Concrete model code for Asia: maintenance

Autor(en): **Misra, Sudhir / Takewaka, Koji**

Objekttyp: **Article**

Zeitschrift: **IABSE reports = Rapports AIPC = IVBH Berichte**

Band (Jahr): **81 (1999)**

PDF erstellt am: **22.07.2024**

Persistenter Link: https://doi.org/10.5169/seals-61435

Concrete Model Code for Asia - Maintenance

Sudhir MISRA
Associate Professor
Dept. of Civil Engineering
IIT Kanpur
Kanpur India

Koji TAKEWAKA
Associate Professor
Dept. of Ocean Engineering
University of Kagoshima
Kagoshima, Japan

Summary

This paper is largely based on the draft report of the Working Group on Repair and Maintenance of concrete structures of the International Committee of the Japan Concrete Institute. It tries to present a comprehensive methodology for the maintenance of concrete structures during their service life, as may be necessitated by exposure to natural environment and ensuing deterioration. The treatment of the subject has been kept general and open ended in order that the committee report can be used as a basis for developing specifications and manuals for structures using different types of concrete, made in different environmental conditions and expected to perform diverse functions.

1. Introduction

In recent years, advances in construction methods have made it possible for concrete structures to be built in severe environmental conditions. At the same time the cost of unplanned and piece-meal remedial action have risen. Further, the need to extend the service life of existing structures and a better understanding of the deterioration mechanisms in concrete, has led to efforts to develop a rational methodology for the maintenance of concrete structures.

The goal for maintenance of a concrete structure during its service life is to ensure that its performance meets a predetermined criteria. It is therefore, important that effort be made to quantitatively define parameters which could be used to monitor the extent of deterioration and lay down minimum required performance levels. However, since concrete is used in different structures (buildings, dams, bridges, etc.), which perform under different environmental and operational conditions, it is not possible to lay down identical performance criterion for all (concrete) structures.

Thus, in this paper, and indeed in the Committee Report, the subject of maintenance of concrete structures has been treated only in a general manner, so that the document can be used as a basis for developing specific quantitative parameters, specifications and manuals for different structures - using different types of concrete, made in different environmental conditions and expected to perform diverse functions - on a case-to-case basis. Indeed, different organisations charged with the responsibility of maintaining concrete structures like the railways, etc. have developed their own tools an know-how for their specific needs. The effort in the committee report and indeed in this paper is to present a basic frame-work, which can be used to develop maintenance strategies in a large cross-section of concrete structures. Such a framework, will help evolve common strategies in addressing issue of mutual interest. Now, an overall maintenance strategy should comprehensively encompass, a rational basis for the maintenance, inspection, estimation of deterioration level and rates, evaluation of structural integrity, and remedial actions, as may be required. These aspects have been briefly discussed in the following paragraphs.

2. Basis of maintenance

On the basis of factors such as, importance of the structure, design service life, impact on a third party, environmental conditions, cost involved and ease of maintenance, maintenance action could be classified into different categories. For example, critical structures (e.g. dams, nuclear power plants), structures required to have a long service life (e.g. monuments), or those situated in very harsh environments (e.g. marine), may be classified to fall in a higher priority category maintenance, than for example, a multi-storey building. Similarly, criteria for classifying structures into other levels of priority need to be developed. It should be pointed out that certain structures, where any maintenance action is very difficult to execute (e.g. underwater), may have to be classified separately.

3. Inspection

Occurrence of deterioration and/or change in its performance in a structure is detected through inspection. Obviously if undesirable signs of deterioration can be detected early, suitable timely remedial action can be initiated. Actual locations for inspection, items recorded and tools used, should be carefully selected so that the desired information can be obtained accurately.

3.1 Types of inspection

Beginning with initial inspection carried out immediately after completion of construction, (or even repair or strengthening work), the structure needs to be periodically inspected. The objective of the initial inspection is essentially to compile the work records, record any deviations from the design / drawings, establish the initial state of the structure (before being put into operation), and prepare final documents, which can serve as basis for further maintenance action.

Now, while the structure is in service, routine and regular inspection need to be carried out to determine whether or not detailed inspection is required. The frequency and rigour of such inspections may be determined depending upon factors such as likely mechanism of deterioration, environmental conditions, importance of the structure, and classification of maintenance action. The underlying assumption is that a decision on whether or not to initiate remedial action, must be based on data gathered during a detailed inspection.

In addition to routine, regular or detailed inspections, as outlined above, extraordinary inspection may also be carried out to assess the extent of damage and need for remedial action, after a structure has been subjected to an accidental load, such as, earthquake, storm, flood, fire, collision with a vehicle or ship.

Further, whereas inspections could at best provide data at a particular point in time, the need to (continuously) monitor deterioration and/or performance of critical structures, through continuous recording of appropriate data, should not be lost sight of. In such cases, appropriate sensors and recording devices should be fixed to the structure, so that relevant data can be collected at any time.

3.2 Equipment used for inspection

Visual inspection : Visual inspection could provide vital information about the changes in the performance and / or deterioration in terms of appearance of pop-outs, cracks, stains, etc. Visual inspection, therefore, needs to be carried out systematically to obtain and record relevant information. It may be appropriate to treat visual inspection as an integral part of periodic inspection, and the frequency and rigour of routine / regular inspections may be adjusted according to the results of visual inspection. Photographic records could also serve as a source for monitoring changes in a structure over its service life, though the information in most cases may be limited to changes at the surface.

Tools during inspection : A detailed or comprehensive treatment of the methods available for non-destructive testing methods is outside the purview of this report. However, it is only appropriate to mention that most of the tools used for non-destructive testing and evaluations of structures have inherent limitations and a range of conditions over which the results are reliable. These should be borne in mind when choosing the tools to use and/or interpreting the data obtained. For example, though a rebound hammer test is often used to estimation of strength of concrete, it actually measure only the surface hardness and is susceptible to variation on account of factors such as roughness, wetness, and properties and proportion of aggregates in the mix. Though correction factors for some of these factors are often given in literature, the fact that the actual parameter recorded is hardness should not be lost sight of. Similarly, the readings for the natural potential of the reinforcing bars, often used in cases of assessing reinforcement corrosion, are highly dependent on the level of saturation of the cover concrete.

3.3 Locations for inspection

Critical locations in the structure for inspection need to be identified. The choice of these locations should be governed not only by structural but also environmental (which directly affects deterioration) considerations. As discussed in greater detail later on, these two approaches could help obtain (almost) independent assessments of the structure. The number of location identified for the purpose could be determined by considerations such as the importance of the structure, nature of structural and environmental loads, tools of inspection, and resources available.

4. Estimation of deterioration levels and rates

As mentioned above, appropriate deterioration parameters need to be identified depending upon the likely mechanism of deterioration, etc. Now, though inspection procedures used may provide the desired information about the instantaneous value of such parameters, appropriate models are needed to be able to estimate rates of change in the deterioration parameters. These models should take into account factors like the likely mechanism and observed characteristics of deterioration, and using the information available from construction records, previous inspections, etc.

For example in the case in chloride induced reinforcement corrosion, chloride concentration at a certain depth from the surface or natural potential of the reinforcing bars could be deterioration parameters. Further, proper sampling and analysis may yield the chloride concentration in concrete at a certain depth from the surface, but appropriate diffusion (or any other) models are needed to estimate the rate chloride ingress into concrete. This is required in order to estimate other parameters, such as, time that may elapse before concentration at a given location (say neighbourhood of the bars to reach a critical level (for example, the critical level required to render ineffective the passivating film around the bars). Relevant information about values of the apparent coefficient of diffusion and the surface chloride concentration should be based on the properties and proportions of the materials (especially cement) used, environmental conditions, etc.

5. Evaluation of results and structural integrity

Periodic (routine and/or regular) inspection should provide a basis for detailed inspection, which in turn should provide the input to the decision on whether or not to initiate remedial action. Though the issue of remedial action has been dealt with in some detail separately at a later stage, the importance of proper assessment of integrity of the structure in terms of performance parameters and the level of deterioration in terms of deterioration parameters, is discussed here.

5.1 Integrity of a structure

This could be taken to refer to the ability of a structure to perform its design functions (the deterioration, notwithstanding). In terms of structural performance, this could be measured in terms of the load carrying capacity, deflections, etc. In certain other cases, where the appearance of the structure is of importance, discoloration and/or staining could be of concern. Thus, from an operational and functional point of view, it is necessary to establish a minimum or threshold level of performance level in terms of relevant parameters, depending upon the environmental conditions and type, importance and maintenance classification of the structure.

5.2 Deterioration level

This can be taken to be the comprehensive assessment of the deterioration in a structure, made on the basis of results from inspection(s), study of design / construction records, models for estimation of future rate of deterioration, importance and maintenance classification. This can be arrived at only after considering the input from the various deterioration parameters, as may be available. For example, an overall assessment of deterioration due to chloride induced reinforcement corrosion can be based only after parameters such as chloride concentration levels, natural potential of reinforcing bars, extent of longitudinal cracks, appearance of rust stains, etc. are all taken into account.

5.3 Decision making

Based on the input from two essentially independent assessments - the critical performance level and the deterioration level - as described above, a decision needs to be taken to initiate detailed inspection and/or appropriate remedial action. However, it is at times difficult to be able to directly link the level of deterioration to the changes in the structural integrity, and in that case, fixing a maximum level of deterioration (in addition to the minimum level of performance) may have to be resorted to.

For example, if changes in structural integrity on account of reinforcement corrosion are considered, substantial and unacceptable levels of changes in structural behaviour have been reported even at fairly low levels of corrosion (in terms of loss in weight of the bars). In such a case, it is important that till such time as the mechanism of corrosion is better understood, a maximum 'acceptable' level of chloride concentration in concrete, or an unacceptable level of natural potential of the reinforcement may be adopted, though their relevance, per se, to the structural performance is limited.

6. Remedial action

On the basis of input from inspection - in terms of changes in performance levels, deterioration level, threat to the environment, etc. - suitable remedial measures may need to be initiated, as briefly discussed below. A complete plan should be drawn up for the works, which should be carried out with minimum disturbance to the environment.

6.1 Repair

Refers to action taken to prevent or slow down further deterioration in a structure and/or reduce the possibility of damage to the environment or any third party. Repair may be undertaken when there is no serious change in structural integrity and action may be limited to surface applications, sealing of cracks, etc.

6.2 Strengthening

Refers to action taken to restore or improve its load bearing capacity to at least the design level. Strengthening works should be preceded by a thorough investigation, including remaining design or desired service life, likely mechanism, causes and extent of deterioration, remaining and desired load bearing capacity, importance of the structure, maintenance classification and previous remedial action taken.

It may also be noted that within the framework of maintenance of a structure, the possibility of having to strengthen it even outside the considerations of deterioration and durability cannot be ruled out, e.g. in the case of adoption of more stringent design criteria and/or (an upward) revision of loads. Thus, it is only appropriate that when a structure is strengthened, efforts are made to go through the entire design procedure and ensure compliance with prevailing requirements.

Further, strengthening may require use of materials and methods, which were not used in the original construction and therefore specifications and other tools need to be developed for proper quality control. In fact, a proper plan of action taking into account all aspects of the job should be drawn up.

6.3 Other remedial actions

Action such as more intensified inspection (increasing the frequency and/or rigour of inspection), usage restriction (speed or load limit), landscaping (application of surface paints), dismantling and removal, etc. can also be called remedial action. When a deteriorated structure poses an immediate threat to the environment, user or any third party, suitable emergency action should be taken immediately, while the plans for further action are drawn up.

7. Maintenance of records

Complete records including details of design, construction, inspection and evaluation procedures, plans and execution of any repair and/or strengthening work undertaken etc., need to be made and retained in a manner that the information is easily accessible throughout the service life of a structure. It may be noted that even when these records may not be required for the maintenance of a certain structure, they may provide invaluable information for the design, construction and maintenance of other (similar) structures. Also, these records may provide relevant information about the structure as a whole or its individual members and preserved for while the structure is in service.

8. Concluding remarks

Concrete is not a maintenance-free material and concrete structures require careful maintenance - encompassing inspection and remedial action, to ensure that they continue to discharge their design functions throughout the service life. Details of inspection procedures, interpretation of results and remedial action have been deliberately left out of the discussion here and an effort has been made to only assemble a broad framework, which can be used for a large cross-section of concrete structures.

Acknowledgements

The authors are grateful to all the members of the International Committee of the Japan Concrete Institute, especially those in the Working Group on Maintenance and Repair, for all their input in preparing this document. Special thanks are due to Professor Taketo Uomoto, Chairman of the committee, and indeed to also the other past Chairmen for their constant encouragement for the work.