GUIDELINES
FOR
LOAD TESTING
OF BRIDGES

(First Revisions)

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GUIDELINES FOR LOAD TESTING OF BRIDGES

(Special Publication 51)

1 INTRODUCTION

The B-8 Committee deliberated the revision of existing Guidelines IRC:SP-51 at a number of meetings and finalised the same at its meeting held on 21st June, 2014 at New Delhi.

These Guidelines provide the procedure for full scale load testing of bridge super structure including recommendations for the acceptance criteria. The bridge load testing is considered as a routine requirement now a days not only in India but the world over, to meet the requirement of the designs, constructional quality of structure and as an acceptance test conforming to the Codal provisions. The load test is carried out mainly to assess the flexural capacity, where in the required parameters can be measured directly and accurately. The super structures are rarely tested for shear strength evaluation due to absence of any reliable method. The load testing envisaged under IRC:SP:37 is only for assessing the strength evaluating the load carrying capacity for purposes of rating. Whereas, the load testing under these Guidelines is for assessing the behavior of a bridge by application of design live loads over a longer period of 24 hours for confirmation of the elastic performance of the superstructure.

2 SCOPE

These Guidelines deal with Proof Load Test. They cover testing of superstructures, excluding arches for evaluation of their flexural capacity. Testing for shear capacity is not considered. This test is not intended to assess ultimate load carrying capacity of bridge superstructure.

3 REQUIREMENT OF LOAD TESTING AND TYPES OF LOAD TESTS

3.1 General

Load testing of bridge components has been used as a tool for many purposes, such as a design tool, for verification of satisfactory performance, for new bridges to meet the acceptance criteria, identification of defects and subsequent repair, rating and posting of bridges, retrofitting to meet new requirements etc. Some of these are covered in more detail in **Clause 3.2**. The basic features of load testing of bridge superstructures are as follows:

1) The test is planned in such a way as to achieve the aims of testing
2) A component of the bridge which represents the superstructure, is selected for the test as required.
3) The test member shall represent either the normal type of element, or the defective (i.e. adversely affected) element due to presence of some known

or suspected shortcomings. Known detailing errors, constructional defects, deterioration of steel connections, corrosion of reinforcement, inadequate strength of concrete are some of the examples of such shortcomings.

4) In the process of design and construction, safety and serviceability are aimed at by following the design codes and construction specifications. Of these, the ultimate strength of the bridge components cannot be tested for obvious reasons. However, serviceability performance can be tested using test loads at a level equal to the design service load, duly considering the aims of the test and procedural limitations.

5) The test load is applied in steps and the response of the structural element recorded using appropriate instruments. The type of response may be strains, rotations, deflections and vibrations.

6) The observed response is compared with the expected response. The expected response is calculated using more advanced analytical methods than those used in the normal design activity.

7) In all cases of load-testing, action effects of the loads of environmental origin, such as flood, normal wind and temperature effects are restricted to the unavoidable minimum. In case of temperature effects, temperature corrections are invariably made to the observed response to test load, measured in terms of strains and/or deformation.

8) As much information as possible is extracted from the test to decide further course of action.

3.2 Purpose of Testing and Types of Tests

The type and details of the load test are decided by the purpose for which the test, or a series of tests, is planned. The purposes and types of test are briefly described below:

3.2.1 *Design Assisted by Testing*

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

The method adopted for interpretation and use of test results shall be such as to confirm the requirements of the design.

For further guidance refer other relevant literature may be referred to.

3.2.2 *Proof Load Test*

Proof Load Test shall be carried out as per **Clause 4.1** on the Bridge or its constituent elements to demonstrate that the design intents are satisfactorily met by measuring the response thereof.

Testing of a superstructure span or part thereof, subjected to combination of self load, imposed loads and some percentage of live loads as specified can be carried out in accordance with the contract for procurement/construction, unless otherwise required in the contract. The detailed technical recommendations for this type of testing are covered in these Guidelines.

3.2.3 *Verification of Adequacy of Overall Structural Member or Part Thereof*

The behavior test are carried out to verify the results for any method of analysis or design as in the following cases. The test load could be equal to or lower than the design load.

a) Where design model is not based on working loads, as in 'Limit State Method', design of some components and detailing of reinforcement is based only on the Ultimate Limit State (ULS).

b) In some cases the design model may not be sufficiently accurate, e.g. stresses around the openings.

c) The load path and load sharing between alternative load paths is too complex or uncertain, requiring its determination by testing.

3.2.4 *Diagnostic Load Tests*

Where load transfer mechanisms have changed over the period of time due to geometrical changes (e.g. settlement of supports), deterioration, and repair/rehabilitation measures, it becomes necessary to verify the extent to which the load carrying capacity is affected, or the type of restoration measures required. Since the method and details of testing depend on the nature of change and its effects, the test has to be specifically designed to obtain the required information and data.

3.2.5 *Load Test for Rating and Posting of Bridges*

Requirements of testing for these purposes are covered in IRC:SP:37. Unless otherwise stipulated, the details of the method shall generally follow the recommendations given in these 'Guidelines'.

3.2.6 *Confirmatory Test After Repair/Rehabilitation*

These tests are of the similar nature and purpose as Proof Load Test, Behaviour Test, or repetition of diagnostic test to measure the improvement after repair as described above.

3.2.7 *To Establish Stress Range for Fatigue Tests*

In steel structures the member stresses are closely predictable. However the design and detailing of joints is based on ensuring adequacy on the basis of plastic redistribution, redundancy, over design, testing or combination of these strategies. Due to this approach, the exact level of stresses is unknown, and non-linear even for load levels for which the main structural members are in the elastic range. The effect of locked - in stresses is significant in welded connections, which have not been stress - relieved as a part of fabrication and after erection. For conducting fatigue load tests on such joints, the strain and stress range can be established by providing strain gauge at typical joints in the structure.

3.2.8 *Dynamic Load Tests*

A new category of tests based on measuring the dynamic response of the structure as a whole or of some of its members is being increasingly used. The structural elements which are susceptible to damage due to dynamic loading are subjected to dynamic excitation and their response in terms of the frequency, amplitude, accelerations, etc. are measured. The response when plotted as a function of time during the test, using suitable recording instruments, produces dynamic signature of the member. These tests can be used for wind sensitive structures, such as suspension bridges, long span cable stayed bridges or only the cables.

For railway bridges the dynamic loading is often used, and can, in theory, be replicated for steel road bridges in suitable cases.

4 EXPECTED BEHAVIOR OF BRIDGE COMPONENTS DURING AND AFTER THE LOAD TEST

4.1 Design Intents of Newly Constructed Bridges and Retrofitted Bridges

1) A newly constructed bridge is load tested in order to verify or demonstrate that its behavior conforms with the design intents, when subjected to the combination of design values of permanent loads and design live loads. This is termed as the ‘Proof load test’. The design loads and load combinations for the serviceability design verifications are defined in IRC:6. The combined action effects of permanent actions and vehicular/pedestrian live loads are simulated as closely as possible in the test by adopting suitable loading pattern, its magnitude, and method of application of the test-load. Some times the load testing is done to meet the requirements of the construction contract, for which purpose, specifications and method is pre-defined in the contact document.

2) Bridges which have been in service for some time are load tested for one of the following purposes:

   a) In rare cases, before taking up the repair/rehabilitation measures, the behavior of bridge component in terms of stresses, deformations, vibrations etc are measured to observe and quantify their deficiencies.

   b) To verify and demonstrate the efficacy of the repair/retrofitting measures. All cases, availability of the design calculations and constructional quality assurance data is necessary to establish the reference values of the performance. However, for the bridges that have been in service for some time, the constructional details might not have been preserved, and even locating the designs and drawings may not be possible. The inspection and maintenance records may give indications of the degree of deterioration. In such cases, re-establishing the design calculations on the basis of the codes existing at the time of its design is necessary (Refer IRC:SP:37).The main purpose of establishing this data is to calculate the expected response of the bridge/bridge components when subjected to the test load. This is a necessary pre-requisite for proper planning of the load test.

4.2 Influence of Actual Material Properties

4.2.1 *Design Codes*

In the design process, after conceptualizing the type of bridge for a particular site, the detailed design is carried out following the design Codes. IRC has carried out a major shift in design paradigm by adopting Limit State Design philosophy for steel composite and concrete bridges while revising respective codes. For planning of load test use of relevant Code is required.

4.2.2 *Design Properties of Materials*

4.2.2.1 General

The design is carried out assuming the basic engineering properties of the main constituents, namely, structural steel, concrete, reinforcing and prestressing steel, and components like bearings, as stipulated in the respective design Codes. The design of foundations and their behavior is also based on the soil properties, soil classification, experience and/or field and laboratory investigations. By necessity, the Codes give simplified descriptions of the material properties, termed as the ‘Design Properties’. The use of the ‘design properties’ of materials alone is, therefore, not adequate to understand and predict the response and compare the same to the actually measured response recorded during the load test. A deeper understanding of the variability of the properties is an important factor influencing the response at serviceability level of loads and are described in the following articles.

4.2.2.2 Variability of compressive strength, tensile strengths and ‘E’ value of concrete

The design characteristic strength in MPa denotes the comprehensive strength of concrete. However the actual strength of concrete in structure under sustained load can be somewhat lower.

a) Variation of Strength

The variation of strength after 28 days is not taken into account while designing new projects. However for the purpose of calculating the effective E value, strains and stresses for the load test, the gain in strength should be accounted for. This is especially valid for the testing of bridges which have been in service for some time. The provision given in IRC:112 shall be used for the purpose. For old bridges where the originally specified design strength is not available, the same shall be based on the cylindrical cores taken from the bridge components and tested as per IS:516. These shall be converted to the equivalent design strength using appropriate factors.

b) ‘E’ Value to be Used;

The strains in concrete which develop at any section on loading of the structure are calculated on the basis of mathematical models, which are appropriate for the type of structure and loading under consideration.

c) Effect of Shrinkage;

Concrete shrinks in volume in the process of setting, and after setting, which changes its linear dimensions. This change is mainly associated with the loss of moisture from concrete and other factors, which are described briefly in IRC:112 and in the extensive literature on the subject. A small portion of shrinkage is recoverable, the rest being irreversible. The rate of shrinkage is different in different parts of the structural member due to different thickness and the gradient set up in the process of loosing moisture from the inner zones through the surfaces.

d) Effect of Creep;

The effect of creep should also be kept in mind, as the creep and recovery of creep are not identical, and affects partly the percentage of recovery after unloading.

e) Effects of Loading/Unloading and Creep Recovery in Prestressed Concrete;

i) The discussion about loading, unloading and creep presented in earlier sections is directly applicable to the reinforced concrete portions of the structure. However while applying these concepts to the prestressed concrete portions; a fundamental difference caused by the introduction of pre-compression in the structure has to be taken into account. It should be realized that introduction of prestress is equivalent to introduction of external load in the structure. IRC:112 has specifically treated prestress as an external load. The nature and action of this load is to introduce in the structure stresses of opposite sense than those created by service live loads. Thus, from the point of its effect on concrete, prestressing is the initial load, and the effect of the externally applied live load is to reduce, or reverse, these stresses caused by prestressing. Hence the action of applying test load is that of un-loading the concrete and removal of test load is an act of re-loading the concrete. The uses of effective E values while loading and un-loading are in the reverse order than the reinforced concrete portion. Same is true about the creep effects. Test loading of structure will lead to recovery of creep and removal of load will re-load concrete, putting back the creep phenomena on its original track. This should be properly accounted for while calculating the expected strain and deformation behavior during the test load.

ii) The other important factor, which leads to simplification of calculations, is absence of cracking of concrete in response to application of test load. Thus the full cross section over the entire length of the span remains in un-cracked condition, allowing use of the fixed values of the sectional properties. This makes the calculated response more accurate than the case of reinforced concrete elements.

4.2.3 *Reinforcing and Prestressing Steel*

The properties of reinforcing and prestressing steel are better established since these are factory manufactured items, with further quality controls applied in their acceptance testing and use at site. Whereas the 'E' value is reliably known, the actual bond between reinforcing steel and concrete in an RC structure is variable.

4.2.4 *Structural Steel*

The properties of the structural steel used in the construction of steel bridges and steel-concrete composite bridges are known accurately. However, the effects of locked-in stresses due to the fabrication activities are not exactly known. Thus the initial state of strains and stresses may be uncertain, but the response to the test-load is expected to be in elastic range. The reason for observed deviations during load testing from the calculated strains and deformations are mostly due to the simplifications introduced in the analysis.

5 STRUCTURAL MODELLING AND METHODS OF ANALYSIS

5.1 General

The results of load tests are required to be compared with theoretical analysis. For proper comparison the theoretical analysis should be compatible with the realistic behavior of the structure. The structural geometry, material properties, support conditions and load effects should be considered in such a way that these reflect the true behavior of structure. For this purpose two types of approaches are available.

a) Theoretical analysis

b) Physical modelling

A brief of these two types of modelling is given hereunder.

5.2 Theoretical Analysis

The behavior and response of the structure to various load effects is analysed using mathematical equations and physical laws. A number of analytical tools are available for analyzing the bridge structures utilizing the modern computing facilities. The choice of analytical tools depends on the following factors:

i) Purpose of structural analysis,

ii) Importance of structure and

iii) Desired level of response and accuracy.

A number of methods are used for analysis of structures viz:

a) Linear analysis/elastic analysis

b) Non linear analysis/Inelastic analysis

c) Static analysis

d) Equivalent static analysis

e) Non linear static analysis (pushover analysis)

f) Free vibration analysis

5.3 Physical Modeling

Physical modelling is done to predict the behavior of the structure using a physical model in the laboratory which is of size much smaller than the prototype where the load effects can be applied and monitored in controlled conditions.

Some of the physical models could be of following types:

a) Global bridge models comprising of entire bridge with all frames and connecting structures

b) Tension and compression models

c) Frame models

d) Bent models

5.3.1 The bridge models are generally made of PVC-N for deformable and of Celluloid for rigid case.

Model of reinforced cement concrete for RCC Bridge is also made for testing in laboratory. The size is proportioned in 1/20 to 1/15 scale. Concrete and steel used are of same proportion and strength as in prototype. Diameter of steel reinforcement is however reduced in proportion of size of structure model. Steel is to be got made by special order.

5.3.2 Physical modelling and testing, also called experimental stress analysis are normally used for research to verify the analytical results, response of structure to assess the behavior of complex structures including connections, local areas.

6 PLANNING OF LOAD TESTING

6.1 Selection of Spans

For existing bridges after study of records and detailed inspection, the critical span/spans for load test shall be decided.

6.2 Flow Chart of Activities

A method statement shall be prepared which includes a detailed activity schedule for the load test as programmed for timely completion of load testing. The method statement shall have the following details for conducting the load test,

i) application of whitewash for critical locations of bridge

ii) mobilization of testing personnel to site

iii) visual inspection of bridge

iv) recording existing status

v) fixing of instrumentation

vi recording of thermal response of the structure

vii) system of measurements for temperature correction

viii) position of the load on the bridge

ix) measurement recording

x) visual inspection during and after load testing

xi) preparation of report

A flow chart shall be prepared for the above said activities as also any other additionally required activities for satisfactory completion of load testing.

6.3 Types of Load Tests

Static load tests are to be carried out to verify and ascertain the actual structural behavior of the bridge compared with theoretical designs. Dynamic load tests may be carried out for special structures where required. The primary objective of the load tests is to better understand bridge's response to static and dynamic loadings.

6.3.1 *Static Load Testing*

Static load testing is performed to measure vertical deformation of bridge at mid span or at any predetermined locations. Measurement of recovery of deflection and crack width will be part of static load testing. In special bridges like suspension and cable stayed, the measured and theoretical deflected shapes of the superstructure during and after the static load tests be also recorded.

6.3.2 Dynamic Load Testing

The purpose of dynamic test is to verify the dynamic behavior of bridges and specialist literature may be referred for details of carrying out such tests.

6.4 Methods of Loading

6.4.1 The method of loading should be such as to either simulate the specific class of vehicle or induce in the member(s) the calculated forces, viz., the bending moments at critical sections,

The test loads shall be in the form of :

a) Static Loads

b) Mobile Test Vehicles

6.4.2 *Static Loads*

Simulation of the specific IRC Vehicles:

6.4.2.1 Static loads on wheel/track imprints of the specific class of vehicle for which the bridge is to be tested

The load effect on a span can be produced by building up preweighed units on loading imprints spaced as per codal provisions. The imprints are built either with steel plates or brick masonry or concrete and rolled steel sections placed across pairs of imprints, so that platforms could be built on a group of four imprints for placement of preweighed units. The area of each platform depends on the magnitude of the load and unit weight of individual unit. A pre weighed unit normally comprises of sand or soil filled gunny bags, concrete cubes, bricks etc, which can be carried manually. Otherwise, large concrete blocks, containers of water or (stone) ballast or steel ingots could be used if mechanical handling facilities are available to load and unload them. The loads are placed eccentrically on the carriageway of a bridge in such a way that maximum bending moment is produced in any longitudinal member.

6.4.2.2 Other types of static loads

Any configuration which produces the design forces (load effects) in the member(s) could be adopted, for instance uniformly distributed load. Any of the appropriate methods of load distribution between the griders can be adopted in arriving at the test load and its configuration on the span. But the method of distribution of loads should be the same as adopted in the approved design.

However, where the approved designs are not available the owner of the bridge should specify the appropriate method of load distribution. In the case of multiple girders, it is possible that the design moments are simultaneously induced in more than one girder. It may well happen that the magnitude of the test load on the span could be greater than that of the design IRC vehicle, however the forces induced in any member should not exceed the specified design force of the load test.

6.4.3 *Mobile Test Vehicles*

Use of mobile test vehicles duplicating the axle loads for various classes of loadings should be preferred as compared to the use of equivalent static load which is difficult, time consuming and requires longer closure of traffic on the bridge. The advantage of using such mobile vehicles is that they can be quickly positioned in the exactly required locations. Also being rolling loads, all cross sections of superstructure are tested without having to workout special loading patterns to represent envelope diagrams of the span for bending and shear. In exceptional cases if commercial vehicles are used, the number and spacing of such vehicles need to be worked out, so as to produce equivalent B.M. and shear at critical sections on those due to the Standard IRC loading.

6.5 Methods of Measurements - Instrumentation

6.5.1 *Instruments for the Measurements*

The correct type, number and location of instrumentation used on a structure during a load test is critical to achieve satisfactory outcome.

Deflections, Strains and Inclinations shall be measured with following devices.

a) Linear Variable Displacement Transducer (LVDT) system with least count of 0.01 mm.

b) Dial gauges, with least count of 0.01 mm

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

d) Inclinometer, with least count 0.1º

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

f) Total station, with least count of 0.1 mm.

g) Thermometers, Digital or Analogue with least count of 0.5ºC

Photos 1 to 6 show typical instruments generally used in bridge load testing.

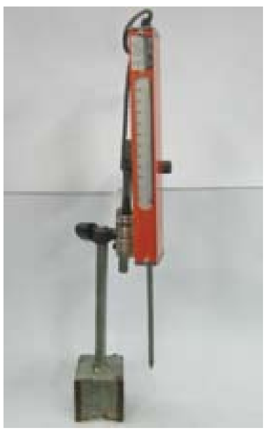

Photo 1 Linear Variable Displacement Transducer (LVDT)

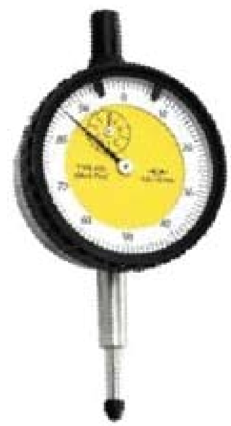

Photo 2 Dial Gauge

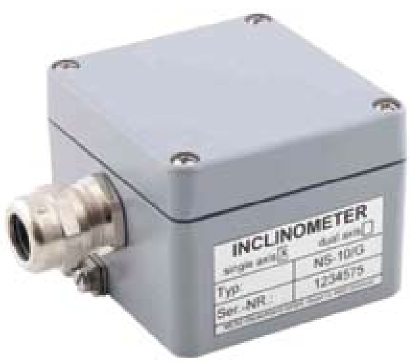

Photo 3 Inclinometer

Photo 4 Strain Gauges

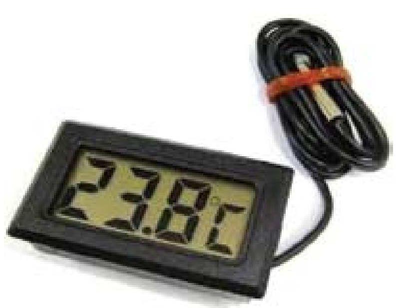

Photo 5 Digital Thermometer

Photo 6 Data Acquisition System

6.5.2 *Placement of Instruments*

LVDT's and/or dial gauges shall be fixed to magnetic stands. They shall be placed on firm scaffolding platforms with steel plates so that the magnetic stands are firmly located. Wherever dial gauges and analogue thermometers are used, the reading shall be recorded at height from the closest range possible to avoid parallax.

Glass plate of size 50 x 50 x 5 mm shall be fixed to the structure at the location of LVDT or Dial gauges. The spindle of LVDT/Dial gauge shall be in touch with the glass plate always while testing.

6.5.3 *Calibration of Instruments*

All testing instruments shall be duly calibrated at accredited laboratories before start of the load testing.

The frequency of calibration of testing instruments shall not exceed the periods specified by the manufacturer or 1 year whichever is less.

6.6 Mobilisation of Personnel and Testing Agencies

Only qualified technical personnel shall be engaged for bridge load testing. The testing Agency shall have satisfactorily completed at least five bridge load tests.

6.7 Supervision and Quality Assurance

6.7.1 The span under test shall be given a lime wash in order to identify formation of cracks during load test.

6.7.2 Scaffolding system provided for instruments shall be independent and shall not come in contact with any bridge component or any part of scaffolding system erected for recording readings from instruments installed for the test span.

6.7.3 Whenever spans are tested in urban limits, where pedestrian or vehicular traffic passes below, a safety scaffolding system shall be provided, as a safety measure. The scaffolding shall be able to take full load of test span in case of any eventuality.

6.8 Acceptance Criteria

The acceptance criteria of load test shall be as under:

6.8.1 Measured deflections and strains at critical location of particular structural member/ members shall be equal to or less than theoretical deflections and strains obtained from respective designs.

6.8.2 The percentage of recovery of deflections for various types of bridges after retention of test load for 24 hrs. shall be :

Type of Bridges	Minimum percentage recovery of Deflection at 24 hrs after removal of test load
1. Reinforced Concrete	75
2. Prestressed Concrete	85
3. Steel	85
4. Composite	75

6.8.3 The structure shall not show any cracks more than 0.30 mm for (normal) moderate exposure and 0.20 mm for severe conditions of exposure, spalling or deflections which are incompatible with safety requirements, as prescribed in the relevant design codes.

6.8.4 Structures which do not meet the above criteria shall be considered as non-compliant.

6.9 Re-Testing after Strengthening Measures

6.9.1 In case any bridge fails to perform in load test, a detailed analysis shall be carried out for non-compliance of load test commencing from designs, execution of work, quality control procedures adopted, existing reinforcements, existing strength characteristics of various structural elements, etc., and causes for non-conformity shall be identified. The details of required strengthening measures of such a structure be worked out for meeting the acceptance criteria and executed in order to restore the structure to its serviceable condition.

6.9.2 Since one span or multiple spans of the bridge are representative samples of the whole bridge, when any single span fails to perform under load test, leading to its rejection, whole of the bridge shall be rehabilitated and not the test span alone.

6.9.3 After satisfactory completion of rehabilitation exercise, of the whole bridge, load test shall be carried out for any randomly selected span, as per the method prescribed in **Clause 5.4** and test repeated.

7 CONDUCT OF LOAD TEST

7.1 Preliminaries for Load Testing

7.1.1 All preliminaries, like white wash to the underneath or/and for critical locations of test span, providing scaffolding system for instruments, scaffolding system for recording test measurements and safety scaffolding system shall be provided. Thereafter, loads shall be organized on the structure in any pre-approved form for completion of load test.

The testing agency shall prepare the required method statement and flow chart of activities, for smooth organization and completion of load test and for procuring calibrated instruments, their erection and fixing at appropriate locations, and recording all test measurements.

7.1.2 Since the load test is a process involving working continuously for a number of days all personnel involved shall be alert and cautious, while load test is in progress. In case of excessive deflections, or strains beyond allowable limits, test shall be stopped forthwith the span off - loaded and certified accordingly.

7.1.3 *The test span shall be floodlit at night while test is in progress.*

7.2 Monitoring for Temperature Effects

7.2.1 The deflection values and ambient temperature data are generally collected from dawn to dusk for two or three consecutive days at 1 hour intervals. The temperature vs.

deflection data are collected on these days and a curve drawn for each station (dial gauge location), which is taken as the basic curve for temperature correction. The temperature - deflection characteristics will be a linear line drawn between points of minimum temperature - least deflection and maximum temperature most - deflection. The deflection reading at any location and temperature during load test is super-imposed on the basic curve. The difference between the two values gives the true deflection for the location under reference, corresponding to the same temperature.

7.3 Main Load Test

7.3.1 Before start of loading, theoretical deflection at critical locations of the span to be tested, shall be worked out, with design load.

7.3.2 The test load shall be applied in stages, so that timely action, such as stopping the test, can be taken, if any untoward distress is observed at any stage. The dead load is already acting and the test load is usually a specified multiple of design live load more than one. The suggested stages of test load placement are 50 percent, 75 percent, 90 percent and 100 percent. These stages can be altered judiciously when loading is by vehicles. While loading the structure in stages, the next incremental loading should be added only after the deflections under the previous load have stabilized, which is normally about one hour, and this period is also called cooling time. Unloading should also be in the same stages as that of loading.

7.3.3 The test span shall be constantly monitored for appearance and widening of cracks at every stage of loading. The entire span under test, i.e. underneath and all critical locations shall be flood lit for easy visibility of cracks or distress, during nights.

The load-deflection characteristics at every increment should normally be linear and any abnormal behavior will get reflected in the load vs deflection data. If the deflection observed exceeds the calculated theoretical deflections at any stage, further loading, shall be stopped and span shall be allowed to stabilize for longer durations. In some cases immediately after placing 100 percent load, deflections may exceed marginally compared to theoretical deflections and deflections will get retrieved less than theoretical deflections in a span of less than two-three hours. If it does not come down then the load shall be removed and placed again after 2 to 3 hours. Subsequent action shall be taken after consulting all concerned Engineers. Occasionally cracking sounds at the location of expansion joints are heard, when the rotation capacity is exceeded, particularly, in balanced cantilever bridges, spalling of delaminated concrete is also possible during load test, however same needs to be investigated before continuation of load test.

7.3.4 The Pre-requisite for load test shall be as follows;

i) All visual defects shall be measured, mapped and plotted.

ii) Bearings shall be ensured for their functional condition.

iii) Expansion joints, gaps shall be ensured for their functional condition.

7.3.5 The following precautions shall be taken

i) All stagings shall be stable and safe.

ii) Staging for instruments and that for observers shall be independent.

iii) Staging for the instruments shall be rigid.

iv) Wherever required depending on site condition a safety staging shall be erected in order to avoid any eventuality to traffic and/or pedestraian below the span under test.

v) Due to temperature variation, the superstructure will tend to hog or sag, therefore, it shall be ensured that, contact with the spindle of the LVDT/ dial gauges is not lost. Spindle extension shall be fixed to take care of this aspect.

7.3.6 *Loading and Unloading Procedure*

7.3.6.1 Loading operation stages from 0 percent, 50 percent, 75 percent, 90 percent to 100 percent of test load shall be completed within 24 hours, similarly unloading operations from 100 percent, 90 percent, 75 percent, 50 percent, 0 percent shall be completed within 24 hours.

7.3.7 After complete loading the structure for 100 percent of its test load, it shall be retained for 24 hours on the structure.

7.3.8 The structure shall be off loaded immediately after 24 hours in the decremental stages of loading.

7.3.9 After 24 hours of unloading of 100% load from the structure, all required measurements be recorded.

Brief about loading and unloading sequence.

Phase	Description	Time Period
Phase - I	Commencement of load testing	0 hours
Phase - II	Start & completion of 50%, 75%, 90%, 100% of loading on the structure	On or before 24 hours after commencement of load test.
Phase - III	Retention of 100% load on the structure	24 hours.
Phase - IV	Start &completion of off loading structure in the sequence of 100%,90%, 75%, 50%, 0%	On or before 24 hours after completion of retention period of 100% load on the structure
Phase - V	Structure without any load	24 hours after complete off loading.

Photo’s 7, 8, 9 and 10 show typical load testing imprints, load testing by static loads & load testing by vehicles.

Photographs of Bridge Load Testing

Photo 7 Imprints Before Start of Load Testing

Photo 8 Load Testing by Static Method

Photo 9 Load Testing by Static Method - a Closeup of Loads

Photo 10 Load Testing by Vehicles

7.4 Recording Response of Bridge Components

7.4.1 *Observations*

Following parameters shall be observed, measured and recorded:

7.4.1.1 Deflection and strain measurements at designated locations (for instance for simply supported spans at mid span and at quarter span, in box girders it will be under each of external ribs) from LVDT's/dial gauges, strain gauges, etc. shall be recorded.

7.4.1.2 Deflection and strain measurements shall be recorded before start of loading, during each stage of loading, at regular intervals of one hour over a period of 24 hours after completion of 100 percent loading, during each stage of unloading, after off loading the test loads and after 24 hours of off loading the loads.

7.4.1.3 Appearance of cracks and their development, length, width, location, orientation shall be correlated with load.

7.4.1.4 Deformation of bearings during the load test shall be recorded for incorporating corrections into deflection measurements. LVDT's/dial gauges shall be placed at bearing locations of the super structure to record deformation of bearings. The recording of deformation shall be carried out as- and - when deflection measurements of super structure is recorded.

7.4.1.5 Ambient temperature in the body of structure shall be recorded for the purpose of incorporation of temperature correction into the deflection measurements. Temperature shall be recorded as - and - when deflection measurements of super structure is noted.

7.4.1.6 In locations of very large head room or continuous water flow below the structure, deflection of superstructure can be measured using total station instruments by placing prism of total station to bottom of girder or any location in girder at critical location. Digital levels with bar - coded staff can be used on top of superstructure after removal of wearing coat.

7.4.2 Measurement of Response from Load Testing

7.4.2.1 Deflection measurements shall be recorded through LVDT's or dial gauges with 0.01 mm least count. Total stations and precision digital levels can be used wherever water flow exists or head room is more than 6.0 m.

7.4.2.2 Wherever deflection measuring instruments cannot be fixed from bottom of span due to water flow or due to very large head room, prisms of total station can be fixed to the bottom of girders or at any location in girder along critical section.

7.4.2.3 A precision digital level can also be used to record deflection measurements from top of the superstructure. In such circumstances wearing coat shall be removed at measuring locations.

7.4.3 *Additional Measurements*

7.4.3.1 Strain gauges may be fixed and strain measurements recorded at locations of LVDT's or dial gauges or at any other specified location.

7.4.3.2 Electronic or optical devices like position sensitive laser device may be used for recording of entire load test operation.

8 ANALYSIS OF RESULTS

8.1 Measured deflections at critical locations shall be compared with theoretical deflections for the purpose of acceptance/rejection.

8.2 Measured strains at critical locations shall be compared with theoretical strains for the purpose of acceptance/rejection.

8.3 Recovery of Deflection

8.3.1 The percentage recovery shall be calculated for values of deflection. The percentage recovery is calculated at 24 hours after removal of load, the analysis is carried out as follows, after effecting temperature correction, bearing displacement correction and or rotation corrections to deflection data:

a) Initial value - deflections before commencement of loading = R1

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

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

d) Deflection measurements immediately after removal of test load = R4

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

f) Total deflection = R3 - R1

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

h) Percentage recovery of deflection 24 hours after removal of test load

$$\frac{R3-R5}{R3-R1}\times 100$$

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

8.3.2 The recovery of deflections shall satisfy the requirements as per **Clause 5.6.2** for various types of bridges.

9 REPORT

9.1 The report of load test shall include all information regarding completed load test.

9.2 General

9.2.1 *Project Identification, Location, Agencies Involved in Load Test*

9.3 About the structure

Description of super structure of bridge and in particular full details of span under test with passing reference to sub-structure and foundations.

9.4 Instrumentation

Details of instruments used like LVDT's, dial gauges, strain gauges, total station, digital level, crack measuring devices, thermometers, inclinometer shall be furnished. Location of instruments in the superstructure and their least count furnished. Description of instruments used in the test shall be furnished like make, model etc.

9.5 Load Testing Methodology

A detailed method statement along with load test scheme and detailed drawing showing location of loads, design deflections shall be furnished. Standard followed for the load testing with respect to that particular bridge shall be described. Photographs of all such arrangements be affixed.

9.6 Details of loadings used shall be furnished.

9.7 Load Test Results

Graphical presentation of temperature vs. deflection shall be furnished. Strain measurements wherever applicable shall be furnished. Load - deflection measurements, after incorporating necessary correction for temperature, deformation of bearings etc. shall be furnished in graphical as well as in tabulated formats.

9.8 References

9.8.1 Guidelines for load testing of bridge – IRC:SP:51- 2013

9.8.2 Approved drawing showing location of loads, design deflections and allowable strains shall be furnished. Any other technical reference used can be furnished.

9.8.3 Acceptance criteria, as per the guidelines and in conjunction with approved drawings shall be furnished.

9.8.4 Conclusions with respect to acceptance criteria shall be furnished.