates Pvt Ltd,

ABSTRACT

A full-scale service load test was performed on the FSLM 434P08-09 girder in Package C6 of the Mumbai–Ahmedabad High-Speed Rail (MAHSR) project. The 40 m prestressed concrete girder, weighing ~1100 tonnes, was tested under 100% service load (1055.81 kN) in accordance with IRC:SP:51-2015, IRC:112-2011, and Eurocode 2. The theoretical midspan deflection was 18.70 mm, whereas the measured deflection was 13.80 mm, representing a 26% reduction compared to permissible values. Recovery after unloading was ≥96%, exceeding the 85% code requirement, and no cracks were observed. The girder exhibited satisfactory serviceability performance, confirming design adequacy and manufacturing quality.

Keywords: High-Speed Rail, Prestressed Concrete, Full Span Launching Method, Service Load Test, MAHSR

Date of Submission: 25-10-2025

Date of acceptance: 04-11-2025

I. Introduction

The MAHSR project (508 km, 320 km/h design speed) is India's first high-speed rail corridor. Package C6 spans ~89 km, including Anand and Nadiad stations. To ensure structural safety, 40 m long Full Span Launching Method (FSLM) girders are subjected to proof load testing. Serviceability performance is critical, as excessive deflection or cracking can impair durability, track geometry, and passenger comfort.

II. Methodology

The full-scale load test was carried out to evaluate the structural performance, serviceability, and behaviour of the Full Span Launching Method (FSLM) girder under simulated loading conditions. The test aimed to validate the design assumptions, confirm the adequacy of the girder stiffness, and monitor deflection, bearing response, and crack development under incremental loading.

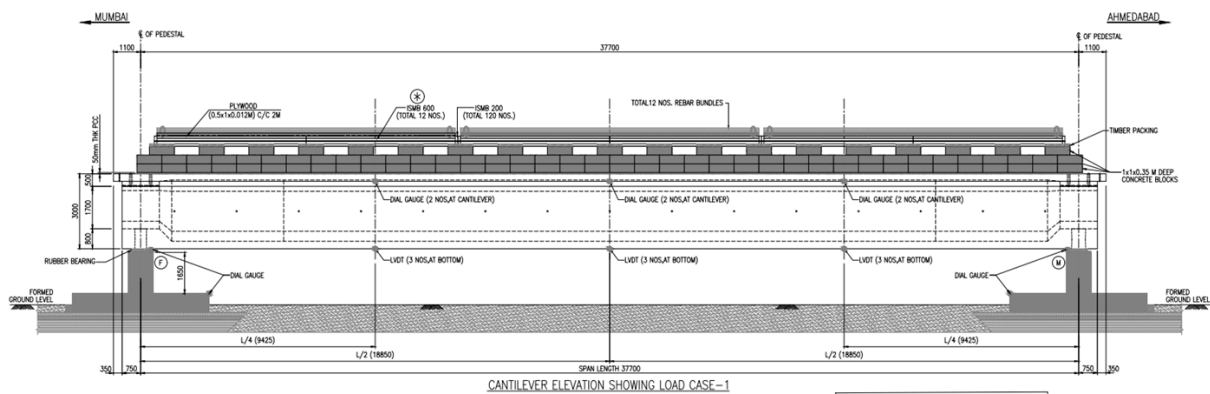
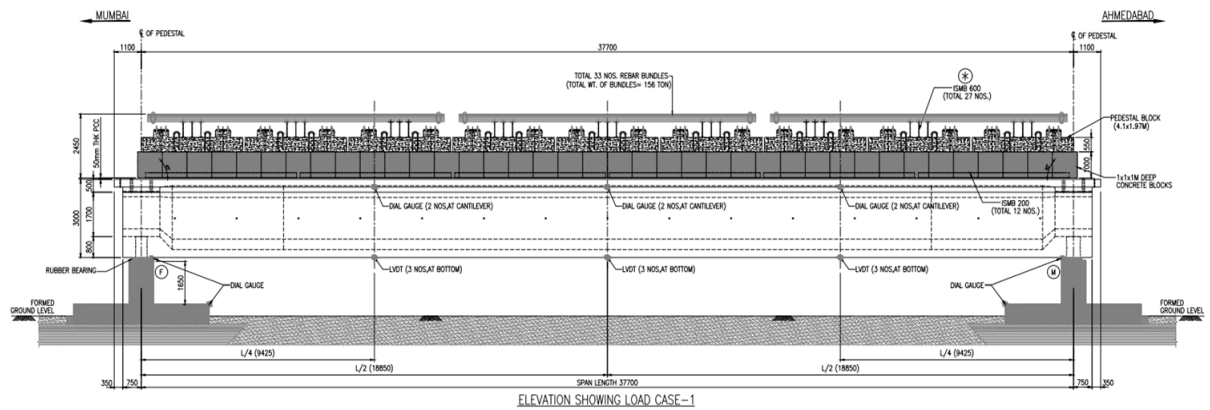
A full-scale load test was conducted on the selected Full Span Launching Method (FSLM) girder at Casting Yard–3 in accordance with the approved Method Statement.

The test site was selected within the casting yard, isolated from vehicular activity, and prepared by cleaning and levelling the ground. The foundation and pedestal layout was marked, Load arrangement schematic

followed by excavation to the designed dimensions. A plate load test verified the bearing capacity of the foundation soil. Plain cement concrete was placed over the compacted base, and reinforced concrete pedestals (1.6 m high) were constructed to uniform elevation. Upon achieving the required concrete strength, elastomeric bearings were installed at designated locations.

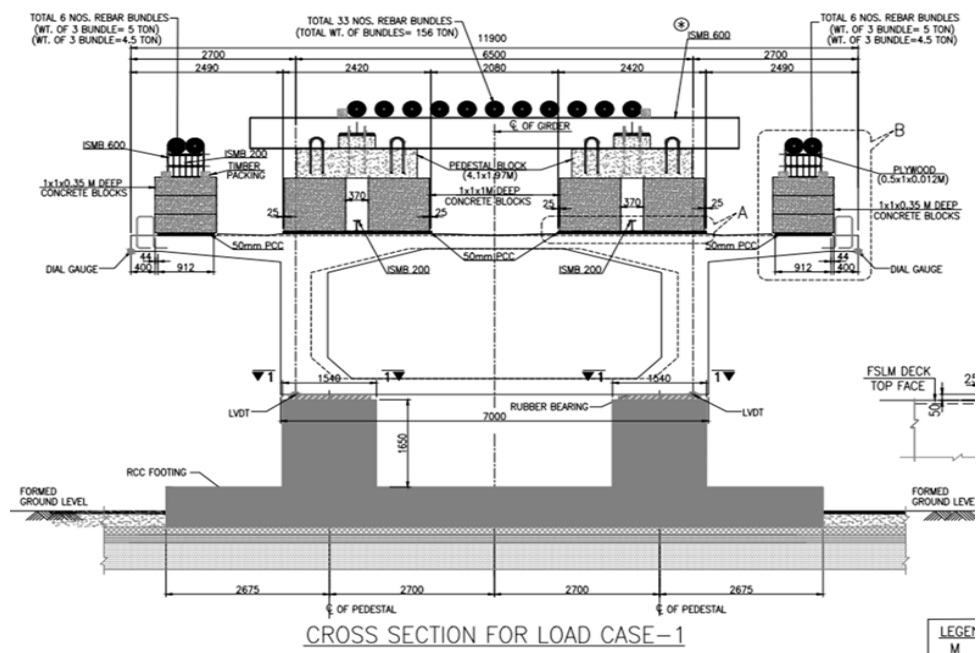
The FSLM girder was positioned on the bearings using a straddle carrier, and the surrounding area was compacted and cleared for safety and accessibility. The soffit of the girder was whitewashed to enhance crack visibility. Load application points, deflection measurement locations, and monitoring points for bearing compression and foundation settlement were clearly marked. Independent supports for LVDTs and dial gauges were erected on stable ground. Surface and ambient temperature points were also identified. The test setup was enclosed with PVC sheets to protect against wind and rain, and appropriate lighting was arranged for continuous inspection.

Calibrated loading materials comprising concrete blocks, steel sections, and rebar bundles of known weights were positioned near the test setup for systematic load application during testing. Load arrangement schematic & location of temperature & deflection layout are shown for clarity.



Load stages for Loads at Construction Stage (Total Load = 274.16 kN/m)

Item	Quantity	Loading in each Cycle (kN/m)			
		50%	75%	90%	100%
50mm Thk. PCC (For Track Load)	For 37.7m Length	5.808	5.808	5.808	5.808
50mm Thk. PCC (For Cantilever Load)	For 37.7m Length	2.189	2.189	2.189	2.189
Concrete Blocks Type 1	For 37.7m Length	96.764	96.764	96.764	96.764
Concrete Blocks Type 2	For 37.7m Length	0.00	55.623	55.623	55.623
Concrete Blocks Type 3	For 37.7m Length	33.867	42.334	42.334	42.334
Steel Beams (For Track Load)	ISMB 200 (18 NOS) – 6.1m Length ISMB 600 (27 NOS) – 8m Length	0.461	0.461	7.374	7.374
Steel Beams (For Cantilever Load)	ISMB 200 (120 NOS) – 6.1m Length ISMB 600 (12 NOS) – 12m Length	0.00	6.914	9.219	9.219
Rebar Bundles (For Track Load)	0Ton for 50% 0Ton for 75% 81Ton for 90% 156Ton for 100%	0.00	0.00	21.077	40.593
Rebar Bundles (For Cantilever Load)	0Ton for 50% 0Ton for 75% 30Ton for 90% 57Ton for 100%	0.00	0.00	7.806	14.832
Total Load (kN/m)		139.089	210.093	248.194	274.74



Placing of Concrete blocks (Type-1&3) On the FSLM Girder for completion of 50% test load



Placing of Concrete blocks (Type-1&3) On the FSLM Girder for completion of 75% test load

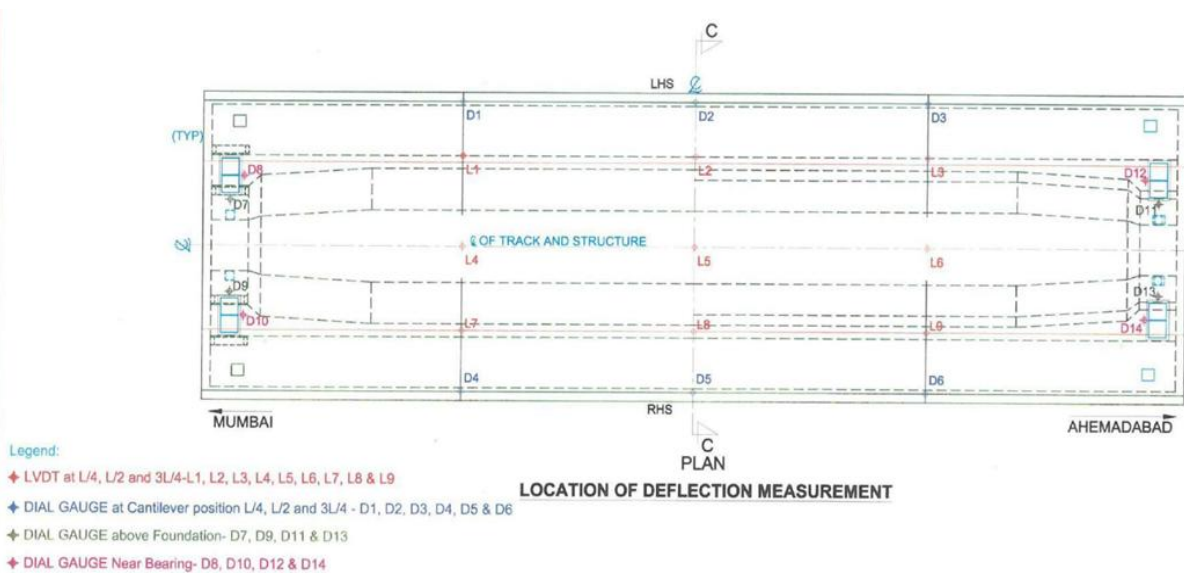
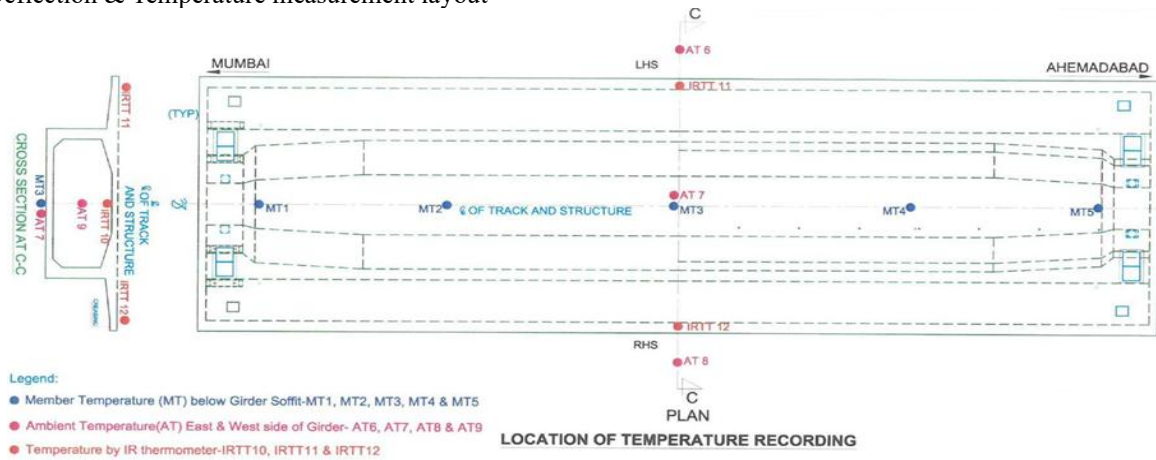


Placing of ISMB steel sections and rebar bundles on the FSLM Girder for completion of 90% test load



Placing of ISMB steel sections and rebar bundles on the FSLM Girder for completion of 100% test load

Deflection & Temperature measurement layout



View of Digital Thermometer with External sensor firmly fixed to the soffit of FSLM Girder of Deflection measurement region.



View of Independent HD Towers at Mid span (L/2) for placing of LVDT's and Dial Gauges

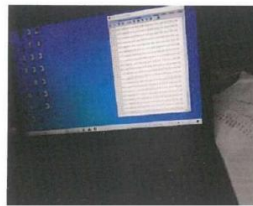
Load Testing Procedure

Instrumentation and loading were conducted in accordance with the approved test procedure. Linear Variable Differential Transformers (LVDTs) and dial gauges were installed at designated locations along the soffit, cantilever arms, and bearing zones of the girder. Glass plates were affixed at all measurement points to facilitate accurate deflection readings. LVDTs were connected

to a data logger interfaced with a laptop for continuous recording, while dial gauges were monitored through cameras connected to a remote display unit located in the site office. Digital thermometers with external sensors were fixed at selected points on the girder surface and in the ambient zone to record temperature variations during the test.



View of Data Logger where all the leads of LVDTs are connected



Data Cable from Data Logger connected Laptop
To view LVDT readings placed at respective locations



View of all Dial Gauge readings displayed in monitor through cameras placed in Respective position



View of FSLM Box Girder with whitewash supported on RCC Pedestals

Prior to loading, a detailed inspection was performed to record any pre-existing surface cracks, followed by the recording of initial readings from all gauges and sensors. The instrumentation was observed continuously for 48 hours to monitor temperature-related deflection variations and to establish baseline data.

Subsequently, loading was applied incrementally in stages corresponding to 50%, 75%, 90%, and 100% of the test load using pre-weighed concrete blocks, steel sections, and reinforcement bundles. At each stage, readings from all LVDTs and dial gauges were recorded after stabilization of values, and the girder was examined for visible distress or crack formation. The full test load was maintained for 24 hours, during which periodic readings were recorded hourly.

After completion of the sustained loading phase, the test load was removed in reverse increments (90%, 75%, 50%, and 0%), with deflection readings and visual inspections performed at each stage. Instantaneous and time-dependent recovery measurements were recorded over the next 24 hours to determine elastic recovery and residual deflection, accounting for foundation settlement and bearing compression effects.

Data Recording and Analysis

All sensor outputs from the LVDTs, dial gauges, and temperature sensors were continuously logged and periodically verified for consistency. Recorded deflections were corrected for foundation settlement and bearing compression based on simultaneous readings at reference points. Load-deflection curves were plotted to assess linearity and stiffness behaviour under incremental loading. Residual and recovery deflections were analysed after unloading to determine elastic recovery and potential plastic deformation.

Temperature data were used to normalize deflection readings and confirm environmental stability during testing. The overall results were compared with design predictions and relevant code requirements to verify the structural performance and serviceability compliance of the FSLM girder.

Load Intensity and Stage-wise Loading

The total test load (Track load & Cantilever Load) on the Full Span Launching Method (FSLM) box girder was calculated based on the design load intensity and span length as follows:

TEST LOAD DETAILS FOR LOAD CASE-1 (TRACK LOAD)

SELF WT. OF 50 mm THK PCC	= 5.808 kN/m
SELF WT. OF CONCRETE BLOCKS TYPE 1	= 96.76 kN/m
SELF WT. OF CONCRETE BLOCKS TYPE 2	= 55.623 kN/m
SELF WT. OF REBAR BUNDLES	= 40.593 kN/m
SELF WT. OF STEEL BEAMS	= 7.374 kN/m
TOTAL LOAD	= 206.158 kN/m
TOTAL LOAD ON EACH SIDE (TRACK)	= 103.08 kN/m

TEST LOAD DETAILS FOR LOAD CASE-1 (CANTILEVER LOAD)

SELF WT. OF 50 mm THK PCC	= 2.189 kN/m
SELF WT. OF CONCRETE BLOCKS TYPE 3	= 42.334 kN/m
SELF WT. OF REBAR BUNDLES	= 14.832 kN/m
SELF WT. OF STEEL BEAMS	= 9.218 kN/m
TOTAL LOAD	= 68.573 kN/m
TOTAL LOAD ON EACH SIDE (CANTILEVER)	= 34.287 kN/m

As per approved Method Statement, all the loads for the testing are applied on the identified area of top slab above the Girder.

On the Girder at Track area, applied test load is $\{(2 \times 103.08 \text{ kN/m}) \times 37.7 \text{ m}\} / 9.81 = 792.28 \text{ Tonnes}$

On the Girder at Cantilever area, applied test load is $\{(2 \times 34.387 \text{ kN/m}) \times 37.7 \text{ m}\} / 9.81 = 263.53 \text{ Tonnes}$
 = 274.74 kN/m

Total Load on FSLM Box Girder = 1055.81 Tonnes

The load was applied in four stages to simulate progressive loading conditions. Details of the load increments and cumulative loads at each stage are summarized in Table 1.

Stage of Loading	Percentage of Test Load (%)	Load Increment (tonnes)	Cumulative Total Load (tonnes)
Stage I	50	527.91	527.91
Stage II	75	263.95	791.86
Stage III	90	158.37	950.23
Stage IV	100	105.58	1055.81

Notes:

- Each stage was maintained for a minimum duration to record deflection and strain stabilization before proceeding to the next stage.

- The final load of 1055.81 tons represents the 100% design test load.

The FSLM 434P08-09 girder was tested at the casting yard on a bed replicating in-situ bearing conditions. Incremental loading up to 100% service load (1055.81 T). Deflections were measured at midspan (L/2) using LVDTs, and visual crack inspection was performed.

Net Deflection and Deflection Recovery

The net deflection of the box girder was determined as the difference between the final and initial readings of the LVDTs and dial gauges, corresponding to 24 hours after the application of

the full test load. Appropriate corrections were applied to account for foundation settlement, bearing compression, and temperature variation. The same approach was adopted to compute the deflection recovery after unloading.

(a) Foundation Settlement Correction:

The measured deflection values were corrected by deducting the average settlement of the foundation supports, obtained from the dial gauges installed at pedestal locations during loading and unloading cycles.

(b) Bearing Compression Correction:

The compression of neoprene bearings under load was measured using dial gauges positioned near the bearing zones. The average compression values were subtracted from the observed deflection to obtain the corrected response of the girder.



Position of Dial Gauges of foundation and Bearing regions for measurement of settlement and compression



View of Digital Thermometer placed closed to the FSLM girder for measurement of ambient temperature

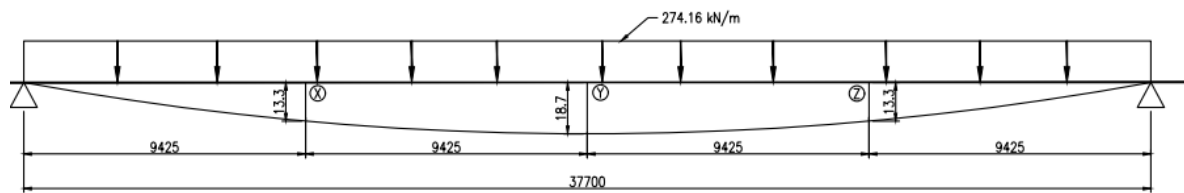
(c) Temperature Correction:

Temperature–deflection relationships were established by monitoring the girder for 48 hours under unloaded conditions. The data from each measurement point were used to plot temperature–deflection curves, which exhibited approximately linear behaviour. The deflection variation due to temperature difference between the start of loading

and subsequent readings was calculated from these curves and applied as a correction (positive or negative) to the observed deflection.

The corrected net deflection and recovery thus represent the true structural response of the girder, excluding the influence of support settlement, bearing deformation, and temperature fluctuation.

(d) Theoretical Deflection (mm)



CASE-1 CONSTRUCTION STAGE-LOAD & DEFLECTION PROFILE

Results of Load Test

a. Theoretical vs. Actual Deflection

The deflection of the box girder was monitored under 100% of the test load after 24 hours. The observed average deflections were found to be within the theoretical limits prescribed in the Table.

Location	Theoretical Deflection (mm)	Actual Average Deflection (mm)
L/4 Span	13.30	9.78
L/2 Span	18.70	13.80
3L/4	13.30	9.32

All deflection values were corrected for foundation settlement, bearing compression, and temperature variation. Detailed computations for Net deflection of Girder, Load Vs Deflection Graph, & Temperature Vs Deflection Graph are presented in **Tables 05 & 16**.



Table - 16

Net Deflection of Girder during 24 hours of loading incorporating corrections

Sl. No.	Date & Time	Duration	LHS Web Soffit			CENTER Soffit			RHS Web Soffit			LHS Cantilever Arm			RHS Cantilever Arm		
			LVDT - 01 (L/4)	LVDT - 02 (L/2)	LVDT - 03 (3L/4)	LVDT - 04 (L/4)	LVDT - 05 (L/2)	LVDT - 06 (3L/4)	LVDT - 07 (L/4)	LVDT - 08 (L/2)	LVDT - 09 (3L/4)	DG - 01	DG - 02	DG - 03	DG - 04	DG - 05	DG - 06
1	15.08.2022 14:00	After 1 hr	9.87	14.10	9.38	9.25	13.33	8.60	8.84	12.80	8.63	10.38	14.66	10.14	9.04	13.21	8.65
2	15.08.2022 15:00	After 2 hr	9.91	14.17	9.47	9.28	13.40	8.69	8.88	12.90	8.72	10.42	14.73	10.18	9.08	13.28	8.71
3	15.08.2022 16:00	After 3 hr	10.11	14.20	9.69	9.35	13.38	8.95	9.08	13.02	8.94	10.71	14.95	10.54	9.39	13.52	9.11
4	15.08.2022 17:00	After 4 hr	10.21	14.29	9.75	9.44	13.41	9.03	9.16	13.07	8.99	10.85	15.06	10.64	9.51	13.60	9.12
5	15.08.2022 18:00	After 5 hr	10.28	14.36	9.76	9.56	13.45	9.05	9.27	13.11	8.98	10.97	15.11	10.66	9.61	13.64	9.21
6	15.08.2022 19:00	After 6 hr	10.38	14.42	9.80	9.66	13.52	9.11	9.39	13.18	9.00	11.07	15.19	10.70	9.72	13.70	9.22
7	15.08.2022 20:00	After 7 hr	10.35	14.45	9.83	9.64	13.54	9.13	9.36	13.19	9.03	11.04	15.18	10.71	9.67	13.68	9.21
8	15.08.2022 21:00	After 8 hr	10.28	14.32	9.75	9.56	13.43	9.08	9.28	13.10	8.95	10.98	15.08	10.64	9.58	13.58	9.18
9	15.08.2022 22:00	After 9 hr	9.96	14.18	9.70	9.25	13.29	9.02	8.96	12.94	8.93	10.62	14.92	10.58	9.26	13.41	9.07
10	15.08.2022 23:00	After 10 hr	9.89	14.10	9.64	9.19	13.18	8.94	8.89	12.86	8.83	10.62	14.89	10.56	9.25	13.36	9.06
11	16.08.2022 00:00	After 11 hr	10.08	14.39	10.03	9.34	13.47	9.36	9.06	13.15	9.24	10.78	15.17	10.95	9.40	13.63	9.44
12	16.08.2022 01:00	After 12 hr	10.06	14.39	10.02	9.35	13.49	9.35	9.03	13.15	9.22	10.77	15.17	10.95	9.38	13.63	9.41
13	16.08.2022 02:00	After 13 hr	10.08	14.42	10.03	9.36	13.50	9.36	9.06	13.19	9.26	10.80	15.21	10.97	9.39	13.65	9.44
14	16.08.2022 03:00	After 14 hr	10.09	14.40	10.04	9.36	13.50	9.36	9.05	13.18	9.26	10.84	15.21	10.98	9.40	13.66	9.44
15	16.08.2022 04:00	After 15 hr	10.07	14.40	10.05	9.35	13.54	9.41	9.07	13.22	9.28	10.81	15.22	11.01	9.40	13.67	9.46
16	16.08.2022 05:00	After 16 hr	10.11	14.46	10.08	9.40	13.55	9.41	9.09	13.21	9.28	10.84	15.25	11.02	9.42	13.69	9.46
17	16.08.2022 06:00	After 17 hr	10.12	14.46	10.07	9.39	13.63	9.40	9.09	13.25	9.30	10.86	15.28	11.04	8.64	13.71	9.47
18	16.08.2022 07:00	After 18 hr	10.10	14.45	10.05	9.41	13.60	9.39	9.08	13.21	9.28	10.88	15.30	11.06	9.47	13.72	9.49
19	16.08.2022 08:00	After 19 hr	10.22	14.63	10.24	9.50	13.76	9.55	9.17	13.35	9.46	10.94	15.42	11.20	9.49	12.84	8.61
20	16.08.2022 09:00	After 20 hr	10.04	14.28	9.74	9.33	13.42	9.03	9.00	12.95	8.94	10.75	15.09	10.68	9.31	14.50	9.12
21	16.08.2022 10:00	After 21 hr	10.09	14.55	9.86	9.69	13.71	9.15	9.36	13.23	9.07	11.11	15.34	10.79	9.66	14.75	9.22
22	16.08.2022 11:00	After 22 hr	10.36	14.51	9.83	9.68	13.68	9.11	9.34	13.19	9.02	11.09	15.32	10.74	9.64	13.72	9.18
23	16.08.2022 12:00	After 23 hr	10.40	14.67	9.87	9.76	13.85	9.11	9.35	13.29	9.08	11.03	15.31	10.67	9.56	13.71	9.10
24	16.08.2022 13:00	After 24 hr	10.33	14.60	9.83	9.71	13.80	9.08	9.29	13.23	9.04	10.98	15.28	10.65	9.52	13.68	9.08



Table - 05
Load Vs Deflection Measurements for LVDT - 05, Mid Span L/2
(FSLM Girder No. - 434/P08-09, Location - CY-03, 434+500)

Sl. No.	Loading in Stages	Observed Average Ambient Temperature LHS & RHS (°C)	Observed Deflection (mm)	Foundation Settlement (mm)						Bearing Compression (mm)						Correction of foundation & bearing at Mid Span L/2	Temperature Correction (mm)	Net Deflection (mm)
				Mumbai Side (LHS)	Mumbai Side (RHS)	Average of Mumbai Side (LHS & RHS)	Ahmedabad Side (LHS)	Ahmedabad Side (RHS)	Average of Ahmedabad Side (LHS & RHS)	Mumbai Side (LHS)	Mumbai Side (RHS)	Average of Mumbai Side (LHS & RHS)	Ahmedabad Side (LHS)	Ahmedabad Side (RHS)	Average of Ahmedabad Side (LHS & RHS)			
1	Before Start of Loading (R1)	27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	Stage I After Placing 50% of load	26	9.21	1.80	1.53	1.67	1.94	2.25	2.10	0.77	0.66	0.72	0.89	0.77	0.83	2.65	0.10	6.46
3	Stage II After Placing 75% of load	32	14.15	3.81	3.39	3.60	3.72	4.57	4.15	1.28	1.09	1.19	1.48	1.23	1.36	5.14	-0.50	9.51
4	Stage III After Placing 90% of load	25	17.70	3.84	3.34	3.59	4.30	4.93	4.62	1.47	1.24	1.36	1.70	1.42	1.56	5.56	0.20	11.94
5	Stage IV After Placing 100% of load	34	19.95	5.19	4.61	4.90	5.62	6.53	6.08	1.73	1.44	1.59	1.99	1.65	1.82	7.19	-0.70	13.46
6	After 24 hours of Loading (R3)	30	20.88	5.25	4.64	4.95	5.86	6.78	6.32	1.77	1.48	1.63	2.06	1.68	1.87	7.38	-0.30	13.80
7	Stage IV After Removing of 10% of load	30	19.40	5.09	4.48	4.79	5.68	6.62	6.15	1.64	1.36	1.50	1.90	1.55	1.73	7.08	-0.30	12.62
8	Stage III After Removing of 15% of load	26	17.13	4.51	3.87	4.19	4.20	5.96	5.08	1.55	1.16	1.36	1.66	1.38	1.52	6.07	0.10	10.96
9	Stage II After Removing of 25% of load	31	12.76	4.25	3.69	3.97	4.90	5.74	5.32	1.06	0.90	0.98	1.30	1.05	1.18	5.72	-0.40	7.44
10	Stage I After Removing of 50% of load (R4)	26	4.33	2.28	1.79	2.04	3.07	3.77	3.42	0.25	0.20	0.23	0.40	0.29	0.35	3.01	0.10	1.22
11	After 24 hours of Removal of Loading (R5)	25	3.11	2.12	1.60	1.86	2.95	3.44	3.20	0.13	0.11	0.12	0.28	0.18	0.23	2.70	0.20	0.21

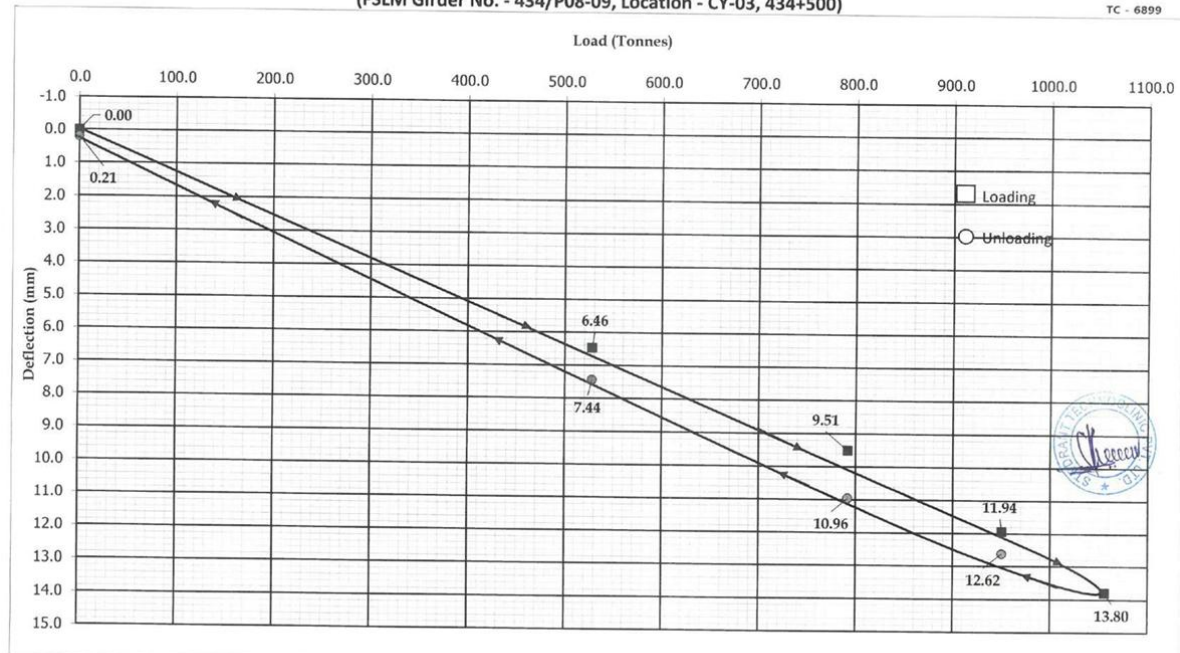
Percentage of recovery of deflection 24hrs after removal of test load
 $= ((R3 - R5) / (R3 - R1)) \times 100$
 $= ((13.80 - 0.21) / (13.80 - 0.00)) \times 100$
 Recovery of Deflection = 98%



Page | 17



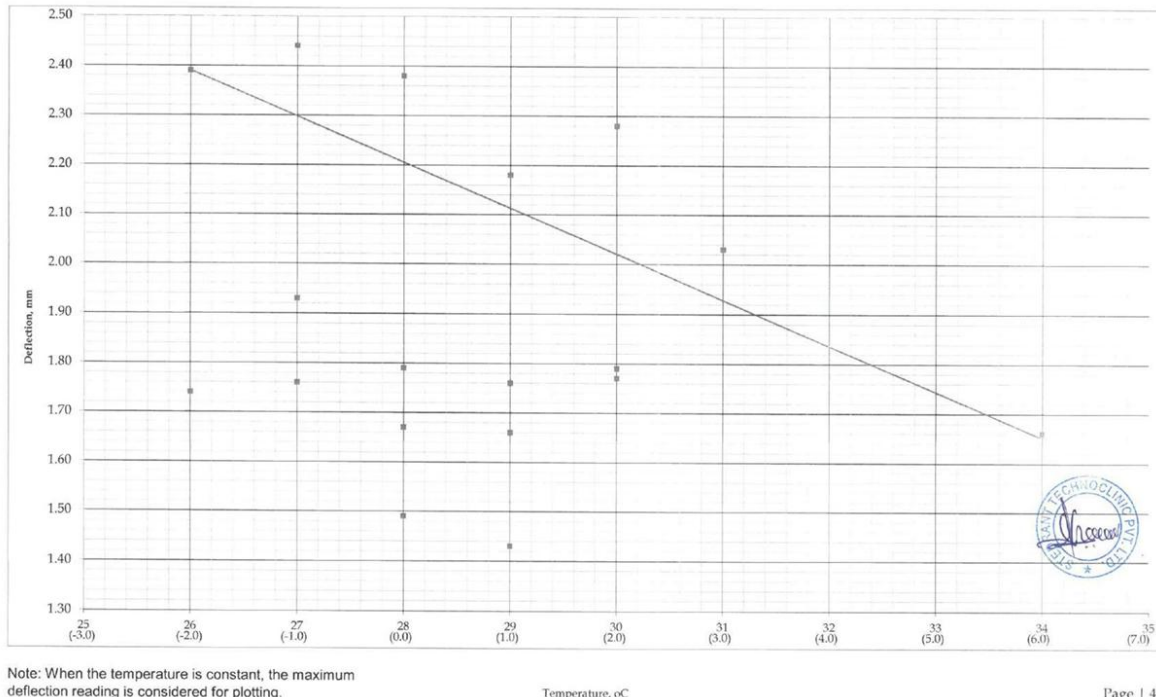
Load V/s Deflection Graph - 05
LVDT - 05, at 0.50L (L/2) Mid Span
(FSLM Girder No. - 434/P08-09, Location - CY-03, 434+500)



Page | 33



Temperature vs Deflection Graph - 17
 LVDT - 02, at 0.50L (L/2) Mid Span
 (FSLM Girder No. - 434/P80-09, Location - CY-03, 434+500)



b. Deflection Recovery

The percentage of deflection recovery at critical locations after 24 hours of unloading is summarized below.

SL No.	Location	Average Recovery (%)	Remarks
1	L/4	96	Satisfies Clause 6.8.2 of IRC: SP:51-2015 ($\geq 85\%$)
2	L/2	99	
3	3L/4	101*	

*As per Clause 8.3.1 of IRC: SP:51-2015, recovery values exceeding 100% are limited to 100%.

c. Crack Observation

Allowable new crack width of **0.2mm** are generally accepted as with in the allowable limits, since the structures are designed for a '**General Environment**' condition as per the **Japanese Railway Design Standard, specifically clause 10.2.2.3 -Limit Value of Crack Width.**

However, no visible cracks were observed during or after testing at any stage of loading. Hence, crack width measurement was not required.

Acceptance Criteria

The girder displayed higher stiffness than theoretical predictions, with actual deflection 26% (at mis-span) below the permissible value. Recovery exceeded 96%(at mis-span), far above the 85% limit, ensuring elastic response. Crack-free behaviour further confirms adequate prestressing and concrete quality. These results align with international benchmarks (Shinkansen, Taiwan

HSR) and validate the FSLM system for high-speed rail applications.

III. Conclusions

Based on the results of the load test, the Full Span Launching Method (FSLM) Box Girder No. 434/P08-09, proposed for the Mumbai-Ahmedabad High-Speed Rail (MAHSR) C-6 Package, demonstrated satisfactory performance under the specified **Service Stage loading** conditions.

The test results confirm that the girder meets all acceptance criteria stipulated in **IRC: SP:51-2015** and in the **approved Method Statement (Document No. MAHSR/C6/MS/054, Rev.00, dated 01 August 2022)**.

Hence, the tested girder is deemed structurally adequate and compliant with design and performance requirements for service load behaviour.

References

- [1]. IRC: SP:51-2015, Guidelines for Prestressed Concrete in Bridges.
- [2]. IRC:112-2011, Code of Practice for Concrete Road Bridges.
- [3]. EN 1992-1-1:2004, Eurocode 2: Design of Concrete Structures.
- [4]. IS:1343-2012, Prestressed Concrete – Code of Practice.
- [5]. Japan Society of Civil Engineers, Guidelines for Prestressed Concrete Structures.
- [6]. Taiwan HSR Technical Reports.
- [7]. Method Statement (Document No. MAHSR/C6/MS/046-Rev 01 &054, Rev.00, dated 01 August 2022)
- [8]. Load Test conducted, and reports submitted by M/S. StedrantTechno clinicPvt. Ltd., Bengaluru
- [9]. IRS CBC: 1997 (Reprint- September 2014 Incorporating A&C 1 to13) – Indian Railway Standard : Code of practice for Plain, Reinforced & PSC for General Bridge Construction.
- [10]. IRC 87:2019- Guidelines for Formwork, False work and Temporary Structures for Roads & Bridges.
- [11]. IS 456: 2000 Code for plain & reinforced concrete.
- [12]. Japanese Design Standard for Railway Structures- Concrete Structures (RTRI, Japan).