Indian Roads Congress
Special Publication 35

GUIDELINES FOR INSPECTION AND MAINTENANCE OF BRIDGES

NEW DELHI 1990

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GUIDELINES FOR INSPECTION AND MAINTENANCE OF BRIDGES

1. INTRODUCTION

1.1. Bridges are the vital infrastructure elements of Highway network. Maintaining serviceability of bridges and consequently retaining their level of reliability during their life time deserves high priority from techno-economic considerations. This aspect, unfortunately, has not hitherto been given the importance it deserves.

1.2. A large number of bridges have been constructed on various roads all over this country and the pace of activity has been particularly intensive in the last two or three decades. Due to lack of regular maintenance of such bridges, incidences of structural deterioration and collapse of bridges have been growing in the recent past. Attention in the next few decades thus needs to be focussed on the preservation and rational management of the large stock of bridges built in the recent past and to rehabilitate and strengthen the older bridges which have deteriorated due to inadequate maintenance. The Indian Roads Congress, realising the paramount need for maintaining durability of such assets, have constituted a Committee (B-10) for Bridge Maintenance and rehabilitation to look into the various aspects of bridge management and to evolve appropriate guidelines thereto with the following personnel :

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The Secretary, IRC (D.P. Gupta)

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Rep. of Structure Engg. Research Centre (M.S. Kapla)	

The Committee decided that it should bring out guidelines on all relevant aspects of bridge management viz :

(i) Inspection and maintenance of bridges

(ii) Evaluation of load carrying capacity of bridges and

(iii) Methods and techniques of major repairs strengthening and rehabilitation of bridges.

This manual covers guidelines on inspection and maintenance of bridges and suggested strategy for a phased programme to ultimately achieve the recommended objectives. The other two guidelines are to be issued as separate documents. The Subcommittee for preparing these guidelines, consisted of :

A.G. Borkar	:	*Convenor*
M.G. Prabhu	:	Member
S.A. Reddy	:	Member
M.C. Sharma	:	Member
M.C. Tandon	:	Member
N.G. Thatte	:	Member

The Committee held four meetings and at the fourth meeting held on 9th March 1990, these guidelines were finalised.

The guidelines finalised by the Committee were considered and approved by the Bridge Specifications and Standards Committee in their meeting held at Bombay on 5th and 6th April 1990 subject to certain modifications. Later on, the modified guidelines were approved by the Executive Committee in their meeting held at New Delhi on 20th April 1990 and the Council of the Indian Roads Congress in their meeting held on 29th April 1990 at Shimla.

It is hoped that the application of these guidelines will assist in improving the understanding of the bridge structures and their long term durability and serviceability.

Any suggestions on these guidelines for future revisions will be appreciated. Need for periodical review of the guidelines can hardly be over emphasised.

1.3. Lack of regular maintenance of bridges in India has led to deterioration of some bridges rather early in their life and quite a few bridges have had to be replaced much earlier than their designed life. Maintenance of bridges generally gets neglected in this country because of the prevailing misconception that the bridges once constructed do not need any substantial maintenance particularly in the first couple of decades after construction. In the absence of proper data base and regular inspection, generally *ad-hoc* decisions are taken regarding maintenance as a sort of fire fighting operation or crisis management without appreciating the magnitude of the overall problem or interse priorities at road network level. The result is that we have not been able to optimise the utilisation of maintenance grants. Again, with more and more cases of bridge deterioration coming to light coupled with increased use of the existing stock of bridges, additional resources will have to be provided hereafter towards maintaining the existing bridges. This emphasises the need for optimal utilisation of resources.

1.4. Scope of the guidelines on inspection and maintenance of bridges is as follows :

(a) **Inspection** : Guidelines have been laid down for inspection of road bridges covering also culverts, minor and major bridges, as well as submersible bridges, bringing out what to look for during inspection of each class of bridge. The type of inspection have been classified together with their respective periodicity and the level of engineering officers to inspect, depending on the importance and environment of the bridge. The guidelines also indicate the various inspection facilities necessary depending on the type and importance of the bridge, and the tools and instrumentation to be used for inspection and testing. The guidelines give proformae to record the details of original bridge features, results of inspection etc.

(b) **Maintenance** : The guidelines cover —

(i) Defining the goals of bridge management and maintenance policy indicating the means to be employed and the strategies for implementation;

(ii) Evolving a methodology of utilisation of data provided by bridge inspection.

(iii) Assessment of present situation as regards the bridge maintenance;

(iv) Making a brief inventory of the different methods and techniques of bridge maintenance'

(v) Defining the research areas to improve the bridge maintenance techniques.

1.5. It should be noted that the guidelines have been evolved only for normal types of bridges (which constitute the majority of existing bridges). Special type of bridges such as suspension bridges and cable stayed bridges have been excluded as these are very few in number and their maintenance needs a more specialised approach.

1.6. Guidelines for Evaluation of Load Carrying Capacity of bridges and Guidelines for Methods and Techniques of major repairs, rehabilitation and strengthening of bridges are to be issued as separate documents.

1.7. The guidelines are intended to serve as a document to be consulted before making decisions in bridge management. Recommendations included in the guidelines are of a general nature and do not exhaustively deal with specific technical issues. While using these guidelines there is an obvious need for each State or Authority to adapt them to develop its own set of detailed instructions, procedures, and regulations in respect of its bridges. The guidelines are to be looked upon as a document on suggested "good practices" and not as mandatory specifications.

2. BRIDGE MANAGEMENT SYSTEM

In these guidelines the following definitions have been adopted :

2.1. Maintenance

This is defined as the work needed to preserve the intended load carrying capacity of the bridge and ensure the continued safety of road users. It excludes any work leading to improvement of the structure, whether by strengthening to carry heavier loads, by widening or by vertical realignment of the road surface. The maintenance operations begin with the opening of the bridge to traffic. It excludes repairs of any damage caused by exceptional causes like landslides, earthquake, cyclones, fire, etc., but it includes preventive maintenance.

2.2. Repairs and Rehabilitation

These activities also meet the above definition of maintenance, but are larger in scope and cost than maintenance. Rehabilitation operations aim at restoring the bridge to the service level it once had and has now lost. In some cases this consists of giving the bridge the service level which was intended, but which has never been attained, because of the deficiencies in the original design or construction.

2.3. Improvements

Strengthening, widening, raising etc. aim at upgrading the level of service of a structure. The basic parameters taken into account in such improvements are :

Load carrying capacity, and

geometric parameters, (width of carriageway, footpaths, vertical clearance, etc.)

2.4. Replacement or Reconstruction are the works carried out when the whole structure or at least its major components such as whole superstructure are removed and replaced.

2.5. Bridge Management Present Scenario

Bridge Management deals with activities related to bridge "from their entry into service until their reconstruction", excluding bridge planning, design and construction. The present maintenance management practices vary from State to State and only a handful of these States have compiled the requirements of periodical inspection and maintenance of bridges for the use of their staff. Occasional inspections are carried out though they may not result in proper maintenance repairs, records and data base are usually inadequate.

Most of the authorities carry out inspections and maintenance of bridges through their own engineers. However, some authorities are not well equipped and get this done through contractors and consultants.

The maintenance is governed by economic and traffic considerations. The criteria applied are the engineering criterion and the financial criterion. The criterion used on engineering basis is normally the subjective assessment by an engineer with experience or training in maintenance and repairs work mostly at the level of an Executive Engineer. For improvement of complex structures the asessment is supplemented by advice from a specialist or the assessment is completely left to the specialist. At times, investigations on testing for detecting the deficiencies, or the presence of deleterious materials is done. However, there appears to be no systematic examination of the general effectiveness of maintenance or repairs. The maintenance policy thus aims at merely ensuring that sufficient work is done each year to prevent accumulation of work which would impose a heavy burden on future highway budgets.

Sufficient data is not available to enable financial requirements to be quantified for satisfactory standard of maintenance or repairs. It may only be possible to express qualitatively whether the allocation of funds is sufficient to prevent the progressive deterioration of the bridge by pursuing a policy of preventive and remedial maintenance and repairs. No formal studies are usually made and expenditure justified by the benefits obtained. In general the level of expenditure on bridge maintenance is rather low and the exercise of comparing the cost of bridge maintenance or repairs or strengthening with the capital cost for reconstruction or replacement is seldom done.

In most of the States regular and systematic maintenance inspection of bridge is not a rule and a rational annual programme of maintenance is not drawn up on the basis of which funds could be asked for. In most of the States again, the provision of funds in the budget is for maintenance of roads and bridges together i.e. no separate budget provision exists for maintenance of bridges. In a few States, the funds are asked for on the basis of some established financial norms, say, a certain amount per metre length of the bridge and this includes the cost of ordinary maintenance and that of unpredictable work that is needed from time to time. Cost of inspection, repairs for rehabilitation, strengthening, improvement etc., and testing, traffic warning signs and control, etc., are also included in this. The funds allocated normally are far short of requirements and consequently the maintenance and other repairs suffer.

In most of the cases there is no exclusive organisation for inspection and maintenance of bridges. The personnel in Public Works or Highways organisations look after the inspection and maintenance of bridges along with the highways and other construction works. The engineering personnel learn by experience, but no formal training in this discipline is given.

2.6. Requirement for Adoption of Scientific Bridge Management System

A scientific bridge management system is a collection of organisational elements, regulations, standards and procedures to monitor, analyse and implement the activities following bridge construction. Road authorities can use the bridge management system to achieve optimum use of available funds, adaptation of existing bridges to traffic needs and public safety. In other words, the bridge management system (BMS) is a rational and systematic approach to organising and carrying out all the activities concerning bridges, such as predicting bridge needs, defining bridge conditions, allocating funds for maintenance, rehabilitation, strengthening, replacement, reconstruction, identifying and prioritising bridges for various actions and finding cost effective alternatives for each bridge, scheduling maintenance, monitoring and rating of bridges and maintaining information data base. The BMS enables the engineers and administrators at all levels to select optimum solutions to achieve the desired level of service within the funds allocated and to assess the future funding requirements. Its logical development would include a minimum of the following six major modules and associated submodules :

(1). Data Base Module

(2). Network level Major Maintenance, Rehabilitation and Replacement (MR&R) Selection Module

(3). Maintenance Module

(4). Historical Data Analysis Module

(5). Project Level Interface Module

(6) Reportng Module

The data base is the core module of the system. Fig. 1 will show, how the other modules and submodules which operate on the data to perform the function of bridge management, all utilise the core.

2.7. Data Base Module

A pre-requisite for attempting any scientific system of management of bridge maintenance is to have a proper data base module comprising bridge inventory, bridge inspection record and maintenance, repair and rehabilitation data.

2.7.1. **Bridge inventory** : The bridge inventory consists of the main administrative and technical data for each bridge such as name, location, administrative unit, type of road, construction data, technical data (foundation, substructure and superstructure), design loading classification, etc. The bridge stock can be classified according to construction

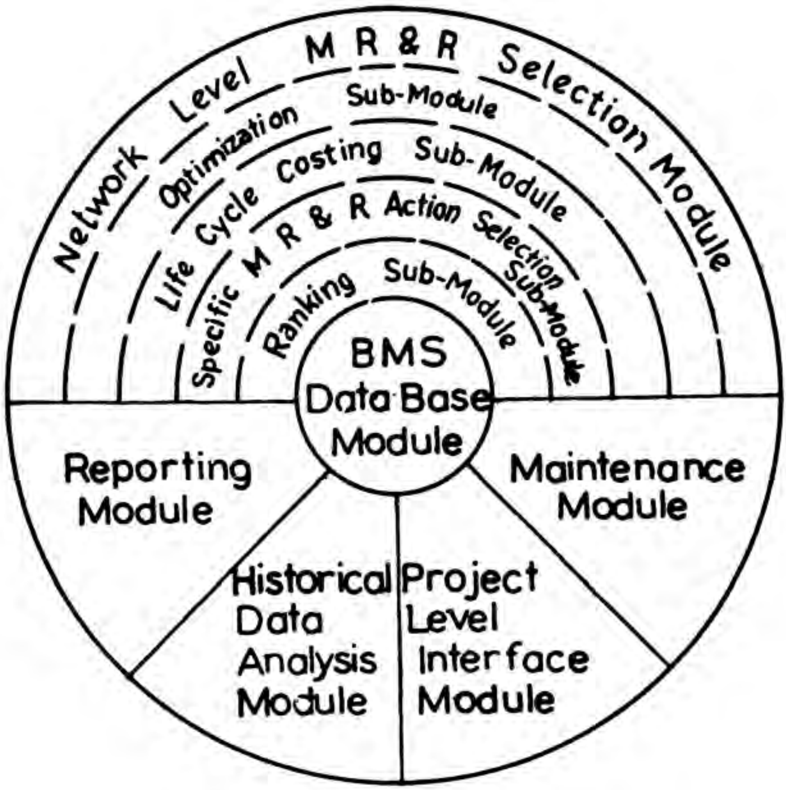


Figure 1. Modules and submodules comprising the model BMS. (SOURCE NCHRP REPORT 300)

data, length, type of material, carriageway width, type of structure etc., and can be useful for deciding the maintenance organisation, definition of different service levels, listing of functionally inadequate bridges or substandard bridges under the given circumstances. A suggested format is given in *Appendix 1* (major bridges) and *Appendix 3* (minor bridges). A specimen is given in *Appendix 2*.

2.7.2. **Bridge inspection record** : Bridge inspection record consists of data gathered and recorded while checking the condition of various spans and following up the deterioration process from one inspection to another. In Chapter 3 detailed guidelines for inspection of bridges have been given.

2.7.3. **Bridge maintenance, repair and rehabilitation data file (MR&R)** : This is the collection of all the data pertaining to the history and condition of the bridge since its inception. In addition to the basic design data and construction data, it contains maintenance, repairs or improvement work data including the recorded drawings of major repairs, traffic data and reports of exceptional events such as earthquakes, abnormal floods, landslides, etc. The data as stored provides adequate information to make decisions on bridge strengthening or load limits.

The bridge data bank should contain the following information for all bridges :

Identification :	Unique structure number related to road network Map reference File No.
Administrative Data :	Owner, Maintaining Authority, Agreements, Statutory mains, services etc. Year constructed. Design certificates and records.
Environment Data :	Conditions of exposure/mild/moderate/severe/very severe/extreme
Crossing Data :	Over or under road, railway water etc. Load carrying capacity clear width, Head-room, Cross reference to crossing road.
Construction Data :	The method of construction, any problem faced, solutions adopted, special points, if any.
Structural Data :	Structure : road bridge, retaining wall, culvert etc. Form : number and length of spans, skew etc. Simply supported or continuous, frame, arch

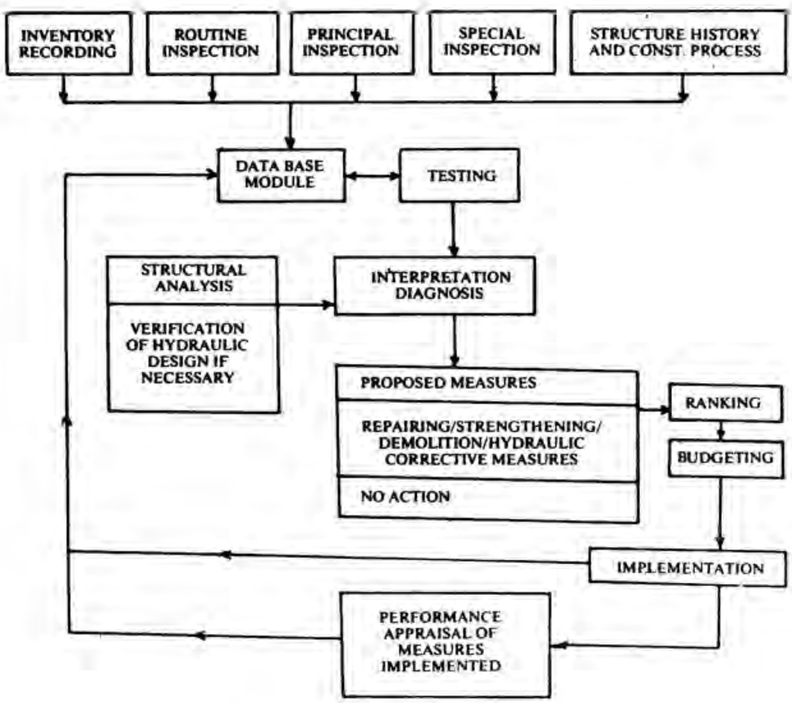
	Construction : solid slab, reinforced concrete, prestressed concrete, structural steel, masonry or brickwork, foundations.
Ancillaries :	Expansion joints, Bearings Railings/Parapets, waterproofing.
Utility Services :	Type of services, Supporting arrangements.
Inspection Data :	Date last inspected, summary of conditions. Evaluation of executed maintenance and repairs.
Particular problems :	Maintenance costs, Durability of components, Paint or coating systems, Feedback of specific details.

2.8. Bridge Management Process

2.8.1. The phases of bridge management process are inspection, repairs for maintenance, evaluation of the bridge adequacy, strengthening and rehabilitation and replacement or reconstruction. Fig. 2 is a chart indicating various steps for assessing a structure and decision making regarding repairs/strengthening/demolition/no action which constitute the data base module. In evaluation of load carrying capacity though safety considerations are of prime importance, considerations relating to flow and comfort of traffic, economic benefits/loss also should receive due weightage. Evaluation of bridges which appear to be in a critical condition, should be carried out on emergency basis. The structural adequacy covers not only the load carrying capacity but also the overall hydraulic and structural soundness including aspects like scour, flood protection works, foundations, approaches, etc.

2.8.2. Rehabilitation or strengthening must be preceded by condition evaluation and proper assessment of repair needs. Some elements of the bridge structure such as expansion joints, bearings, waterproofing, parapets, railings, wearing courses, drainage spouts, etc. which account for nearly 15 to 20 per cent of the total cost of the bridge may not have the same life as that of the bridge proper and may require frequent repairs and replacement. It may also be economical to improve the maintenance techniques so as to limit the expenditure on major repairs or replacement. Improvements might be necessary on account of strengthening required to cater for increased loads or widening to cater for increased volume of traffic.

2.8.3. Replacement of a bridge becomes necessary only after the existing bridge has outlived its life or is considered not suitable for strengthening to cope with the increased demands or when the costs of



DATA BASE MODULE OF THE
BRIDGE MANAGEMENT SYSTEM

Fig. 2.

strengthening and rehabilitation are too high compared to replacement costs considering the residual life of the existing structure. A factor in favour of replacement could be that traffic can continue to use the existing bridge while it may not always be possible to permit traffic on a bridge which is being strengthened or rehabilitated. On the other hand funds being limited, rehabilitation may allow more than one bridge to be brought back into service as against one replacement. Replacement should, therefore, be examined as an alternative solution to strengthening or rehabilitation.

2.8.4. **Suggested guidelines**

2.8.4.1. Bridge management is a part of the general road management function as well as a part of the general bridge policy, the latter setting the standards from the first design phase through construction and maintenance to the final replacement if need be. The concept of bridge management policy to be adopted should take into account availability of resources and forecast of the future needs. This would necessarily involve having a reliable data base of the existing stock of bridges, traffic loads, environmental and socio-economic constraints. The various options available deserve careful consideration. A proper rationale will have to be established for estimating the extent of priorities, ranking of overall bridge needs, including the existing stock. Similarly, a judicious choice from the various options available for a given bridge like doing nothing, regular maintenance, imposing load restrictions, keeping the bridge under extensive surveillance, repairing, strengthening and replacement will have to be made and also prioritisation will have to be done amongst the bridges at network level for various actions. So far as maintenance is concerned detailed policy proposals are given in the subsequent paragraphs.

2.8.4.2. **Broad guidelines for rehabilitation and strengthening of existing bridges comprise the following** :

(a) Forecasting of the following needs :

(i) Traffic trends as regards traffic volume, vehicle loads and size.

(ii) Environmental constraints due to increasing trend in favour of preservation and safeguarding the environment while carrying out bridge works, in particular, avoiding permanent changes.

(iii) Socio-economic considerations These apply to increase demand for overall safety and to maintaning of existing service levels, avoiding traffic restrictions during rehabilitation and strengthening which may imply major additional costs.

(b) In planning rehabilitation and strengthening work priority setting concepts using discount rates can be employed. This method is suggested to estimate future expenditure while evaluating the various solutions to a given problem.

(c) A choice must be made between rehabilitation and strengthening or replacement. Intermediate solution such as limited rehabilitation, servicing to postpone replacement may also be envisaged. Their respective merits should be analysed in the light of the following:

  (a) The cost and benefits including those occurring in the future, with appropriate discounting.

  (b) The technical and financial uncertainties of rehabilitation or strengthening, and

  (c) Inconvenience caused by replacement (to users, residents, possible environment damage etc.)

Such analysis should be made in all cases where works of any significant scale are needed on existing structures.

2.8.4.3. **Prioritisation of strengthening/rehabilitation** : It is essential that before prioritisation for repairs, inspections are carried out and evaluation of load carrying capacity is also done. The former, i.e., inspection, will decide the condition marks and the latter, i.e., evaluation of load capacity, will determine the load marks of each bridge. These will form the basis of ranking of bridges in need of repairs. The importance of each element in the functioning and safety of the bridge and also the importance of route are considered before a final ranking point is calculated for the bridge. The rank of each element will thus reflect :

— the current condition
— the load carrying capacity in relation to the current traffic.

— the importance of the element for the functioning of the bridge.

— the importance of the route on which the bridge is located.

Alternative repair plans should be considered for the bridge in the top of the ranking list for which repair works can be carried out within available budgets. Selection among evaluated repairs plans is normally based on the net present value of the repairs plan applying appropriate discount rate with possible consideration of traffic costs imposed on users by the work programme (detours etc.)

2.8.4.4. **Organisation and Personnel** : Routine inspection and maintenance are best carried out by the normal departmental staff in charge of the concerned bridges. Principal and special instructions require special skills and experience and could be carried out by special departmental teams assisted by outside agencies as may be necessary. Likewise, major repairs, rehabilitation and strengthening measures are specialised tasks requiring expert agencies for implementation. Depending on the work load in the organisation, it might be advantageous to set up exclusive units within the department to carry out most of these operations departmentally with the help of trained engineers and special equipment and machinery procured for the purpose. These have to be supplemented by selected outside agencies to excute such special works according to specific needs. While sanctioning staff for such departmental units it must be recognised that the norms of work load for them have to be more conservative than for routine construction and maintenance jobs.

2.9. **Suggested Maintenance Policy**

2.9.1. Though at present, the bridge maintenance policy varies from State to State a need for a well defined common policy cannot be overemphasised. As mentioned earlier, maintenance covers all operations aimed at maintaining the state of serviceability i.e. maintaining the load carrying capacity as per design and the level of comfort and functional security both for users and those in its vicinity.

Maintenance policy will include three important considerations : (a) safety (b) flow of traffic and (c) economic and technical aspects. These three considerations may carry slightly different weightages for different classes of roads on which the bridges are situated. However, the safety aspect shall prevail.

The bridge maintenance includes all operations needed to keep the bridge in good order till it is replaced, such as (1) conservation of original facilities, (2) repairs of damage due to environmental effects (traffic loads, climate etc.) and (3) repairs of accidental damage. The maintenance policy, therefore, has implied prerequisites like satisfactory design and construction, effective bridge inspection and documentation, satisfactory evaluation techniques and a suitable maintenance organisation qualified to implement the maintenance policy.

2.9.2. **Safety aspects :** Safety of bridges should be considered as an important aspect of bridge maintenance policy. Even though the risks arising from the collapse of bridges are very low as compared to those from other causes, there should be no doubt that preservation of structural safety is of paramount importance in bridge maintenance not only because it is technically feasible to safeguard the structure but also because it is economically sensible to do so. Inferior maintenance is likely to cause potential loss of investments or initiate major repairs. Disregard of deterioration and faults in structural members may create risks of failure by collapse. An evaluation of the risks and their potential consequences must be made.

2.9.3. **Economic aspects :** When considering bridge maintenance from economic point of view the life cycle of bridge must be considered. Within the cycle of maintaining and replacing the bridges many decisions have to be made. The time it takes for a full cycle is the life span of a bridge and the life of the bridge very greatly depends on the environment (traffic loads, climatic condition), quality of design and construction and quality of maintenance and repairs. In a given environment, bridge building and maintenance techniques offer a choice of quality levels within which the tasks can be performed. The maintenance work usually allows a choice of quality levels, provided that requirements for safety of the user are not neglected. Within the designated life cycle of the bridge there is a choice of both qualities and techniques for maintenance. These alternatives need to be evaluated. In evaluation of alternatives, significance of future costs has to be assessed. The future costs are of lower present value (LPV) or consequence than present costs. To quantify this, the concept of discounting should be employed. The consequences of not taking up maintenance repairs in time should also be worked out in financial terms in a similar manner.

2.9.4. **Traffic aspects :** It should be recognised that strengthening of bridges for increasing traffic volumes and loads is more difficult than the same for roads, because of cost and technical complexities. This fact must enter into the maintenance policy. A division of bridges into three categories in accordance with the traffic importance, traffic volume and traffic risks may serve the purpose for allocating funds for bridge maintenance.

2.9.5. **Engineering aspects :** The existing bridges could be of timber, steel, cast iron, concrete, and masonry each of which has its own maintenance problems. The bridge design should consider the total cost of the structure throughout its life span including maintenance, repairs and replacement and it should be emphasised that feed-back of maintenance experience to the designers is imperative for the reduction and improvement of future maintenance operations. Accessibility to all parts requiring inspection and maintenance is a must. These accesses can be in the form of stairs, ladder or negotiable slopes, etc.

Sometimes just an inspection path will do. Use of more advanced inspection and maintenance equipment such as travellers, mobile bridge inspection units should be encouraged. The bridge should be so designed that the need for maintenance is minimised with due regard to the possible increase in construction costs. In fact, preventive maintenance should start with the design. The choice of material is also important. However, radical changes of materials for bridges should be investigated thoroughly before using them. It is felt that maintenance work and cost can be reduced significantly when the design of bridge considers that (a) the bridge deck is drained properly, (b) the deck top is adequately waterproof and (c) expansion joints and construction joints and bearings which are vulnerable elements are as few as practicable. Also, utility services, if provided, should not interfere with the requirements of effective maintenance of the bridge. Provision of appropriate instrumentation in the bridges during construction could help in monitoring the condition and performance of the bridges.

At present, assessment for maintenance depends on the individual experience of the engineer. It is likely that such experience will continue to provide the basis in many decisions on the various tasks that comprise maintenance. There is a real need for collective experience on bridge maintenance to be assembled and evaluated at both the State level as well as National level. For ordinary bridges built with conventional materials and techniques, assessment of requirements of maintenance should not be a problem. However, for important bridges and bridges designed and constructed with specialised techniques and/or using comparatively non-conventional materials, maintenance requirements of each such bridge will be different and special. In fact the designer and constructing agency of the bridge should prepare a maintenance manual for such a bridge highlighting the special requirements to suit its construction method and design, and hand over the same to the authority who will maintain the bridge according to the instructions in the manual. The road authority, for such bridges should make it a practice to insist on a maintenance manual for such special bridges from the designer and builder, by making it a contract condition.

The maintenance organisation should systematically examine, record and review the effectiveness and condition of maintenance work done in previous years. This will indicate where improvements are needed and will enable the engineer to assess the long term durability of different materials and methods.

2.9.6. **Responsibility for maintenance**

2.9.6.1. Bridges form a part of the transport network. The maintenance of bridges should be the responsibility of the Authority usually responsible for maintaining the associated network. Along with this the issue to be considered is centralisation versus decentralisation. It is always advantageous to restrict centralisation to only the bridges on the primary routes for the purpose of decision making and allocation of funds while bridges located in remote areas or serving rural areas are better maintained by those who have constructed them viz. local authorities. Bridge management requires in depth knowledge of inspection of individual bridges which is better acquired at local level than from a remote governmental agency. The costs are also better assessed locally.

The following principles are recommended :

(i) A Bridge may often be common to networks e.g. where a road crosses over or under a waterway or another road belonging to a different network. In such cases maintenance should be carried out as far as possible by the Authority of the overpassing network. (Due to extant provisions in the Railway Act this will not apply to bridges over or under railway line).

(ii) Inspection and maintenance of a bridge should be the responsibility of a single Authority only.

(iii) When one of the Authorities concerned is considerably better equipped than another to inspect and maintain a bridge, preference should be given to the former in carrying out the maintenance, unless some complex administrative or legal problems are likely to arise.

(iv) Authority responsible for inspection and maintenance should keep the other Authority informed with regard to all works carried out on the bridge.

2.10. **Training**

Bridge management requires extensive team work involving various levels of responsibility and skills. Training programmes need to be organised in order to develop such expertise and team work. Local consultants and specialised agencies could be involved for this purpose. Training facilities should be set up at central level for training of trainers and at local level for imparting training to actual field engineers.

3. INSPECTION OF BRIDGES AND DOCUMENTATION

3.1. Purpose of Inspection

Bridge inspection is undertaken to ensure safety and serviceability to the user. The purpose of bridge inspection can be identified as follows :

(a) to provide assurance that the bridge is structurally safe and fit for its designed use. (This relates to the gradual deterioration of the bridge with time or to an accidental occurrence such as impact, flood or overloading);

(b) to identify actual and potential sources of trouble at the earliest possible stage: and propose remedial and preventive measures.

(c) to record systematically and periodically the state of the structure. (to provide necessary information on which decision will be made for carrying out maintenance repairs, strengthening or replacement of the structure.) and

(d) to provide feed-back of information to designers and custodians of bridges on those features which are likely to give maintenance problems and to which necessary attention is best given during design and construction stages.

3.2. For the purpose of maintenance inspection, the bridges and cross drainage works will be classified into two categories;

(i) Major bridges with length between abutment faces upto 60 metres or more.

(ii) Minor bridges and culverts with length between abutment faces less than 60 metres.

Bridges could further be classified according to the type of environment to which they are exposed and/or according to the form of the bridge or the material.

3.3. Documents

In accordance with the provisions contained in IRC : SP-18- "Manual of Highway Bridges and Inspection", it is necessary to compile an original bridge report on the basis of as-built drawings alongwith the design assumptions, details of reinforcement and other details supplemented by site inspection. The information contained in the original bridge report will be utilised to compile the bridge inventory record given in *Appendix 1* (for major bridges) and *Appendix 3* (for minor bridges). a typical case of a bridge has been compiled and is given at *Appendix 2*. An inventory so prepared will form a part of the data base module in due course as discussed in Chapter 2.

3.4. There should be three classes of maintenance inspection as below :

(1) **Routine Inspection:** Routine inspection shall be carried out periodically by competent and qualified engineering officers of the authority in charge of bridges. The purpose is to report the fairly obvious deficiencies which might lead to traffic accidents or cause high maintenance and repairs cost, if not attended to promptly. The routine inspection will have to rely mainly on visual assessment using conventional standard tools *(Appendix 6)* and methods. The routine inspection of minor bridges and culverts shall be the responsibility of junior level officers (say below the rank of Executive Engineer) while the routine inspection of major bridges shall be the responsibility of senior level officers (say at the level of Executive Engineer and above). The frequency of inspection shall be at least once a year, but preferably twice a year, before and after monsoon. However, bridges located in hilly terrain prone to effects of landslides and bridges in severe exposure conditions shall be inspected twice a year before and after the monsoon. To facilitate proper routine inspection, a simple checklist is suggested *(Appendix 4)*. Each officer responsible for inspection shall prepare a calendar of inspection of bridges in his jurisdiction.

(2) **Principal Inspection:** This is a more intensive and detailed inspection and will involve close examination of elements of the structure. It will be primarily close visual assessment supplemented by standard instrumented aids. Detailed inspection of the foundation should also be included and it may involve underwater inspection wherever appropriate. This inspection shall be carried out by a senior level engineer against a comprehensive check list of items related to the material, condition and situation of the structure as given in *Appendix 5*. The first principal inspection shall be done before the defect liability period of contract expires but not later than 6 months after completion and opening of the bridge to traffic and later this principal inspection

shall be followed by subsequent inspections at intervals of maximum three years. The observations made in the first principal inspection shall serve as a bench mark for subsequent inspection observations. More frequent inspections shall be essential if the routine inspection reveals any distress in the bridge structure. A calendar also for principal inspections of bridges shall be prepared by each officer responsible for such inspections.

(3) **Special Inspection :** This shall be undertaken in the event of unusual occurrences such as strong earthquake, accidents, passage of unusual loads or floods, major weaknesses noticed during routine or principal inspection, unusual settlement of foundations, and substantial changes of traffic pattern. When any bridge of similar design and constructed almost at the same time are showing some distresses, all such bridges may be subjected to special inspections. Such inspections may require a good deal of supplementary testing and structural analysis and will invariably require detailed involvement of design organisations and experts in the relevant fields who should be senior level engineers.

3.5. Inspection Procedure

3.5.1. The inspecting Engineer should familiarise himself with the details of the structure and as to how it is intended to function. The earlier inspection reports should be studied so that the condition of the defects earlier noticed could be checked. Forms at *Appendices 1, 3, 4 and 5* should be used. The activities scheduled during the inspections of the bridge should be planned in detail including sequence of inspection. Advantage should be taken of any situation which will facilitate inspection such as erection of scaffolding for repair work, closure of traffic lanes of road works etc. Where mobile bridge inspection unit is decided to be used the inspection should be carefully planned before hand so as to minimise the period of use of such equipment as the hourly cost of use of mobile inspection unit is quite high, and it obstructs one lane of traffic on the bridge.

A preliminary visit to the bridge site to locate the positions of bridge inspection unit is desirable.

3.5.2. Effectiveness of an inspection depends on proper recording of the actual state of affairs. Every point should be noted as soon as the observation is made. In addition to recording defects or damages their absence also should be recorded. If any previously noted defects have been rectified the same should be noted and recorded. The inspection should follow a pre-determined pattern to ensure that no component is overlooked. A typical pattern of inspection may be on the following basis :

Foundations
Abutments
Wing walls/returns
Piers
Columns and bearings
Soffits of the deck including beams
Details under the deck
Condition of road surface, drainage, parapets,
Expansion joints
Condition of approaches
Condition of protective works.

3.5.3. **Underwater inspection :** Visual examination of the surface may be done by minimum cleaning to remove marine growth like coral deposits, algae, etc. Detailed inspection for obtaining more information of deteriorated areas should be done, after clearing the surface growth, so as to enable closer inspection. Where underwater damages are reported or are expected special inspection shall be carried out which shall utilise selected non-destructive testing methods or even destructive sampling procedures. The purpose of this inspection should be to detect hidden damages or loss of cross section area and to assess the integrity of the material.

Underwater inspection is a highly specialised activity and as such should be entrusted only to competent agencies experienced in underwater inspection. Such agencies should be fully briefed on the components to be inspected and the nature of defects to be inspected. Close circuit television may be used where the water is reasonably clear. Where visibility is poor, portable echo sounding equipment can be used to provide a reasonably accurate profile. If despite detailed underwater inspection there is still concern for the safety of the structure it will be necessary to dewater the area (where possible) with the help of suitable cofferdams or small air locks to enable visual inspection of the components under dry condition.

3.5.4. Where design of a bridge, hydraulic and/or structural, has been done on the basis of model experiments, some of the parameters emerging out of such model study may also be monitored during inspections e.g. scour depth, velocity etc. during floods.

3.6. Means of Access

Appropriate means of access are a prerequisite for all the three forms of inspection. For every means of access, special emphasis shall be laid on safety, ease and convenience. Due consideration shall be given at the design stage itself to the provision of proper means of access taking into account individual requirements of the structure and its components such as type of structure, topographical, local and climatic conditions of the bridge site, height, minimum water level, possible clearance, safety etc. The possible means of access can be of the following type :

I. Built-in access;

II. Semi-mobile access :

- (i) access ladders;
- (ii) manholes;
- (iii) hand-rails;
- (iv) catwalks;
- (v) platforms;
- (vi) inspection pits;
- (vii) provision for setting up planking, scaffolding etc.;
- (viii) fixtures and provisions for operation of semi-stationery inspection equipment;

III. Mobile equipment:

- (i) equipment operating under the bridge (travellers) from the ground boat/barges'
- (ii) equipment operating from the bridge deck (snoopers).

Provision should be made for power supply for connection of lamps, tools or other electrically operated type of equipment. It is absolutely essential that every state should have adequate number of mobile bridge inspection units. For underwater inspection, the inspecting personnel should utilise the services of special equipment and divers and where possible necessary television cameras with remote control brought into proper position by a diver with the advice from inspecting personnel could be employed.

3.7. Assessment Techniques and Equipment

These should be considered as an integral part of bridge inspection. They should be selected in relation to the number and type of bridges to be inspected, the personnel available with appropriate standard of professional training and level of inspection.

In a very general way routine inspection will be by visual assessment using conventional standard tools listed in *Appendix 6.* Principal inspection will also have to rely primarily on visual assessment but will be supported by more advanced tools and methods. Special inspection may require rather advanced techniques and equipment apart from visual assessment.

Possible instrument-aided assessment methods (only indicative) are listed in *Appendix 7.* Standard tools listed in *Appendix 6* could be used along with the Guidelines on field tests, including tests of non-destructive and destructive type are given in *Appendix 8.*

3.8. **Inspection Report**

The inspection report shall be in the prescribed formats given at *Appendices 4 and 5*. Sketches or photographs should be used to illustrate the defects and other condition of the bridge. Free hand sketches should be made during the inspection at the site itself. The size and location of the defects should be dimensioned though the sketch itself need not be to scale. For taking photographs reference number of the bridge and the location of the defects may be written in colour at the appropriate place. Apart from reporting defects and deficiencies any proposals or recommendations for strengthening and repairs of the affected components should also be included.

3.9. **Follow up Action**

Minor points or shortcomings noticed during inspection shall be immediately attended to by the engineer in charge. However, in case of any important or major shortcoming/distress noticed either during routine inspection or principal inspection the matter shall be reported to the senior level engineer and the latter should decide further the line of action in consultation with the Design Organisations or Design Consultants, if he considers it necessary and give detailed instructions as to whether special inspection is called for.

If during the inspections (routine, principal, special) any bridge is found to indicate distress of serious nature leading to doubt about structural adequacy, the bridge will have to be evaluated for its load carrying capacity. Similarly, very old bridges for which neither record drawings are available nor the design loads are known, the engineer may evaluate its load carrying capacity. It is difficult to give any quantified norms based on inspection only, for selecting a bridge for rating. This selection will have to be left to the judgement of a senior engineer who, if necessary, with the help of a design engineer, will be able to discern whether such an assessment (evaluation of the load capacity) is called for.

If the bridge inspection reveals deficiencies in its hydraulic design and behvaiour, appropriate actions to provide additional spans, to raise the level and/or to provide protective measures will have to be taken as per the design engineer's advice.

Where design is based on model experiments and inspections show substantial variation from the assumptions made, such parameters should be reported and if so advised by the designer the model experiments may be redone and necessary corrective measures taken.

If the assessment shows the bridge to be inadequate for the design loads, one or more of the following actions should be taken :

(i) The load on bridge should be restricted to its assessed capacity. The condition of the bridge should be monitored by special inspections at intervals not exceeding six months.

(ii) The bridge should be closed for all traffic where the rated capacity of the bridge is lower than the lowest level of traffic load expected to ply on it.

(iii) Replacement or strengthening of the bridge or its affected part should be undertaken.

4. MAINTENANCE TECHNIQUES

4.1. Guidelines on Methods and Techniques for repairs for strengthening and rehabilitation are covered under a separate document. In this Chapter, however, it is proposed to very briefly cover only the more important techniques currently used in bridge maintenance. The operations described in this Chapter have been selected for frequent need of their application.

4.2. Maintenance Operations

These operations can be of two types, viz. ordinary maintenance operations and specialised maintenance operations. The operations of repetitive or periodical type are in general technically rather simple and could be classified as ordinary maintenance operations. The specialised maintenance operations are those which are unpredictable regarding their necessity and are relatively more complex. However, it must be admitted that the line separating them is rather a fine one. The list of these maintenance operations, is divided into two parts, viz. ordinary and specialised maintenance operations.

(a) **Ordinary Maintenance Operations**

Simple cleaning by mechanical means or by hand (of carriageways, footpaths, verges, joints, drains, gulleys, gutters etc.); removal of foreign material such as trash or parasitic vegetation and similar operations;

Substitution of deteriorated elements by removal and replacement operations (e.g. safety barriers);

Small restorations, repointing of masonry and brickwork, replacement of missing stones, sealing and repairs with cement or resin mortars;

Localised repairs to pavements and waterproofing, using bituminous materials, fillers in expansion joints.

Clearing of ventholes in superstructure (Localised painting operations to protect against corrosion; renewal of protective treatments on timber; Lubrication and greasing operations).

(b) **Specialised Maintenance Operations**

Restoration of concrete (reinforced or otherwise) structural parts, to be carried out with different techniques (simple or special cement mortars, synthetic mortars, etc.)

Restoration of brick or masonry structure;

Protection of concrete or masonry from degrading action by frost, salts or the atmosphere by means of painting (protective films), impregnation, etc. disinfestation of timber structures;

Injection of cement grout or thermosetting resin into cracks in brick, stone, reinforced or prestressed concrete structure;

Injection of cement grout or synthetic resin (pure or with additives) into sheaths containing pre-stressing tendons;

Maintenance of bolts or weldings of metal structures; cleaning, greasing and substitution of wearing parts of same;

Anti-corrosion protection of metal structures entailing complete stripping and repainting of part or all of the surface;

Repair or reconstruction of drainage systems (gullies, channels, collector and discharge pipes etc):

Repair or reconstruction of pavements or waterproofing of deck:

Repair or reconstruction (partial or total) of expansion joints, depending on their types:

Maintenance of bearings by means of different operations depending on the type (repainting and graphiting, for example); setting of same, also by raising decks:

Reclamation operations to river and sea beds to protect foundation structures.

Repairs for damages to guide bunds, aprons for raft foundations

Making up settlement on bridge approaches:

Replacement of any structural members (mainly for timber or steel structure).

4.3. The lists in para 4.2. are not exhaustive, but only indicative. It should also be appreciated that as the technology advances, the lists will have to be updated.

5. SUGGESTED STRATEGIES

5.1. It is necessary for the road authorities,to issue detailed instructions for classification of their bridges according to size, span length, type of structure, condition of exposure, materials of construction etc. and assign the responsibilities for their inspections (routine, principal and special) at various levels depending on the importance, vulnerability and complexity of the structure, along with periodicities of such inspections. Steps should be taken to procure the necessary means of accesses for bridge inspections, including at least one mobile bridge inspection unit in each State. Where so justified by the work load separate units may be set up for inspections, particularly the principal and special ones for important bridges, creating data base and inventorisation in phases.

Equally important is the task of adequate monitoring to ensure that the necessary inspections as prescribed are being actually carried out properly and the necessary follow up actions arising out of these inspections are initiated and implemented. It is desirable that one senior engineer for the whole organisation in the road authority should be exclusively provided for this purpose.

5.2. It is recommended that in following the guidelines, the road authorities should at the earliest carry out Principal/Special Inspections of all major bridges to assess their conditions. While it might be relatively easier to compile a bridge inventory on basic data from record drawings (which may also not be readily available in many cases), considerable efforts will be required to compile the bridge data files after carrying out inspections. Considering the magnitude of the work involved the compilation in the first phase may have to be confined to bridges on selected arterial or important routes such as the National Highways, major State Highways or through roads carrying traffic exceeding 10000 tonnes per day. Inspections should also be carried out particularly in respect of bridges known to have some history of distress or those located in aggressive environments. All new bridges should be inspected soon after their construction. This will help in noticing the defects within the defect liability period of the contract, and to serve as a bench mark for subsequent inspections.

5.3. There is a need to develop bridge maintenance and bridge rehabilitation agencies. Specialised equipment required for bridge rehabilitation and strengthening should be procured by the concerned authorities and preferably some core units should be set up to carry out such works departmentally. For any particular bridge where problems are of complex nature consultants should be employed depending on the nature and magnitude of the work. In some cases it will be necessary to supplement the Departmental efforts by consultants who would be in a position to command the required man-power as well as expertise to cope with the increased work load on short term basis. It might be necessary to encourage and develop consultancy firms for bridge inventorisation and rehabilitation in addition to the agencies for carrying out the actual work of rehabilitation and maintenance of bridges which work is going to increase considerably in the coming years.

5.4. Investigation of the distresses, their causes and finding remedial measures require special expertise. Only the experienced and competent bridge engineers are able to diagnose the distresses and suggest most appropriate methods of repairs in a given situation. More often than not the officer directly in charge of bridge structures may not have the expertise to deal with major distresses in a bridge structure. The major distresses in a bridge could form a multi-disciplinary problem, involving structural defects, corrosion, deficiencies in hydraulic design, concrete technology, soil mechanics etc. for dealing with which consultation with experts from different relevant fields both within the

Department as well as from outside may become necessary and extremely useful, especially for important and vital bridge structui

5.5. The management of bridges has not been receiving as much attention as it should, concerning both the financial and engineering inputs. As already mentioned, the funds for repairs and maintenance are normally allocated in lumpsum amounts for repairs and maintenance of roads including bridges. In order to focus attention of both the Government and Engineers, it is recommended that there should be a separate budget item for inspection, repairs, rehabilitation and strengthening of bridges.

A bridge maintenance programme along with cost estimates should, therefore, be prepared every year and funds to the extent of estimated expenditure should be provided in the budget.

5.6. Maintenance of structure has to be handled by experienced engineers and trained technicians. Training of these personnel is essential. The concerned engineer will find it difficult to keep his knowledge uptodate on the testing techniques, materials and maintenance procedure. So in-service training courses addressed by specialists in the field are most valuable and are recommended and these should be held frequently. Similarly, practical courses are desirable for all maintenance teams with additional short courses whenever new material and techniques are introduced. It is also important that the maintenance team working on site is adequately insured against the risks and should know and practice the safety precautions needed in maintenance work and this should include the use of protective clothing, helmet, breathing mask, eye shields, safety belts, working on elevated structures, on scaffolding, in confined places and over water. A separate manual for training of personnel engaged in bridge inspection needs to be compiled and made available to organisations having a large number of bridges under their control. The manual should contain detailed instructions for the personnel in charge of inspections at all levels, their qualifications, handling equipment and tools, observance of necessary safety precautions, filling in of inventory forms and inspection forms, use of camera for taking appropriate photographs etc. The instructions must be in simple language and formats like "Do's and Dont's" and should be illustrated with appropriate sketches and photographs to guide the bridge inspection personnel in their task.

5.7. Apart from the technical aspects, the engineers and the authorities should be aware of the importance of non-technical aspects of management of distressed bridges, such as public safety, public relations, legal issues, etc. These aspects need to be handled tactfully and competently at the top level of management depending on the importance of the bridge. As soon as distresses or damages to the bridge come to light and if the traffic is either to be restricted or diverted or stopped completely it is essential to keep the public informed of all the facts regarding the bridge through suitable media. A standard hand-out should be kept ready and should be distributed, updating it from time to time. For vital bridges and bridges of strategic importance, as soon as distresses are noticed a contingency plan should be worked out and kept ready for implementation the moment it becomes necessary. The contingency plan has to be prepared in consultation with all concerned Departments. Merely investigating the causes of distresses and carrying out remedial measures and restoring the traffic is not enough. One must also draw lessons from such occurrences for improvements in future structures so as to minimise chances of recurrence. The lessons learnt should be made known to other engineers also.

5.8. Suggested action plan for Road Authorities as well as for IRC is given at *Appendix 9*.

6. MAINTENANCE : RESEARCH AND DEVELOPMENT ASPECTS

6.1. Requirements

A great deal of research is going on in India and other parts of the world on structural aspects. These deal with concrete bridge deck, their waterproofing and corrosion protection of reinforcement, damaged concrete repairs, repairs to prestressed concrete members, strengthening of old bridges, metal protection, etc.

It is somewhat difficult to clearly separate out research considerations that pertain only to bridge maintenance. However, the main requirements of research and development in maintenance can be summarized as follows :

(a) The need to investigate the effectiveness of present methods of maintenance.

(b) The need to develop performance criteria for evaluation of different maintenance strategies.

(c) Developing improved materials and techniques for bridge maintenance and

(d) The study of economics of maintenance of bridges of various ages and types.

6.2. Future Research

It will be observed that there is a considerable gap between the present bridge maintenance practices and the desired maintenance practices. To close the gap, a great deal of knowledge of all aspects of bridge maintenance must yet be gained and disseminated. Carefully planned and executed research has to be continued. The research could be broadly classified into (a) physical maintenance research and (b) non-physical maintenance research dealing with costs, practices and policies.

6.2.1. Research needs for physical maintenance could be :

(i) Repairs of concrete like crack repairs, development of suitable material, methods and techniques to repair deteriorated concrete; and protective coating;

(ii) Corrosion protection of high tensile steel in prestressed concrete;

(iii) Development of expansion joints and bearings with improved serviceability;

(iv) Grouting technology of prestressing cables including techniques for examining the quality of grout in embedded cables;

(v) Fatigue crack repairs in steel bridges;

(vi) Use of polymer modified concrete, latex modified concrete and fibre concrete in replacement of removed concrete;

(vii) Development of appropriate instrumentation and computer based multi channel data acquisition system. (The instrumentation would be based on deflection transducers, strain gauges and temperature gauges).

(viii) Development of a special standard testing vehicle in which it is possible to gradually increase the axle loads conforming to national classification such as 18R, 24R, 40R and 70R as per IRC : 6.

(ix) Addition of steel reinforcement in the shape of bars, plates, flats etc. to the distressed structures. Successful bonding to the parent structure requires development of appropriate gluing materials as well as techniques of execution;

(x) Measurement of prestressing forces in embedded tendons;

(xi) Strengthening by external prestressing;

(xii) Non-destructive method of detecting corrosion in prestressing steel and to measure rate of corrosion of steel in concrete.

(xiii) Underwater bridge inspection and repairs;

(xiv) Techniques; for controlled and rapid removal of concrete without damage to concrete and steel left in place.

(xv) Assessment of residual prestress in case of snapped tendons in parts away from the snapped section.

(xvi) Improvements in metallurgy of steel reinforcement and for prestressing steel to improve corrosion resistance.

6.2.2. The research needs of non-physical aspects of maintenance will be :

(i) Proper maintenance accounting;

(ii) Long term behaviour studies for methodical evaluation of effectiveness of various repair techniques.

(iii) Assessment of bridge condition by sufficiency ratings.

(iv) Maintenance strategies and their effectiveness.

The above lists are not exhaustive. As time goes on and with more modern facilities more areas for research will be opened.

6.2.3. In seeking to devise improved techniques to carry out maintenance and repairs, it is necessary to meet the criteria of practicability like :

(a) Techniques must be robust and should not be unduly sensitive to workmanship or defects.

(b) Techniques must be resistant to environmental conditions.

(c) Techniques should preferably involve proven technology, and new ideas should be introduced with due care and attention.

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Appendix 1

INVENTORY OF ROAD BRIDGES
(Suggested contents of Data Base)

Sr. No.	Information Item	Suggested field width in D Base for coding
1.	State	2
2.	Category of Road	3
3.	Road No.	3
4.	Section	30
5.	Location Chainage	6
6.	Structure Number	5
7.	Features Interesected	25
8.	Type of Structure	25
9.	Popular/Official Name	15
10.	Highway/Circle/Division	30
11.	Nearest City/Town	20
12.	Year of Construction	4
13.	Overall Bridge Length	4
14.	No. of Lanes	1
15.	Load Rating	4
16.	Design Loading	4
17.	Year of Inventory	4
18.	Design Velocity in m/sec	5
19.	Design Discharge	10
20.	HTL	7
21.	LTL	7
22.	Design HFL	4
23.	OFL	7
24.	LWL	7
25.	Design Scour Level at Pier	4
26.	Design Scour Level at Abutment	4
27.	Founding Strata	1
28.	Whether Bridge has any Gradient	1
29.	Road Level	4
30.	Footpath Width	3
31.	Overall Deck Width	4
32.	Approach Roadway Width Including Shoulders	3
33.	Average Skew	2
34.	Conditions of Exposure	20
35.	Whether Navigable	1
36.	Vertical and Horizontal Clearance	10
37.	Soffit Level at Centre of Bridge	7
38.	Importance Factor	3
39.	Total No. of Spans	3

Sr. No.	Information Item	Suggested field width in D Base for coding
40.	**Maximum Span**	5
41.	**Type of Superstructure**	4
42.	**Pier Type**	2
43.	**Abutment Type**	2
44.	**Pier Foundation Type**	2
45.	**Abutment Foundation Type**	2
46.	**Type of Bearings**	1
47.	**Type of Wearing Coat**	1
48.	**Type of Expansion Joint**	1
49.	**Type of Railing**	2
50.	**Corrosion Protection**	3 × 3
51.	**Bank Protection Type**	4
52.	**Floor Protection Type**	4
53.	**Suspension of Traffic**	3
54.	**Erosion of Banks/Bunds**	3
55.	**Abnormal Scour Level Around Piers**	6
56.	**Abnormal Scour Level Around Abutments**	6
57.	**Abnormal Flood Level**	6
58.	**Distress and Repairs in Foundation**	3
59.	**Distress and Repairs in Guide Bunds**	3
60.	**Distress and Repairs in Substructure**	3
61.	**Distress and Repairs in Superstructure**	3
62.	**Any Other Observation/Data**	100

Using the above list a suitable data base can be created to suit individual needs wherein restrictions on field width are not necessary. However, as an example, the information to be given in the field widths suggested above is indicated below for some of the items in the data base.

Item 1 : State (2 digits)

Mention two digit code for States as under :

State Name	Code
Andhra Pradesh	AP
Arunachal Pradesh	AR
Assam	AS
Bihar	BR
Goa	GO
Gujarat	GJ
Haryana	HR
Himachal Pradesh	HP

Jammu and Kashmir	**JK**
Karnataka	**KN**
Kerala	**KR**
Madhya Pradesh	**MP**
Maharashtra	**MH**
Manipur	**MN**
Meghalaya	**MG**
Mizoram	**MZ**
Nagaland	**NG**
Orissa	**OR**
Punjab	**PN**
Rajasthan	**RJ**
Sikkim	**SK**
Tamil Nadu	**TN**
Tripura	**TR**
Uttar Pradesh	**UP**
West Bengal	**WB**
Andaman & Nicobar Islands (U.T.)	**AN**
Chandigarh (U.T.)	**CH**
Dadra and Nagar Haveli (U.T.)	**DH**
Delhi (U.T.)	**DL**
Lakshadweep Island (U.T.)	**LK**
Pondicherry (U.T.)	**PD**
Daman & Diu (U.T.)	**DA**

Item 4 — Section (30 digits)

Record the name of the section of the highway on which the bridge falls. This item is justified without trailing zeroes. As such the spaces unifilled by the name of Section should be left blank and no zeroes need be put therein e.g.

N A W A D A H — B A R H I

Item 5 — Location (6 digits)

Location of the centre of the bridge should be given in nos.

The last three digits show thousandth of a Kilometre e.g.

Location	Code
281.380	281380
84.120	084120

Item 6 — Structure No. (5 digits)

Structure number may be noted as follows :

Location of Structures	Structure No.	Code
2nd structure after completion of 280 km	281/2	28120
5th structure after completion of 84 km	85/5	08550

If any structure is added subsequently between structure number 281/2 and 281/3, the same may be numbered as 281/2A and codified as 2812A. It would however be advisible to reserve structure numbers for structures likely to be added in future.

For multi-lane carriageways, there would be either one combined structure or separate bridge structures. In the case of one combined structure, the structure number shall be noted as mentioned above. However, in case of separate bridge structure, the structure number shall be indicated as follows. As the kilometreage of the Section progresses, the left hand side structure will have a suffix 'L' and right hand side structure will have a suffix 'R', e.g.

	Location of structures	Structure No.	Code
	2nd structure after completion of 280 km.		
(i)	Left side structure	281/2	2812 L
(ii)	Right side structure	281/2	2812 R
	5th structure after completion of 84 km		
(i)	Left side structure	85/5	0855 L
(ii)	Right side structure	85/5	0855 R

Item No. 7 — Features intersected (25 digits)

The information to be recorded for this item will be the name or names of the feature intersected by the structure, like a river, road, railway line, canal, nallah, creek etc. If it is an under bridge, the features intersected above the strructure should be given. If there are more than one feature intersected by the same bridge, the names of all features should be separated by semi-colon or a coma, Commonly use and meaningful abbreviations may be used, if necessary. This item is justified without trailing zeroes.

Item 9 — Popular/official name (15 digits) :

Give the popular or official name of the bridge e.g. MALVIYA BRIDGE, NEHRU BRIDGE.

The item is justified without trailing zeroes.

Item 28 — Average skew (2 digits)

Indicate average skew angle of the bridge in degrees. If there is no skew write 00.

Item 33 — Superstructure type (4 digits)

The superstructure type should refer to the most important main spans, if the type in some of the main spans is different. This will be filled in a four digit code as under :

First digit	— Material
Second digit	— Type of design/construction
Third and Fourth digit	— System

(a)

Material	*Code*
R.C.C.	1
P.S.C.	2
Steel	3
Steel and concrete	4
Masonry	5
Timber	6

(b)

Type of design/construction	*Code*
Slab	1
T-beam and slab	2
Box-girders-with single cell	3
Box-girders with multiple cell	4
Arches with packfill	5
Open spandrel arches	6
Truss	7
Plate girders/R.S. Joists with decking	8
Others	9

Appendix 2

INVENTORY OF ROAD BRIDGES
(Specimen for one Bridge)

Sr. No.	Information Item	Information of Bridge across Sawaleswar —Nala on N.H. 9 Pune — Solapur Section
1.	State	MH
2.	Category of Road	NH
3.	Road No.	NH 9
4.	Section	Pune-Solapur
5.	Location Chainage	225000
6.	Structure Number	225 AB
7.	Features Intersected	Nalla
8.	Type of Structure	High Level Bridge
9.	Popular/Official Name	Sawaleswar Bridge
10.	Highway/Circle/Division	NH-9/Solapur/Šolapur
11.	Nearest City/Town	Solapur
12.	Year of Construction	1989
13.	Overall Bridge Length	85.88 m
14.	No. of Lanes	2
15.	Load Rating	70 R
16.	Design Loading	70 R
17.	Year of Inventory	1990
18.	Design Velocity in m/Sec.	3.9
19.	Design Discharge in Cumecs	1285
20.	HTL	Nil
21.	LTL	Nil
22.	Design HFL	446.700
23.	OFL	444.900
24.	LWL	Nil
25.	Design Scour Level at Pier	438.000
26.	Design Scour Level at Abutment	436.000
27.	Founding Strata	Hard Rock
28.	Whether Bridge has any Gradient	Nil
29.	Road Level in m	450.100
30.	Footpath Width in m	Nil
31.	Overall Deck Width in m	8.45
32.	Approach Roadway Width Including Shoulders in m	11.45
33.	Average Skew	18
34.	Conditions of Exposure	Moderate
35.	Whether Navigable	No
36.	Vertical and Horizontal Clearance	1.2 M
37.	Soffit Level at Centre of Bridge	448.35
38.	Importance Factor	1

Sr. No.	Information Item	Information of Bridge across Sawaleswar —Nala on N.H. 9 Pune — Solapur Section
39.	Total No. of Spans	5
40.	Maximum Span	17.26
41.	Type of Superstructure	12
42.	Pier Type	32
43.	Abutment Type	12
44.	Pier Foundation Type	12
45.	Abutment Foundation Type	1
46.	Type of Bearings	2
47.	Type of Wearing Coat	1
48.	Type of Expansion Joint	1
49.	Type of Railing	11
50.	Corrosion Protection	000
51.	Bank Protection Type	000
52.	Floor Protection Type	000
53.	Suspension of Traffic	000
54.	Erosion of Banks/Bunds	000
55.	Abnormal Scour Level Around Piers	000
56.	Abnormal Scour Level Around Abutments	000
57.	Abnormal Flood Level in m	000
58.	Distress and Repairs in Foundation	000
59.	Distress and Repairs in Guide Bunds	000
60.	Distress and Repairs in Substructure	000
61.	Distress and Repairs in Superstructure	000
62.	Any other Observation/Data	The bridge is functioning satisfactorily both hydraulically and structurally.

Appendix 3

SIMPLIFIED BRIDGE INVENTORY FORM

Identification Number :

Photograph (Prefarably Coloured) or sketch (showing span arrangement)	Name : ______ State : ______ District : ______ Road number : ______ Section : ______ Kilometric point : ______

GENERAL DATA

Authority responsible for management :

Road crossed : ☐ Road n° | ☐ River, waterway | ☐ Railway
☐ Under ☐ Under
☐ Above ☐ Above

Construction date : ______ Design load : ______

Name of Builder contractor. ______

Date of latest improvement/rehabilitation : Design load:

Traffic volume
(at km point ______)
Year : ______ Volume ______

Traffic limitations :
☐ Yes ☐ No
Possible detour ☐ ☐
Detour length ______

TECHNICAL DATA

Total length : ______ Number of spans : ______ Distribution of spans : ______

Total width : ______ Carriageway width ______ Width of footpaths ______ Vertical clearance ______ ☐Above : ______ ☐ Under

SUPERSTRUCTURE

Material : ☐ Steel ☐ Concrete ☐ Composite ☐ Timber Cross section ______

Expansion joints ☐ Yes ☐ No Type : ______ Utilities ☐ Yes ☐ No.

SUBSTRUCTURE

Abutments : Type : ______ Material : ______ Channel protection ☐ Yes ☐ No Type

Piers : Type : ______ Material : ______ Bearings : Type : ______

FOUNDATIONS Type : ______

Observations : Equipment required for inspections ☐ Yes ☐ No Utilities carried ☐ Yes ☐ No

Appendix 4

INSPECTION PROFORMA
(for Routine Inspection)

1. General
   - 1.1. Name of bridge/No. of bridge/Name of river
   - 1.2. Name of Highway/Location of Bridge
   - 1.3. Type of Bridge High level/submersible

2. Last Routine Inspection on by

3. Traffic Intensity PCU/T per day
   (latest census)

4. Condition of
   - (a) Approaches
   - (b) Protective works
     (Pitching, apron, toes, floor, guidebunds)

5. State
   - (a) H.F.L. Yes/No
   - (b) Inadequacy of waterway Yes/No
   - (c) Erosion of banks as evident Yes/No

6. Foundation and substructure
   (State whether any abnormal scour, settlement/tilting/ cracks/cavitation/damages/growth of vegetation)

7. Bearings
   (State condition/movements/deformation/cleanliness/ condition of grease)

8. Superstructure
   - (a) *Concrete* (RCC and PSC)
     (State whether leaching/stains/cracks/spalling/ scaling/excessive deflection condition of articulation and inside box)
   - (b) *Steel*
     (State condition of protective system/corrosion/ deformations/rivet and weld condition/buckling and kinking/waviness/fracture/cleanlines)
   - (c) *Masonry Arches*
     (State condition of joints/cracks/vegetation growth/ bulging of spandrel walls and parapets/ deformation).

9. Miscellaneous
   - (a) Wearing urse (Surface condition and drainage)
   - (b) Drainz (Spouts/Ventholes/clogging/cleanliness)

(c) Parapets and Handrails, etc.,
(condition and profile)
(d) Footpath (condition and drainage)
(e) Expansion joints
(Cleanliness/Wearing out and alignment/
gap width/hump/drainage/deformation/
corrosion/cracks)
(f) Utilities (State condition)

10. Have actions been taken on the observations and recommendations from the last Routine/Principal inspection ? Yes/No

11. Recommended corrective measures
(Attach separate sheet if space is insufficient)

Name, designation and dated signature of reviewing officer (Next higher Authority of the Inspecting Officer)	Name, designation and dated signature of Inspecting Officer

Appendix 5

INSPECTION PROFORMA
Check List for Inspection Report

1. **GENERAL**

1.1. Name of bridge/No. of the bridge/Name of the River.

1.2. Name of the Highway, Bridge Location

2. **Type of Bridge — High level/Submersible**

3 (A) Date of last such Inspection by

(B) Date of last routine Inspection by

(C) Traffic Intensity PCU/T per day (The latest census)

4. **APPROACHES**

4.1. Condition of pavement surface (check unevenness settlement, cracking, pot holes, etc.)

4.2. Side slopes/(Check pitched or unpitched, condition of pitching/turfing, any signs of slope failure etc.)

4.3. Erosion of embankment by rain cuts or any other damage to embankment.

4.4. Approach slab (check settlement, cracks movement etc.)

4.5. Retaining walls: (Checks, subsidence, tilting, condition of weepholes guardstone and railing)

4.6. Accumulation of silt and debris on submersible, approaches in cutting and embankment.

4.7. Approach geometrics (check whether it satisfies the standards in force).

5. **PROTECTIVE WORKS**

5.1. Type (mention whether guidebund or protection around abutments or spurs).

5.2. Check damage to the layout, cross section profile (check whether the layout and the general cross sections are in order).

5.3. Check condition of slope pitching, apron and toe walls indicating the nature of damage if any (check for proper slope, thickness of pitching in the slopes, width and thickness of appron, erosion of toe walls, etc.)

5.4. Check condition of floor protection works, indicate nature of damage if any, (Condition of impervious floor, flexible appron, curtain walls, etc.)

5.5. Check any abnormal scour noticed.

5.6. Reserve store material (check against specified quality).

6. **WATERWAY**

6.1. Check presence of obstruction, island formation, vegetation, undergrowth etc.

6.2. Check any abnormal change in flow pattern

6.3. Check maximum flood level observed during the year and mark the same on the pier/abutment both on the U/S and D/S (Local enquiry if necessary)
6.4. Check signs of abnormal aflux from U/S & D/S watermarks on piers if any
6.5. Check adequacy of waterway
6.6. Check of erosion of bank

7. **FOUNDATION**

7.1. Check settlement, abnormal scour, tilting, if any
7.2. Check cracking, disintegration, decay, erosion, cavitation etc.
7.3. Check damage due to impact of floating bodies, boulders, etc.
7.4. For sub-ways report seepage, vehicle impact, if any, damage to the foundations, etc.

8. **SUBSTRUCTURE** : (piers, abutments, return walls and wing walls).

8.1. Check efficacy of drainage of the backfill behind abutments (check functioning of weep holes, evidence of moisture on abutment faces, etc.)
8.2. Check tilting, cracking, disintegration decay and other damages, etc.
8.3. Check conditions of side retaining walls like cracking, disintegration and seepage, if any (For subways)
8.4. Check large excavations done in the road below in the vicinity of flyover or road over bridge of viaduct
8.5. Check damages to protective measures to pier and abutments (for viaducts, flyover and R.O. Bs.)
8.6. Check damages to protective coating or paint.

9. **BEARINGS**

9.1. Metallic bearings (State types/Sliding plate/Rocker Roller/PTFE/Pot bearings
9.1.1. Check general condition (check rusting, cleanliness, seizing of plates), silting, accumulation of dirt in case of submersible bridges
9.1.2. Functioning (check excessive movement, tilting, jumping off guides)
9.1.3. Greasing (check date of last greasing/oil bath and whether to be redone or not)
9.1.4. Effectiveness of anchor bolts (check whether they are in position and tightened)
9.2. Elastomeric bearings (State numbers)
9.2.1. Check condition; of pads (oxidation, creep, flattening, bulging, splitting, displacements, if any)
9.2.2. Check general cleanliness
9.3. Concrete bearings
9.3.1. Check any signs of distress (cracking, spalling, disintegrating staining, dishing etc.)
9.3.2. Check any excessive shifting
9.3.3. Check loss of shape
9.3.4. Check general cleanliness

9.4. Check cracks if any in supporting member (abutment cap, pier cap, pedestal)

9.5. Condition of d/s stoppers (for submersible bridges)

10. **SUPERSTRUCTURE**

10.1. Reinforced concrete and prestressed concrete members

10.1.1. Check spalling, disintegration or honey combing, (special attention; to be given at points of bearings)

10.1.2. Check cracking (pattern, location, explain preferably by photograph and plotting on sketch. A map of the cracking should be produced. The size and distribution of cracks and their penetration should be noted)

10.1.3. Check exposed reinforcement, if any

10.1.4. Check wear of deck surface

10.1.5. Check scaling (This is gradual and continuous loss of surface mortar and aggregate over irregular areas)

10.1.6. Check surface stains and rust stains along with the locations

10.1.7. Check Leaching (Effects are most usually evident on the soffits of decks)

10.1.8. Check corrosion of reinforcements, sheathing and tendons if visible

10.1.9. Check leakage (Leakages of water can take place through concrete decks, construction joints or thin component sections of the deck viz., kerbs, etc.)

10.1.10. Check damages if any due to moving vehicles

10.1.11. Check condition of drainage system (spouts, collection pits, grating, etc.)

10.1.12. Check condition of articulation (cracks, exposed reinforcement if any)

10.1.13. Check excessive vibrations, if any

10.1.14. Check excessive deflections (sag) or loss of camber if any at same point each time

10.1.15. Check cracks, if any, around anchorage zone for prestressed concrete members

10.1.16. Check excessive deflection (sag) at central hinge, tip, of cantilever for cantilever bridge

10.1.17. In box girders, the interior faces of flangers and webs need to be examined for signs of cracking and report excessive accumulation of water or debris. Interior diaphragms will also require examination, particularly for any signs of cracking at their junction to the webs

10.1.18. Check accumulation of silt and debris on surface of deck (for submersible bridges)

10.1.19. Check peeling off of protective coat or paint

10.2. Check Steel Members

10.2.1. Check condition of protective system

10.2.2. Check corrosion, if any

10.2.3. Check excessive vibrations, if any

10.2.4. Check alignment of members

10.2.5. Check condition of connection (adequacy, looseness of rivets, bolts or wornout welds, specially on connection of stringers to cross girders, cross girders to main girders, gussets or splices, condition of hinges, splices, etc.)

10.2.6. Check excessive loss of camber and excessive deflections and deformations, if any

10.2.7. Check buckling, kinking, warping and waviness

10.2.8. Check on the cleanliness of members and joints (check choking of drainage holes provided in the bottom booms).

10.2.9. Check apparent fracture if any

10.2.10. Check excessive wear (such as in pins in joints of truss) and their locations requiring close monitoring

10.2.11. Check conditions inside the closed members

10.3. Check masonry arches

10.3.1. Check condition of joints mortar, pointing, masonry, etc.

10.3.2. Check Profile, report flattening by observing rise of the arch at centre and quarter points

10.3.3. Check cracks, if any, (indicate location, pattern, extent, depth; explain by sketches)

10.3.4. Check drainage of spandrel fillings (check bulging of spandrel walls, if any)

10.3.5. Check growth of vegetation

10.4. Check all Cast Iron/Wrought Iron Components

10.4.1. These materials occur in older bridges and the defects which they exhibit are in general very similar to those described above for steel. It should be recognised that the homogeneity and purity of the material will not be upto the present day standards of steel, as such the inspection process has to take into account the variability of materials. (Blow holes and cracking are probably the main defects that occur during the casting of the metal and its cooling.)

11. EXPANSION JOINTS

11.1. Functioning (cracks in wearing course, existence of normal gap, excessive noise, etc.)

11.2. Check condition of sealing material (for neoprene sealing material. check for splitting, oxidation, creep, flattening, bulging and for bitumen filler., check for hardening, cracking, etc.)

11.3. Check secureness of the joints

11.4. Top sliding plate (check corrosion, damage to welds, etc.)

11.5. Locking of joints (Check locking of joints especially for finger type expansion joints).

11.6. Check for debris in joints

11.7. Report rattling, if any

11.8. Check drainage for expansion joint

11.9. Check alignment and clearance

12. WEARING COAT (CONCRETE/BITUMEN)

12.1. Check surface condition (cracks, spalling, disintegration, pot holes, etc.)

12.2. Check evidence of wear (Tell-Tale rings, check for thickness as against actual thickness, check data of last inspection)

12.3. Compare additional thickness with design thickness, with reference to kerb height

13. DRAINAGE SPOUTS AND VENT HOLES

13.1. Check clogging, deterioration and damage, if any

13.2. Check the projection of the spout on the underside (see whether structural members are being affected)

13.3. Check adequacy thereof

13.4. For subways report about adequacy of drainage and pumping arrangements, etc.

13.5. For submersible bridges, report on functioning.

14. HANDRAILS, PARAPETS

14.1. Check general condition (check expansion gaps, missing parts if any etc.)

14.2. Check damage due to collision

14.3. Check alignment (report any abruptness in profile)

15. FOOTPATHS

15.1. Check general condition (damage due to mounting of vehicles)

15.2. Check missing footpaths slabs

15.3. Cleanliness of ducts along footpaths

16. UTILITIES

16.1. Check leakage of water and sewage pipes

16.2. Check any damage by telephone and electric cables

16.3. Check condition of lighting facilities

16.4. Check damages due to any other utilities

17. BRIDGE NUMBER

17.1. Check condition of painting

18. ENVIRONMENT

Check for signs of aggressiveness

19. AESTHETICS

19.1. Check any visual intrusion, hoardings, vegetation on structural members, etc.

19.2. Check whether all actions for maintenance and repairs recommended during last inspection have been done or not (give details)

20. MAINTENANCE AND IMPROVEMENT RECOMMENDATION

S.No.	Item needing attention	Action recommended	Time by which to be completed	Remarks

21. Certificate to be accorded by the inspecting official
Certified that I have personally inspected this bridge.

Signature of the Inspecting Officer

Date :
Duration of Inspection

From AM/PM
to AM/PM
Method of inspection

Appendix 6

STANDARD TOOLS

Clip boards, chalk, markers, clamps etc.
Pocket tapes, folding rules, tapes (10 m to 50 m)
Feeler gauges, callipers
Straight edge, plumb bob, protector, spirit level
Thermometers, inspection mirror, binoculars, magnifying glass, camera
Flash light
Pocket knife, wire brush
Chipping hammer
Thin steel rod for use as probe (8 to 20 mm diameter)
Crack meter
Scrapper and emery paper
Plastic Jars and bags (for samples)

Appendix 7

POSSIBLE ASSESSMENT METHODS (ONLY INDICATIVE)

Assessment of	Possible method (s)
Concrete	
Strength	"Schmidt-hammer"
Quality	Ultra-sonic;
Lamination	Sounding
cover	Profometer
Steel	
Cracks	Ultra-sonic;
Cable/wire failure	radiographic;
corrosion	electrical halfcell potential; electrical resistivity meter;
Global behaviour movements	Surveying instruments; dial gauges (straining gauges)
extensometric measurement	Strain gauges and extensometers;
pressures, Forces	Pressure transducers or load cells
Miscellaneous	
thickness of coatings	Paint film gauge
waterproofing	(digital elecometer)
membranes	electrical resistance;
vibrations	Accelerometer
widening of cracks	Glass tell-tales

Appendix 8

TESTS

A large number of destructive and non-destructive test (NDT) procedures are available for evaluating the strength of components of bridges. However the limitations concerning the use of non-destructive testing and the reliability of the results should be closely examined. Non-destructive testing should be undertaken only by agencies qualified for the purpose.

Some of the test procedures for concrete are listed below:

A. **Non-Destructive Tests**

1. Rebound and penetration tests that measure the hardness of concrete are used to predict the strength of concrete. The hammer is used to compare the quality of concrete in different parts of the bridge rather than to determining the absolute values of strength. The relative strength of concrete can also be assessed by the Windsor probe.

2. **Sonic Methods** — Electronics sonic methods have been used for assessing the strength of concrete. The travel time of the sonic pulse between monitoring points is related to the modulus of elasticity and hence the strength. The system is capable of detecting differences between areas of sound and unsound concrete.

3. **Ultrasonic Techniques** — These techniques are used for measuring the velocity of pulse in concrete. The pulse velocity depends on the composition and maturity of the concrete and its elastic properties. The correlation between the pulse velocity and compressive strength is reasonably good provided the system has been calibrated with cores of the particular concrete being evaluated. Corrections are required to be made to account for any reinforcement present.

4. **Magnetic Methods** — The magnetic methods are used for determining the position of reinforcement as well as the assessment of the concrete cover. Several portable battery operated cover meters are available for the purpose. Such meters can measure concrete cover with an accuracy of ± mm in the range of upto 75 mm.

5. **Electrical Methods** — Electrical methods for inspection of concrete bridge components include resistance and potential measurements. These methods are particularly useful to detect corrosion of reinforcement.

6. **Nuclear Methods** — Nuclear methods are used to measure the moisture content in concrete by neutron absorption techniques. The moisture measurements are used to determine the possibility of corrosion of reinforcement.

7. **Radiography** — Gamma radiation techniques have been particularly useful for assessment of voids in concrete as well as in grouted tendon ducts (Vide B.S. 4408)

8. **X-Ray diffraction and differential thermal analysis of concrete samples** — This is useful in determining hydration characteristics. The results indicate extent of attack due to sulphates or sea water and any unusual hydration product.

9. **Electrochemical Potentials** — The procedure is as per ASTM C876. This is useful in finding the condition of embedded steel.

10. **Electrical Resistivity Management** — This also is useful in indicating the condition of embedded steel.

11. **Microscopic Examination using optical and polarised light microscopy** — Useful in identifying aggregate source, presence of slag etc.

12. **Dye Penetration Test and Optical Microscopy** — These tests give qualitative evaluation of incidence of pores and voids in concrete.

13. **Deflection Monitoring** — This is done with precision levels, theodolites, laser aligners.

14. **Strain Measurements** — These are done with the help of ER strain gauges and strain measuring bridges.

15. **Crack Meters** — To measure the width of cracks.

A combination of various non-destructive tests may be required to assess the structure. Usually no single non-destructive test can be relied upon to furnish the necessary information.

B. Destructive Tests

1. Concrete strength

Testing core samples (As per I.S. 516-1959) from concrete component under reference results in the actual strength of concrete being obtained. Core drilling equipment is available in various formats for taking cores in horizontal, vertical or inclined directions. Battery powered portable versions are also available.

2. Carbonation

Carbonation of concrete in the cover region results in loss of protection of the steel against corrosion. The depth of carbonation is measured by painting the freshly coated concrete surfaces with the 2 per cent solution of phenolphthalein. The colour of the concrete surface after painting may be compared with standard charts to indicate the areas of carbonation.

3. Endorscope

Endorscope consists of usually flexible viewing tubes that can be inserted into holes drilled into the concrete bridge components. A light is provided by optic fibres from an external source. Endorscopes are used for detailed examination of parts of the bridge structure which could not otherwise be assessed. Endorscopes are also available with attachments for a camera or TV monitor.

4. Pull Out Test

This measures the force required to pull out a steel road with enlarged head cost in concrete or introduced by drilling. It is possible to estimate compressive and tensile strength of concrete by correlating with the pull out force.

5. Pull Off Test

This is used to evaluate the tensile strength of concrete or the bond tensile strength between two different concrete or mortar layers. The tensile force is applied to a circular steel disk 50 mm diameters glued to a concrete surface by an epoxy resin. The test can be carried out with a portable lightweight equipment. The steel disc diameter is 50 mm and the pull-off force ranges from 500 N to 50000 N depending on the type of the equipment. This test is easy to operate at site and can be used specially for the quality control of repaired concrete surfaces.

6. **Internal Fracture Test**

In this the force required to pull out an anchor bolt is measured. It is used to estimate tensile concrete strength of concrete through a correlation with the pull out force.

7. **Break Off Test**

This is mainly used to estimate flexural tensile strength of concrete. 55 MM diameter core, 70 MM deep is prepared and the force required at the top and right angles to the axis to break off the axis to break off the core at the bottom is measured. The core is drilled in the hardened concrete. The test can also be used to evaluate bond between two concrete or mortars of different ages.

8. **Water Penetration Test**

In this the flow rate of water through concrete is measured and this indicates the degree of protection of reinforcement offered by the concrete cover. The specimen is sealed in a permeability test rig and water pressure applied on one face and the flow rate is measured. The test is susceptible to laboratory conditions of storage.

9. **Rapid, Chloride Test and Rapid Sulphate Test**

Results in terms of chloride content and also depthwise penetration are possible.

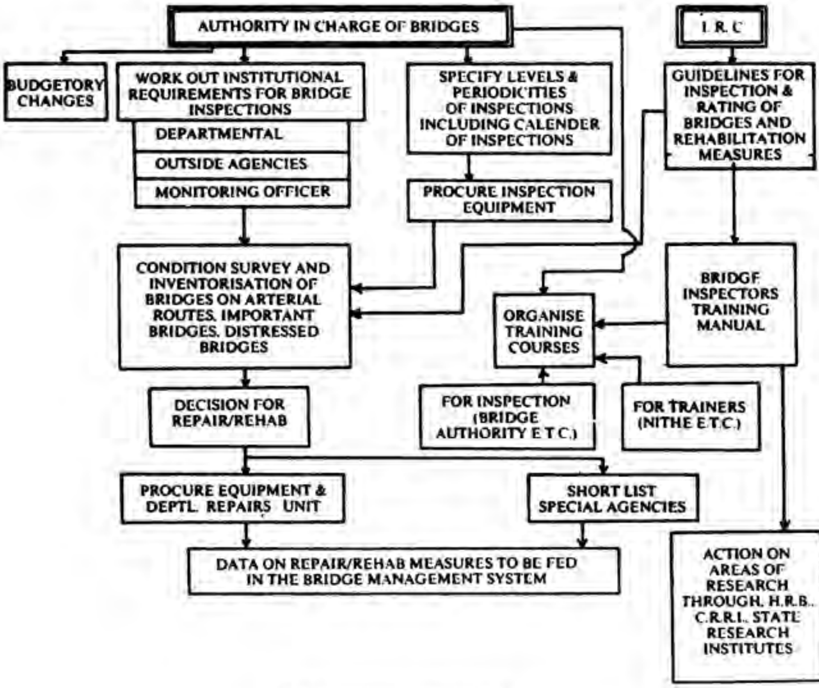
10. **Analysis of Hardened Concrete**

Determination of cement content is possible in hardened concrete.

11. **Optical microscopy and expansion test on concrete cores**

This can detect the alkali-aggregate reaction.

Appendix 9



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