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Bridge Load Testing as Per IRC SP 51

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Abstract: Bridge load testing is popular means of demonstrating bridge's capability to carry safely design loads. It is commonly used to determine the issues which cannot be resolved by only visual inspection or analysis.

This paper deals with the study of load testing of major Bridge on River of 17.20 meter span Between Pier P5 and Pier P6. Under this project bridge was loaded with vehicular loading and tested for design load. Deflection of bridge is measured by dial gauges and recorded for bridge analysis. This study consists preparation of load test on bridge for deflection load as per IRC SP 51(2015) and how load testing is carried out by visual inspection, by applying vehicular loading or dynamic loading , its behaviour under loading and unloading conditons, behavior of bridge under the different temperatures to check how bridge is going to behave under weather conditions , maximum permissible deflection of girders , total deflection of girders, total recovery and percentage recovery of deflections after removal of load and comparison between theoretical deflections and actual deflections to find out testing bridge capability and its structural integrity.

Keywords: Bridge Load Test, Dial Gauge, vehicles, Loading, Unloading, Deflection, Design load, Temperature effect, Temperature correction, Total recovery, Total Deflection, Theoretical Deflection, Percentage recovery.

I. INTRODUCTION

Load testing is mainly used for assessing the flexural capacity of bridge. It is used to assess the condition and safety of bridge. The situations in which the testing is carried out if there is excessive creep deflection, materials defect, structural deterioration, uncertainties in current built in conditions , bomb or fire damage, or structural strength unknown. The load testing is used to check whether maximum deflection and percentage recovery are within permissible limits or not. If the bridge fails to meet the criteria, the bridge is no longer used.



Fig 1: - Bridge Load Testing

II. OBJECTIVES OF LOAD TESTING

The overall goal of conducting load tests on the Bridge is to :

- 1) Quantify its response to various loading conditions.
- 2) Measuring roadway-surface deflections due to various live loads.
- 3) Deriving stresses from measured deflections via analytical models, and comparing analytical results with design standard.
- 4) Testing may be carried out to assist the design in the following circumstances:
 - a) Where adequate analysis models are not available
 - b) Where large number of similar components are used
 - c) To check assumptions made in the design

III. METHODS OF MEASUREMENT

Deflections, Inclinations and Strains are measured with following instruments.

a) *Dial gauges, with least count of 0.01 mm*



Fig.2 : - Dial Gauge

b) *Strain gauge and measuring system, with load-count of 1 micro strain*

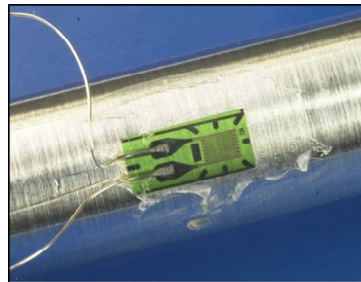


Fig.3 : - Strain gauge

c) *Inclinometer, with least count 0.1o*



Fig.4 : - Inclinometer

d) *Precision digital leveling instrument with bar coded staff., with least count 0.1 mm*



Fig 5 : - Data Acquisition system

- e) *Thermometers, Digital or Analogue with least count of 0.5°C.*



Fig.6 : - Digital Thermometer

IV. PROCEDURE OF LOAD TESTING

- 1) The test was carried out as per IRC SP 51 -2015 (IRC – Indian Road Congress Special Publication)
- 2) Instruments assembled at desired location such as, Dial Gauge , Strain Gauges , Digital Thermometer , Data Acquisition System.
- 3) Visual inspection of bridge is done. In Visual Inspection, Bearing and expansion joints were checked. Both must be in their functional and working condition. The traffic was closed for further testing and whitewash is applied to the superstructure for monitoring of cracks.
- 4) Dial Gauges were placed on magnetic stands. They were placed firm on scaffolding platforms with steel plates , so that magnetic stands are firmly located. Dial gauges were mounted just by touching the soffit of structure.
- 5) Glass plate of size 50x50x5mm shall be fixed to structure at location of Dial Gauges For Positioning.
- 6) Before Loading The precautions should be taken:
 - a) All staging provided shall be stable and safe.
 - b) Staging for instruments and observers shall be independent.
 - c) Staging for instruments shall be rigid.
- 7) As per IRC SP 51, Loading Operation Stages from 0% , 25% , 50% , 75% , 100% of test load in 5 stages , which shall be completed in 4 hrs. At the starting of Bridge load test 25% of load on bridge is taken, out of total 120MT which is 30MT, then 50% then 75% then 100%. We had to increment the load at the interval of every 1 hr. during this the deflection were recorded at each stage of loading.
- 8) After completing loading, we had to keep it retained for 24 hrs and observe.
- 9) After 24 hrs, Structure shall be unloaded at same stage of loading i.e. 100% , 75% , 50% , 25% , 0% ,But unloading shall be done in same way of loading , load shall be removed at 1 hr of interval from 100% to 75% to 50% , as well as deflection is rewarded at each stage.
- 10) Measurements were recorded at every hour of loading and unloading.
- 11) Data was collected by visual observation before and after loading and there will be interpretation of results.

V. DATA COLLECTION

A. Visual Inspection

In visual inspection test , all visual defects were measured, mapped, and plotted. Bearings were checked. Bearing were ensured for their functional condition. Expansion joints were in working condition. Expansion joints gaps shall be ensured through their functional condition. The traffic was closed. All the vegetations on site was removed .Then whitewash was applied to the soffit of superstructure for better monitoring of cracks. Digital caliper was used for measurement of cracks.



Fig.7 : - Digital Caliper

B. Temperature Correction

The temperature readings are taken without applying the load . at every one hour of interval temperature readings are noted and how much deflection is caused due to temperature is noted.

TABLE I
Initial Loading, Dial Gauge Reading (Load 0.00 MT) for 24.00 hr

Load: 0.00 MT for 24 Hrs.										
Sr. No	Date	Time	Loading	Duration in Hours	Temp. oC	Dial Gauge Reading (in mm)				
						On Girder-I (DG-1)	On Girder-II (DG-2)	On Girder-III (DG-3)	On Girder-IV (DG-4)	On Girder-V (DG-5)
1	24/11/21	08:00PM	0.00MT	0	26.1	3.156	5.29	4.60	4.85	8.50
2	24/11/21	09:00PM		1	25.5	3.57	5.33	4.67	4.90	8.50
3	24/11/21	10:00PM		2	24.7	3.57	5.35	4.71	4.90	8.46
4	24/11/21	11:00PM		3	24.5	3.59	5.40	4.74	4.98	8.5
5	25/11/21	12:00 AM		4	24.4	3.60	5.45	4.77	5.05	8.52
6	25/11/21	1:00 AM		5	23.8	3.62	5.45	4.81	5.06	8.54
7	25/11/21	2:00 AM		6	23.8	3.63	5.47	4.93	5.11	8.54
8	25/11/21	3:00 AM		7	23.9	3.66	5.49	4.98	5.14	8.50
9	25/11/21	4:00 AM		8	22.3	3.65	5.51	5.01	5.15	8.50
10	25/11/21	5:00 AM		9	22.9	3.67	5.60	5.08	5.17	8.50
11	25/11/21	6:00 AM		10	22.9	3.67	5.61	5.14	5.18	8.50
12	25/11/21	5:00 AM		11	23.5	3.66	5.69	5.18	5.23	8.54
13	25/11/21	6:00 AM		12	27.4	3.87	5.76	5.22	5.19	8.62
14	25/11/21	7:00 AM		13	30.9	4.34	5.95	5.25	5.20	8.70
15	25/11/21	8:00 AM		14	30.6	4.12	5.59	5.28	5.11	8.67
16	25/11/21	9:00 AM		15	31.10	3.96	5.45	5.31	5.01	7.95
17	25/11/21	10:00 AM		16	32.45	3.96	5.46	5.35	4.83	7.68
Sr. No	Date	Time	Duration in Hours	Temp. oC	Dial Gauge Reading (in mm)					
					On Girder-I (DG-1)	On Girder-II (DG-2)	On Girder-III (DG-3)	On Girder-IV (DG-4)	On Girder-V (DG-5)	
18	25/11/21	11:00 AM	17	32.64	3.74	5.23	5.41	4.68	7.67	
19	25/11/21	12:00 PM	18	32.79	3.68	5.10	5.43	4.47	7.62	
20	25/11/21	1:00 PM	19	33.08	3.60	4.90	5.49	4.43	7.60	
21	25/11/21	2:00 PM	20	30.50	3.50	4.86	5.51	4.43	7.62	
22	25/11/21	3:00 PM	21	29.1	3.44	4.86	5.57	4.41	7.45	
23	25/11/21	4:00 PM	22	27.4	3.31	4.90	5.60	4.48	7.38	
24	25/11/21	5:00 PM	23	25.7	3.30	4.92	5.62	4.47	7.37	
25	25/11/21	6:00 PM	24	23.6	3.21	4.92	5.67	4.48	7.24	

C. Initial Stage of Loading

After taking temperature reading, the load is applied on bridge in 5 stages. Starting from 0%, the load is applied at every one hour of interval upto 0%, 25%, 50%, 75%, 100%.

TABLE II
Initial Loading, Dial Gauge Reading (Load 0.00 MT to 120.00MT)

Load: 0% (0.00 MT) to 100 % (120MT), for 24 Hrs.										
Sr No.	Date	Time	Duration (Hrs)	Temp. (oC)	Load	Dial Gauge Reading(in mm)				
						On Girder-I (DG-1)	On Girder-II (DG-2)	On Girder-III(DG-3)	On Girder-IV (DG-4)	On Girder-V (DG-5)
1	25/11/21	7:00PM	0	27.1	00 MT	3.21	4.92	5.67	4.48	7.24
2	25/11/21	8:00PM	1	27.1	30 MT	3.70	5.10	5.76	4.99	7.50
3	25/11/21	9:00PM	2	28.8	60 MT	3.90	5.75	5.88	5.25	7.70
4	25/11/21	10:00PM	3	28.8	90 MT	4.10	6.10	5.98	5.99	7.99
5	25/11/21	11:00PM	4	30.1	120 MT	4.530	6.810	6.01	6.44	8.45

D. 24 hour Retention of Load (100%)

After Initial stage of loading, the loading is retained for 24 hours. Again, the readings are taken at every 1 hour of interval for 24 hours while retaining the load.

TABLE III
100% Loading Dial Gauge Reading (Load 120.00MT) for 0.00hr. to 24.00hr

Load: 100 % (120MT), for 24 Hrs.										
Sr No.	Loading	Date	Time	Duration (Hrs)	Temperature (oC)	Dial Gauge reading (in mm)				
						On Girder-I (DG-1)	On Girder-II (DG-2)	On Girder-III (DG-3)	On Girder-IV (DG-4)	On Girder-V (DG-5)
1	120.00 MT	25/11/21	11:00PM	0 min	30.1	4.530	6.810	6.040	6.440	8.450
2		26/11/21	12:00AM	1 hr	31.8	4.535	6.810	6.980	6.445	8.500
3		26/11/21	1:00AM	2 hr	32.4	4.405	6.795	6.105	6.495	8.500
4		26/11/21	2:00AM	3 hr	32.9	4.430	6.870	6.110	6.510	8.510
5		26/11/21	3:00AM	4 hr	33.1	4.335	6.825	6.111	6.800	8.510
6		26/11/21	4:00AM	5 hr	32.4	4.310	6.819	6.143	6.750	8.480

7	26/11/21	5:00AM	6 hr	30.9	4.270	6.815	6.165	6.725	6.410
8	26/11/21	6:00AM	7 hr	29.6	4.215	6.810	6.188	6.710	8.340
9	26/11/21	7:00AM	8 hr	28.7	4.195	6.805	6.199	6.695	8.325
10	26/11/21	8:00AM	9 hr	28.6	4.105	6.800	6.200	6.675	8.310
11	26/11/21	9:00AM	10 hr	27.8	4.090	6.790	6.204	6.550	8.310
12	26/11/21	10:00AM	11 hr	26.4	4.090	6.785	6.245	6.535	8.285
13	26/11/21	11:00AM	12 hr	25.8	4.085	6.785	6.275	6.530	8.285
14	26/11/21	12:00PM	13 hr	25.2	4.070	6.710	6.298	6.530	8.270
15	26/11/21	1:00PM	14 hr	23.9	4.010	6.380	6.300	6.490	8.260
16	26/11/21	2:00PM	15 hr	23.8	4.010	6.340	6.335	6.485	8.260
17	26/11/21	3:00PM	16 hr	23.6	4.00	6.335	6.375	6.480	8.255
18	26/11/21	4:00PM	17 hr	22.8	4.00	6.335	6.388	6.475	8.255
19	26/11/21	5:00PM	18 hr	22.3	4.120	6.348	6.400	6.480	8.320
20	26/11/21	6:00PM	19 hr	22.9	4.165	6.450	6.445	6.310	8.445
21	26/11/21	7:00PM	20 hr	32.5	4.180	6.510	6.498	6.350	8.450
22	26/11/21	8:00PM	21 hr	25.4	4.210	6.530	6.500	6.340	8.450
23	26/11/21	9:00PM	22 hr	26.0	4.280	6.530	6.550	6.400	8.510
24	26/11/21	10:00PM	23 hr	25.6	4.280	6.530	6.600	6.490	8.530
25	26/11/21	11:00PM	24 hr	25.2	4.310	6.610	6.700	6.530	8.580

E. Initial Stage of Unloading

After 24 hours of loading, the structure shall be unloaded as same 5 stages. Starting from 100%, the bridge is unloaded at every 1 hour of interval upto 100%, 75%, 50%, 25%, 0%.

TABLE IV
Initial Unloading, Dial Gauge Reading (Load 120.00 MT to 0.00MT)

Sr No.	Date	Time	Duration (Hrs.)	Temp (0C)	Load	Dial Gauge readingin (mm)				
						On Girder-I (DG-1) in mm	On Girder-II (DG-2) in mm	On Girder-III(DG-3) in mm	On Girder-IV (DG-4)	On Girder-V (DG-5)
1	26/11/21	11:20PM	0Min	28	100	4.310	6.610	6.700	6.530	8.580
2	27/11/21	12:20AM	1 Hr	28	75	3.930	5.830	6.000	6.230	4.100
3	27/11/21	01:20AM	2 Hr	28.2	50	4.120	5.770	5.980	5.410	8.220
4	27/11/21	02:50AM	3 Hr	28.3	25	4.010	5.710	5.960	5.150	7.900
5	27/11/21	03:50AM	4 Hr	28.5	0	3.990	5.620	5.950	4.905	7.790

F. 24 Hour Retention of Load (0%)

After removal of load , once more the deflections are measured at every 1 hour of interval for 24 hours.

TABLE V
0% Unloading Dial Gauge Reading (Load 00.00MT) for 0.00hr. to 24.00hr

Load: 0 % (0 MT), for 24 Hrs.										
Sr No.	Loading	Date	Time	Duration	Temperature	Dial Gauge reading (mm)				
						On Girder-I (DG-1)	On Girder-II (DG-2)	On Girder-III (DG-3)	On Girder-IV (DG-4)	On Girder-V (DG-5)
1	0.00MT	27/11/21	3:20AM	0 min	29.20	3.990	5.620	5.900	4.905	7.790
2		27/11/21	4:20AM	1 hr	31.40	3.995	5.620	5.875	4.915	7.805
3		27/11/21	5:20AM	2 hr	31.60	3.995	5.620	5.845	4.920	7.880
4		27/11/21	6:20AM	3 hr	26.00	4.105	5.690	5.810	5.105	7.915
5		27/11/21	7:20AM	4 hr	24.20	4.125	5.720	5.795	5.135	7.935
6		27/11/21	8:20AM	5 hr	23.10	4.135	5.745	5.775	5.175	7.965
7		27/11/21	9:20AM	6 hr	23.00	4.215	5.805	5.755	5.351	8.015
8		27/11/21	10:20AM	7 hr	21.20	4.310	5.910	5.715	5.910	8.650
9		27/11/21	11:20AM	8 hr	20.10	4.310	5.915	5.700	5.915	8.650
10		27/11/21	12:20PM	9 hr	20.10	4.310	5.915	5.675	5.780	8.780
11		27/11/21	1:20PM	10 hr	20.00	4.310	5.915	5.655	5.600	8.915
12		27/11/21	2:20PM	11 hr	17.34	3.680	5.920	5.635	5.410	8.915
13		27/11/21	3:20PM	12 hr	16.60	3.675	5.960	5.610	4.100	8.920
14		27/11/21	4:20PM	13 hr	15.00	3.680	5.960	5.600	4.420	7.920
15		27/11/21	5:20PM	14 hr	14.50	3.651	5.951	5.595	4.450	7.890
16		27/11/21	6:20PM	15 hr	14.20	3.505	5.916	5.555	4.498	7.814
17		27/11/21	7:20PM	16 hr	14.00	3.497	5.873	5.435	4.519	7.687
18		27/11/21	8:20PM	17 hr	15.60	3.447	5.823	5.401	4.587	7.635
19		27/11/21	9:20PM	18 hr	21.40	3.123	5.784	5.398	4.450	7.601
20		27/11/21	10:20PM	19 hr	24.20	3.376	5.690	5.357	4.476	7.587
21		27/11/21	11:20PM	20 hr	27.50	3.201	5.568	5.344	4.499	7.550
22		28/11/21	12:20AM	21 hr	28.40	3.267	5.493	5.300	4.540	7.500
23		28/11/21	1:20AM	22 hr	29.40	3.299	5.346	5.275	4.501	7.475
24		28/11/21	2:20AM	23 hr	28.60	3.300	5.211	5.245	4.589	7.430
25		28/11/21	3:20AM	24 hr	29.20	3.350	5.140	5.200	4.650	7.400

G. Uninstallation of Instruments

After noting final deflection for the bridge, the instruments and scaffolding were safely removed from the site.

VI. RESULTS

As per IRC SP 51, the percentage recovery is calculated for bridge after removal of load for 24 hours. The data of temperature correction, total deflection and total recovery is determined.

As per IS SP 51, clause 8.3.1, page no.17 :

Initial value- deflections before commencement of loading= R1

Deflections at one hour, after placement of 100 percent test load = R2

Deflections at 24 hours after placement of 100% test load= R3

Deflection measurements immediately after removal of test load = R4

Deflection measurements at 24 hours after removal of test load = R5

Total deflection = R3 - R1

Total recovery of deflection after 24 hours after removal of test load = R3-R5

Percentage recovery of deflection 24 hours after removal of test load= (R3-R5/R3-R1)*100

(Where this value exceeds 100% it shall be restricted to 100%)

TABLE VI
Percentage recovery of deflections after retention of test load for 24 hours (G –V)

Sr. No	Description	Girder V(P5-P6)	
		L/2	Deflection of Girder Notations
		DG-V (mm)	
1	Initial Value on Dial Gauge (Deflection before Commencement of Loading)	7.24	R1
2	Final value (Deflection) after placement of test load (Thereafter, measurements are to be taken at regular intervals of one Hour)	8.45	R2
3	Deflection Value at 24 hrs. after placement of test load	8.588	R3
4	Deflection Value immediately after removal of test load (Thereafter, measurements are to be taken at regular intervals of one Hour)	7.790	R4
5	Deflection Value at 24 hrs. after removal of test load	7.40	R5
6	Total Deflection	1.34	R3 - R1
7	Total recovery 24 hrs. after removal of test load	1.18	R3 - R5
8	Percentage of Recovery of Deflection 24 hrs. after removal of test load	88.05	$[(R3 - R5)/(R3 - R1)] \times 100$

TABLE VII
Summary Sheet of Total Deflection and Total Recovery

Table no.07, Summary Sheet of Total Deflection and Total Recovery:

Girder No.	Total Deflection (Unit : mm)	Total Recovery (Unit : mm)	Percentage Recovery
G-I	1.1	0.96	87.26%
G-II	1.69	1.47	86.98%
G-III	1.74	1.5	86.20%
G-IV	2.05	1.88	98.70%
G-V	1.34	1.18	88.05%

TABLE VIII
Maximum Permissible deflection of girders

SR. No.	Girder Identification	Maximum Permissible deflection as per Design (Span/800) = (16200/800) (Unit: mm)
1	G-I	20.25
2	G-II	20.25
3	G-III	20.25
4	G-IV	20.25
5	G-V	20.25

TABLE IX
Theoretical Deflection vs Actual Deflection, After 24 hours of Loading of 100% of loading i.e.(120.00 Metric Ton)

Table No. 09 Theoretical Deflection vs Actual Deflection, After 24 hours of Loading of 100% of loading i.e.(120.00 Metric Ton):

SR. No.	Girder No.	Maximum Theoretical Deflection for 70R Loading including Impact Factor (Unit : mm)	Actual measured maximum Deflection (Unit :mm)	Remark
1	Girder-I	4.500	1.1	Measured maximum deflection is less than theoretical deflections
2	Girder-II	4.500	1.69	
3	Girder-III	4.500	1.74	
4	Girder-IV	4.500	2.05	
5	Girder-V	4.500	1.34	

VII. CONCLUSION

Following are the acceptance criteria as per IRC SP 51-2015 and conclusions of test conducted on said bridge.

1) *Criteria-I: Deflection Recovery:* (Clause no. 6.8.2 page no. 12) The percentage recovery of deflections for various types of bridges after retention of test load for 24 hours shall be:

Types of Bridges	Minimum percentage Recovery of Deflection at 24 hours after Removal of Test Load
1.Reinforced Concrete	75
2.Prestressed Concrete	85
3.Steel	85
4.Composite	75

Minimum Percentage recovery as per IRC SP 51

Conclusion: The percentage recovery of deflection of all dial gauges is more than 75% which is within the acceptance criteria of IRCSP 51 – 2015.

2) *Criteria-II:* (Clause no. 6.8.1 page no. 12) Maximum Permissible deflection as per Design should not be more than $(\text{Span}/800) = (16200/800) = 20.25 \text{ mm}$

Conclusion: The maximum deflection of tested bridge is observed 2.05 mm at Girder No. 4, which is less than Permissible deflection as per Design, which is within the acceptance criteria

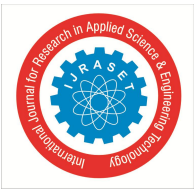
3) *Criteria-III:* (Clause no. 6.8.3 page no. 12), The Structure shall not show any cracks more than 0.3mm for moderate exposure, spalling or deflections which are incompatible with safety requirements.

Conclusion: Observed Crack width in the tested bridge is less than 0.3mm, which is within the acceptance criteria.

Tested bridge passed all the criteria, Hence it is concluded that **the bridge is safe and ready for service.**

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