UNIT 1 MAINTENANCE AND REPAIR STRATEGIES

2 MARKS

1. What is theobjective of Maintenance.(April/May 2017)(April/May 2018)

Maintenance is the act of keeping something in good condition by- checkingor repairing it regularly.Activities include inspection and works necessary to fulfill the intendedfunction or to sustain original standard of service. It is preventive in nature.

2. What are the causes of deterioration? (April/May 2017)(April/May 2018)

(i) Deterioration due to corrosion
(ii) Environmental effects
(iii) Poor quality material used
(iv) Quality of supervision
(v) Design and construction flaws.

3. Define inspection and mention its purpose (Nov/Dec 2017)

Some of the useful information may be obtained from the physical inspectionof damaged structures, like nature of distress, type of distress, extent of damageand its classification etc., their causes. preparing and documenting the damages,collecting the samples for laboratory testing and analysis, planning for in-situtesting, special environmental effects which have not been considered at the design
stage and information on the loads acting on the existing structure at the time of damagemay be, obtained. To stop further damages, preventive measures necessarymay be planned which may warrant urgent execution.

4. Write the importance of maintenance?(Nov/Dec 2018)

- Petty repairs, replacement and structural repairs of buildings, white and colour washing distermpering and painting at prescribed intervals.
- Repair and renewal of furniture
- Operation, periodical maintenance, repairs and renewals of machinery and equipment for electric and water - supply, air conditioning, refrigeration, vehicles and sewage installations.
- Repair of roads, culverts and resurfacing the roads.

5. How do you classify maintenance of structure?(Nov/Dec 2018)

- Daily, maintenance
- weekly maintenance
- monthly maintenance

6. Distinguish between repair and rehabilitation?(April/May 2017)

Repair	Rehabilitation
The repair of concrete structures may vary between a cosmetic treatment and total replacements. By a proper investigation and well designed equipment. Tools and materials can be reinstated economically, an appropriate repair method can be selected depending upon the cause and extent of damage, importance of the structural elements, and its location.	Support the structural members properly as required. Remove all cracked, spalled and loose concrete. Clean the exposed concrete surface and steel reinforcement. Providing additional reinforcing bars, if the loss in reinforcement is more than 10%.

7.What are the objectives of maintenance?(April/May 2017)

To preserve building

To restore buildings

To make improvements in serviceability

8. Differentiate between maintenance and rehabilitation (Nov/Dec 2017)

Maintenance actions help slow the rate of deterioration by identifying and addressing specific pavement deficiencies that contribute to overall deterioration.

Rehabilitation is the act of repairing portions of an existing pavement to reset the deterioration process.

9. Compare "Preventive maintenance" and "routinemaintenance".(April/May 2019)

Preventive Maintenance	Routine Maintenance
It is the maintenance done to prevent the defects or damage occurs In the structure	The nature of the work done and interval of time at which it is done depends upon specifications and materials of the structure.

10. **What are thevarious aspects to be investigated during inspection of building (April/May 2019)**

- Electrical Accessories
- Flushing sewer line
- Leakage of water line
- Cleaning Doors, windows, etc
- Checking Septic Tank/Sewer

- Observation for cracks in the elements
- Cleaning of overhead tanks

9. Define Repair.

Repair is the process of restoring something that is damaged or deterioratedor broken, to good condition. Repair is the technical aspect of rehabilitation. Thisrefer to modification of a structure partly or wholly which is damaged inappearance or serviceability.

10. Define Rehabilitation.

Rehabilitation is the process of returning a building or an area to its previousgood conditions. Strengthening consists in endowing the structure with a servicelevel higher than that initially planned by modifying the structure including partswhich is not necessarily the damaged area.

11. What are the two facets of maintenance?

The two facets of maintenance are

(i) Prevention

(ii) Repair

12. How deterioration occurs due to corrosion?

- Spalling of concrete cover
- Cracks parallel to the reinforcement
- Spalling at edges
- Swelling of concrete
- Dislocation
- •Internal cracking and reduction in area of steel reinforcement.

13. What are the steps in selecting a repair procedure?

- Consider total cost

- Do repair job in time
- If defects are few and isolated repair on an individual basis. Otherwise do in a generalized manner.
- Ensure that the repair prevents further development of defects.
- Incase of lost strength, repairs should restore the strength.
- If appearance is a problem, the number of applicable types of repairs become limited and the repairs must be covered.
- Repair works should not interfere with facilities of the structure.
- Take care in addition of section to a member and in redistributing live loads and other live load moments. After selecting a suitable method of
- Repair, and after considering all the ramifications of its application, the last step is to prepare plans and specification and proceed with the work.

14. Discuss about the environmental effects which leads to deterioration of concrete structures.

Micro-cracks present in the concrete are the sources of ingress of moistureand atmospheric carbon di-oxide into the concrete which attack reinforcement andwith various ingredients of concrete. In aggressive environments, concrete structurewill be severely affected.

15. What is the effect of selecting poor quality material for construction?

Quality of materials, to be used in construction, should be ensured by means of various tests as specified in the IS codes. Alkali-aggregate reaction and sulphurattack results in early deterioration. Clayey materials in the fine aggregate weaken the mortar aggregate bond and reduce the strength. Salinity causes corrosion of reinforcing bars as well as deterioration of concrete.

16. How can we determine the cause for deterioration of concrete structure?

- Inspect and observe the structure.

- Observe in bad and good weather
- Compare with other constructions in the area or elsewhere.
- Study the problem and allow enough time to do the job.

17. What are the factors to be considered by the designer atconstruction site?

- Minimum and maximum temperatures
- Temperature cycles
- Exposure to ultra violet radiation
- Amount of moisture
- Wet/dry cycles
- Presence of aggressive chemicals.

18. What are the steps in repair aspect?

- Finding the deterioration
- Determining the cause
- Evaluating the strength of existing building or structure
- Evaluating the need of repair
- Selecting and implementing a repair procedure.

19. Define the fixed percentage method of evaluating the strength existing structure.

It is to assume that all members which have lost less than sopredetermined percentage of their strength are still adequate and that all members which have lost more than the strength are inadequate. It usually varies from 15% onwards. Higher values are applicable for piling percentage stiffness, bearplates etc.

20. Discuss about the design and construction errors leading todeterioration of a structure.

Design of concrete structures governs the performance of concrete structures.Well designed and detailed concrete structure will show less deterioration incomparison with poorly designed and detailed concrete, in similar conditions. Thebeam-column joints are particularly prone to defective concrete, if detailing andplacing of reinforcement is not done properly. Inadequate concrete cover may leadto carbonation depth reaching up to the reinforcement, thus, increasing the riskof corrosion of the reinforcement.

21. Discuss about the quality of supervision to be followed at a site.

Construction work should be carried out as per the laid down specifications.Adherence to specified water-cement ratio, controls the strength, permeability and

durability of concrete. Insufficient vibration may result in porous and honey combed concrete,whereas excess vibration may cause segregation.

22. What are the possible decisions that can be made after evaluating thestrength of a structure?

- To permit deterioration to continue.
- To make measures to preserve the structure m the present conditionwithout strengthening.
- To strengthen the construction.
- If deterioration is exceptionally severe, to reconstruct or possiblyabandon it.

23. How can we evaluate the strength of an existing structure by stressanalysis?

This method is to make detailed stress analysis of the structureas it stands includingallowances for loss of section where it has occurred. This is more difficult

and expensive. Here also the first step is to make preliminary analysis by fixedpercentage method and if it appears that major repairs will be required, thestrength is reevaluated based on detailed stress analysis, considering allcontributions to such strength.

24. Define the load test method of evaluating the strength of existing Structure.

Load tests Play be required according to the local building conditions. Butthey should only be performed where computations indicated that there isreasonable margin of safety against collapse, so that the test will not bring thestructure down. Load tests show strengths much greater than computed strengthswhen performed on actual structures. In repair work, every little bit of strengthis important.

25. What are the possible decisions after finding a structure to be inadequate?

- If the appearance of the existing condition is objectionable - repair now.
- If appearance is not a problem
- Put the structure under observation to check if the defect IS dormant orprogressive.
- If dormant - no repair.
- If progressive - check the feasibility and relative economics of permittingdeterioration to continue and performing a repair at some later date ormaking the repair right away.

26. Briefly discuss about repairing of concrete floor?

- Prior to removal of masonry or concrete floor adequate support andcentering should be provided.
- Planks of sufficient strength should be provided to give workmen firmsupport to guard against any unexpected floor collapse.
- No person should be allowed to work in a area directly underneath andaccess to such area as should be barricaded.

27. When do you go for repair of a structure?

Repair of the concrete structures is decided upon the factors such as

- The cause of damage
- Type, shape and function of the structures
- The type and extent of damage
- The availability of repair materials.

28. Give two methods of semi-destructive testing systems commonly usedin construction industry?

- Pullout and pull off test
- Core cutting sampling and testing
- Penetration techniques
- Permeability test

29. What is the pullout test?

In this test either an insert is cast in the concrete or fixed into a hole whichis drilled in to the concrete and force required to pullout the insert is measured.This force is correlated with compressive strength.

30. What are the factors that affect cracking?

- Water
- Cement
- Aggregate
- Bleeding
- Improper curing
- Exposure
- Cover.

31. Define the fixed percentage method of evaluating the strength existing structure.

It is to assume that all members which have lost less than sopredetermined percentage of their strength are still adequate and that all members which have lost

more than the strength are inadequate. It usually varies from 15% onwards. Higher values are applicable for piling percentage stiffness, bearplates etc.

32. What do you mean by deterioration?

The process that adversely affects the performance of a structural over time due to defects and damages occurred by naturally occurring chemical, physical or biological actions repeated actions such as those causing fatigues, normal or severe environmental influences.

33.what do you mean by structural cracks?

Structural cracks are those which arise due to incorrect design, faulty construction or verloading. For example, extensive cracking of a RCC beam.

34. Why is inspection needed for a damaged structure?

- To understand the nature of distress and prevent the ingress of same.
- To know the extent of damage
- To eliminate possibilities of damage in near future
- To design repair procedures
- To re-instate the structural integrity of the member
- Maintain the aesthetics of damaged structure

35. What are the factors influencing maintenance?

(i) Cost, (ii) Age of building, (iii) Availability of physical resources, (iv) Urgency of maintenance, (v) Future use, (vi) Social considerations.

36. Define Retrofit and Restoration.

Retrofit:

Actions that improve the strength and other attributes of the integrity of a structure or a member with respect to resisting seismic forces. The structure or member need not be deteriorated. The action is to mitigate the effects of a future earthquakes.

Restoration:

Actions that improve the strength and appearance of a structure. The term is mostly used for historical structures. Restoration may also include repair for a deterioration or damaged structure.

16 MARKS

1. What is preventive maintenance?(April/May 2019)

Preventive maintenance (PM) has the following meanings:

1. The care and servicing by personnel for the purpose of maintaining facilities in satisfactory operating condition by providing for systematic inspection, detection, and correction of incipient failures either before they occur or before they develop into major defects.
2. Maintenance, including tests, measurements, adjustments, and parts replacement, performed specifically to prevent faults from occurring.

The primary goal of maintenance is to avoid or mitigate the consequences of failure of structure. This may be by preventing the failure before it actually occurs which Planned Maintenance and Condition Based Maintenance help to achieve. It is designed to preserve and restore structure reliability by replacing worn parts before they actually fail.

Preventive maintenance means the regularly scheduled repair and maintenanceneeded to keep a building component operating at peak efficiency and extend itsuseful life.It includes scheduled activities intended to prevent breakdowns, suchas periodic inspections, lubrication, calibrations, and replacement of equipment.Replacing filters in an air-handling unit on a regularly scheduled basis is anexample of preventive maintenance. Because prolonging the life of majorbuilding systems requires periodic replacement of equipment, preventivemaintenance typically requires both capital and operating expenditures.

2. What are the factors influencing the maintenance in buildings? (April/May 2019)

Cost:

The cost of maintenance may at first sight seems to be a simple matter ofhow much to spend on the material and labour. The cost of maintenance comprisesof direct and indirect cost. The maintenance materials vary to a great extent andits cost also varies dramatically. The direct cost in maintenance operations rangesgenerally from 70% to 90% of the total cost. Before coming to a decision toimplement a particular item of maintenance indirect cost factors like restrictedaccess production stopping, safety aspects, availability of time, overhead expenses

etc. must also be considered along with the direct cost.

Age of Building:

All buildings and structures consist of materials and components linkedtogether to form the desired unit of accommodation. All such materials andcomponents will start aging from the moment these are used in the buildingconstruction.Any building structure constructed will have certain life expectancy since thematerials and components wear out. This wearing out will reduce the overallserviceability of the building and also affect its remaining useful life.To obtain the maximum life out of materials components services, equipmentand the building itself, a planned programmer of inspections and maintenanceshould be established as soon as the building has been constructed.

Availability of Physical Resources:

Physical resources for maintenance of buildings can be defined as all thematerials, components, services and equipment which are necessary formaintenance. Therefore, when an item of maintenance is being planned, theavailability of all these physical resources must be considered and ensured.

Urgency:

The matter of urgency may outplay other factors when decision is to be takento carry out a specific maintenance job. An urgent maintenance task may berequired for a number of reasons such as the repair of services which, unlessrectified immediately, would render them unserviceable, causing lot ofinconvenience. When such a problem arises, the important question which mustbe addressed is, how urgent is the urgency? Urgency is a relative term andtherefore it must be established whether the repairs need to be carried outimmediately, within hours or within days. Accordingly, action for maintenance mustbe undertaken.

Future Use:

The future use of a building as a whole must be considered while decidingwhen and how much maintenance is to be carried out at any given period of time,If the lease is for a short period and changed occupancy is expected, thenmaintenance of the building in question must be accordingly planned. If required,some efforts has to be made to carry out the maintenance in the context of theproposed future use.

Social Considerations:

Agencies engaged in maintenance works cause influence on social environment also. The results of good endeavours of maintenance agencies are left behind as an asset to the owner' if no inconvenience is caused to the society and the environment is also maintained clean and safe.The agencies carrying out maintenance activities create disturbances such asnoise, safety, dust, smells, and temporary interruption of services. It must,therefore be one of the objectives to recognize the social responsibility. Plan themaintenance in such a manner that the disturbances will be kept to a mirumumlevel, particularly when working within the occupied building.

3. Describe in detail about the various aspect of maintenance. (Nov/Dec 2018)(April/May 2018)

Of the two considerations - prevention and repair, prevention is moreimportant.During construction the defects that may seem minor, will have seriousconsequences. The design engineer is responsible for the selection of

propermaterials suitable for the exposure conditions of site, detailing of the structure in
a manner to prevent serious deterioration atleast for the assumed service life and through the inspection staff must insist on proper construction.
These three points - proper materials, proper details, and proper constructionrequire knowledge of what is improper at a site or construction; about the variousways of deterioration and about their causes. But there are some generalconsideration that should be taken into account for both the construction of newconcrete structures and the repair of deteriorated structures. They are as follows.

(i) Match the materials to the environment:

Durability becomes an issue when a material's resistance to deterioration 'isless than that required to withstand the aggressiveness of the environment in which it is to function. For· e.g.: Steel will not corrode in a dry and salt freeenvironment, but it will do so in the presence of moisture and chloride ions.

To ensure the choice of an appropriate material, the environmental conditions.to which the material will be exposed must be known so that its behaviour underthese conditions can be predicted and addressed in the design. When a designercontemplates using a new material, problems may arise if there has not beensufficient experience with the material to adequately understand it's behavior orto allow for the development of standards.
In the absence of standards, several factors should be critically evaluated, among them the relevance of the test data provided in product literature, and the limitations and requirements associated with the environmental conditions of the project.
The following factors should be considered by the designer at the construction site.

- Minimum and maximum temperatures
- Temperature cycles
- Exposure to ultra violet radiation
- Amount of moisture

- Wet/dry cycles
- Presence of aggressive chemicals.

(ii) Combine only materials with similar properties:

Concrete is a solidified mixture of diverse materials. When these materialsare incompatible with one another, the concrete cracks and spalls, resulting inunsightly surfaces and the need of expensive rehabilitation work. Materials areconsidered to be incompatible when the differences in their physical or chemicalproperties exhibit a state of instability.

For e.g.: Galvanic corrosion is promoted when two metals with differentelectrochemical properties are combined in a building assembly.

The use of materials with different thermal coefficients or different modulliof elasticity should also be avoided, since they expand and contract at differentrates, and their deformation characteristics are significantly different. In bothinstances, the incompatibility of the selected materials will lead to deterioration ofthe concrete. When the load is perpendicular to the bond line, the difference inmodules does not cause problems.

(iii) Assess the limitations of a particular material in its functional context:

The selection of materials, particularly those used in repairs, must be basedon knowledge of their functions and of the environment in which the materialshave to function. Their physical &chemical properties as well as their limitationswith respect to installation and performance must also be considered. In particular, the designer shouldanticipate the degree of abrasion or wear to which a surfacewill be subjected.

For eg: Parking garages should be designed to resist moreabrasjon by using special cast concrete and on applied polymeric coatingimpregnated with a abrasion resistant material such as corundum.

(iv) Protect materials from general deterioration:

In choosing a material the designer should be aware not only of the propertiesthat seem to address the intended function but also the auxiliary properties thatdid not constitute the basis for selecting the material. For eg: Air entrainment isused to

provide durability with respect to freeze and thaw cycles but it alsoenhances workability.

Most concrete deterioration can be attributed to water penetration sinceconcrete absorbs moisture until it become, saturated, preventing entry of waterfrom collecting on surfaces is of prime importance. Moisture fosters deteriorationnot only where it carries dissolved chemicals that can react with steel, lime andother components in the concrete, it also plays a major role in concretedeterioration through freeze thaw cycles. By providing sufficient slopes and effectivedrainages, it is possible to prevent water from ponding and thus being absorbed.

Concrete design should accentuate water shedding characteristics for verticalelements. For eg: proper window shades prevent the wall from wetting. Sealingthe surface with a penetrating concrete sealing and the use of 50 mm thickreinforcement cover to protect steel are other means of protection.

(v) Design level Factors:

Concrete structures are an assembly of operating systems that experiencetemperature, air pressure and vapour pressure and gradients. Seasonal and dismal

fluctuations on outdoor conditions provide variability and direction of the gradients.These operating conditions can accelerate premature failure of the components in

a repair. The relative severity of these factors will vary depending on the use and location of the structure, and the types of repair material used and so on.Predicting these fluctuations and accommodating them at design stage is important.

Allow for change in use in design:

During the service life of a structure, its environment and occupancy maychange. As a result, the structure will have to withstand stresses different fromthose for which it was originally intended. For e.g.: Addition of roof garden to parking lot requires additional protectionagainst ponding of water on the roof of parking lot.

Even though designers allow a large margin of safety in their designs, oncedeterioration reaches a critical limit, immediate repair is needed to restore thelevel of performance to its intended level of service. In fact, if the rehabilitationworkis not carried out in time, the structure may not be repairable to the requiredlevel of service. The execution of such a repair is an exacting, technical matterinvolvingfive basic steps.

1. Finding the deterioration
2. Determining the cause
3. Evaluating the strength of existing building or structure
4. Evaluating the need of repair
5. Selecting and implementing a repair procedure.

(i) Finding the deterioration:

Before the repair can be effected, there must be a realization that somethingis wrong, and the realization must come before it is too late to make a repair,i.e., before the structure has collapsed.For e.g: timbers and timber piling can be damaged by insects or marineorganisms, virtually to the point of collapse, without exhibiting any externalevidence which would be apparent except to a trained observer. Even a commondefect like corrosion of steel can be difficult to detect because if it occurs,principally, in the most inaccessible parts of the structure. The reason is simple.The accessible parts are painted, but the inaccessible parts often are neglected.

The point to be made is that the engineer charged or interested inmaintenance must be trained, technically in, where to look, how to look and whatto look for, before he can even be expected and realize that there is trouble.Knowingall these requires knowledge of various kinds and causes of deteriorationand before checking, the engineer must know all these.

(ii) Determine the Cause:

To select the repair step, the cause has to be identified. Incase of concrete,the specific cause might not be known due to several agents acting. What can be done is to eliminate possibilities and design repair procedure for any of theremaining part

of the structure. In such cases the cost will go higher. But it should also be noted that the failure to understand the cause of a defect can lead to theselection of a repair procedure which would be harmful, rather than helpful. Thereare no set rules for determining the cause but with experience you can determine.For eg: cracks in walls due to foundation settlements run diagonally.

Cracks due to corrosion of reinforcement run straight and parallel at uniformintervals and show evidences of rust, and staining

(b) Observe in bad and good weather

A few tips are as follows:

(a) Inspect and observe the structure

(c) Compare with other constructions in the area or elsewhere and be patient

(d) Study the problem and allow enough time to do the job.

(iii) Evaluate the strength of the Existing structure:

This should be done to know whether it is safe to continue using the structureor limit it to a less severe extent of usage if the structure has not completelydeteriorated, the adequacy of determination of strength becomes important. Forthis the following methods can be used.

(a) Fixed percentage method:

It is to assume that all members which have lost less than somepredetermined % of their strength are still adequate and that all members whichhave lost more than the strength are inadequate. It is usually from 15% onwards;higher values are applicable for piling, percentage stiffness bearing plates etc.

(b) Analysis of the Actual stress condition:

This method is to make detailed stress analysis of the structure, as it standsincluding allowances for loss of section where it has occurred. This is more difficult

and expensive. Here also the first step is to make preliminary analysis by fixedpercentage method and if it appears that major repairs will be required,

thestrength is reevaluated based on detailed stress analysis, considering allcontributions to such strength.

(c) Load test:

Third step is load test. Load tests may be performed according to the buildingcodes.But they should only be performed where computation indicated that there

is reasonable margin of safety against collapse, lest the test bring the structure down. Load test show strengths much greater than computed when performed on actual structures. In repair work every little bit of strength isimportant.

Accordingly the use of load test is recommended but with a full and clearunderstanding of their limitations and range of applicability.

(iv) Evaluate the need of repair:

When the cause of the deterioration has been determined and the strengthof the existing structure has been checked, a decision must be made whether.

(a) to permit deterioration to continue

(b) to take measures to preserve the structure in its present condition without strengthening.

(c) to strengthen the construction

(d) If deterioration is exceptionally severe to reconstruct or possibly abandonit.

These decisions are based on:

(a) safety

(b) economy and

(c) appearance; different decisions may be appropriate for different elements of the same structure.

Case (a): Analysis show that, structure still has adequate strength:

- If the appearance. of the existing condition is objectionable - repair now
- If appearance is not a problem then
- Put the condition under observation to check if it is dormant orprogressive.
- If dormant - no repair

• If progressive - check the feasibility and relative economics of permittingdeterioration to continue and performing a repair at some later date ormaking the repair straight away.

Case (b) Analysis shows that the strength of the structure currently is inadequate:

• Either repair it or
• Rebuild it or
• Abandon it, partially or completely or
• Consider a change of use.

(v) Select and implement a Repair procedure:

• Select the least expensive that can suit the job

Steps of Repair:

• Consider total cost
• Do repair job in time
• If defects are few and isolated repair on an individual basis. Otherwisedo in generalized manner.
• Ensure that the repair prevents further development of defects
• Incase of lost strength, repairs should restore the strength
• If appearance is a problem, the number of applicable types of repairsbecomes limited and the repair must be covered.
• Repair works should not interface with facilities of the structure.
• Take care in addition of section to a member and in redistributing liveloads and other live load moments. After selecting a suitable method of repair, and after considering all the ramifications of its application, thelast step is to prepare plans and specifications and proceed with the work.

4. Describe the steps in the assessment procedure for evaluate damages in a structure. / With a flow chart explain the procedure for assessing the damages of a distressed structure? (April/May 2019)(Nov/Dec 2018)(April/May 2017) (Nov/Dec 2017) (April/May 2018)

The following steps may be necessary

(i) Physical inspection of damaged structure.

(ii) Preparation and documenting the damages.

(iii) Collection of samples and carrying out tests both in-situ and in laboratory.

(iv) Studying the documents including structural aspects.

(y) Estimation of loads acting on the structure

(vi) Estimation of environmental effects including soil structure integration,

(vii) Taking preventive steps not to cause further damage'

(viii) Retrospective analysis to get the diagnosis confirmed

(ix) Assessment of structural adequacy

(x) Estimation on future use

(xi) Remedial measures necessary to strength and repairing the structure,

(xii) Post repair evaluation through tests

(xiii) Load test to study the behavior

(xiv) Choice of course of action for the restoration of structure.

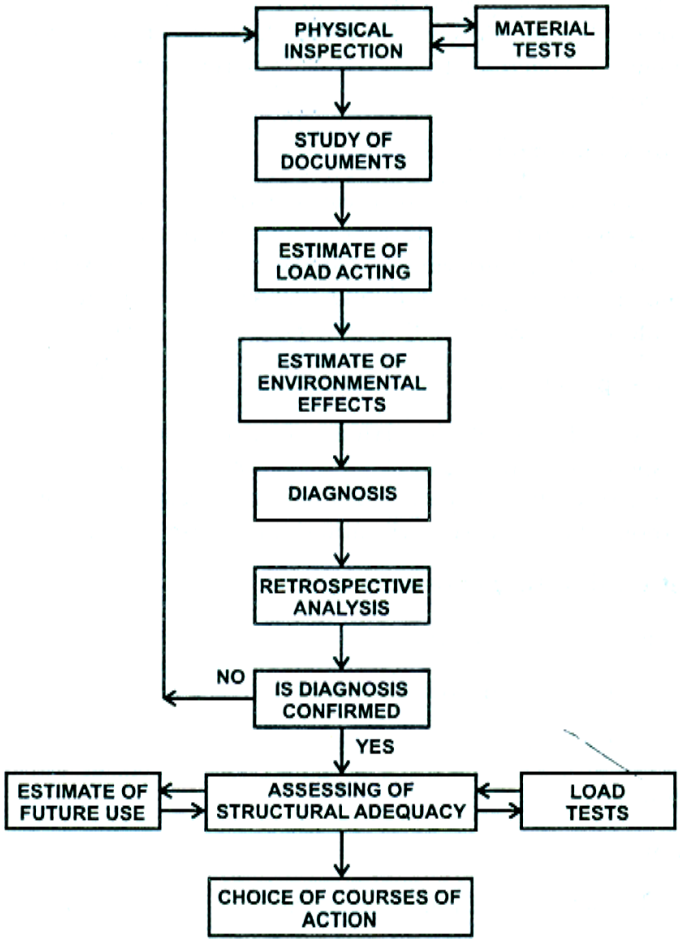


Fig: The steps in the assessment procedure to evaluate damages in a structure.

1.Preliminary investigations

The following data are to be collected:

1) Sources and properties of the materials with which the structure was
2) constructed.
3) Assumptions made in the design and the design calculations.
4) The construction procedure adopted, problems during construction, any
5) Abnormal observations, details about the work carried out during rainy season, flooding problems at the site, any stoppages of the work, test results of concrete and steel members.
6) The results of sub-soil investigations, ground water analysis, foundation systems used in the area, any subsequent excavations in the area adjacent to the structure.

7) The general stability of the ground mass, erosion/scour problems, earthquake effects, corrosive atmosphere, floods and vibrations.
8) Any changes in the service conditions of the structure, any modifications carried out.
9) Quality control and methods of construction.
10) Whether the structure will be worth its rehabilitation cost.

2. Analysing the Problem:

With the help of the data collected above the construction engineer shouldanalyse the problem of the structure and arrive at its root cause. This is importantfor a successful rehabilitation work.

3. Observations for confirming the findings in the Analysis:

This is done by fresh observations. Typical observations will include the following:

a) Settlement readings on the plinth of the building, pile caps, beams, adjacent
b) ground, flooring and pipelines.
c) Tell-Tale strips across cracks or separations
d) Deviations from plumb-line of columns
e) Seepage flow-both inward and outward
f) Mapping of 'honey combs' in concrete

These observations can be done once a day and the data should reach the rehabilitation engineer without delay.

4.Tests to be carried out:

The following tests are to be carried out on the samples taken out from thestructure and on the structural members.

(i) Testing the concrete for the strength of the mix proportions.
(ii) Sampling and testing of the subsoil.
(iii) Chemical analysis of the ground water
(iv) Chemical or x-ray diffraction tests on concrete
(v) Testing of leached materials

(vi) Hammer or Ultra-sonic tests on the concrete

(vii) Load tests on beams or slabs

(viii) Permeability tests for concrete or masonry

(ix) Vibration studies-amplitude and frequency

5. Diagnosis and Solution:

Based upon the past information, observations and tests conducted, it isreasonably possible to locate the actual root cause and also to it is reasonablypossible to locate the actual root cause and also to select the remedial action. Atthis stage, various alternative methods of rectification may be studied from thepoint of view of feasibility, safety, economy and time. The most appropriate methodamong the various alternatives is chosen.

5.Explain the various causes for deterioration of concrete structures. (OR) Damage classification of structures (or) various causes of distress(April/May 2019)(April/May 2017)(Nov/Dec 2018)

Some of the causes of deterioration of concrete structures are discussed below.

(i) Design and construction flaws:

Design of concrete structures governs the performance of concrete structures.Well designed and detailed concrete structure will show less deterioration incomparison with poorly designed and detailed concrete, in the similar condition.The beam-column joints are particularly prone to defective concrete, if detailingand placing of reinforcement is not done properly. Inadequate concrete cover maylead to carbonation depth reaching up to the reinforcement, thus, increasing therisk of corrosion of the reinforcement.

(ii) Environmental effects:

Micro-cracks present in the concrete are the sources of ingress of moistures:
Atmospheric carbon di-oxide into the concrete which attack reinforcement and with various .ingredients of concrete. In aggressive environment concrete structure will be severely affected.

(iii)Poor quality material used:

Quality of materials, to be used in construction, should be ensured by meansof various tests as specified in the IS codes. Alkali-aggregate reaction and sulphateattack results in early deterioration .. Clayey materials in the fine aggregatesweaken the mortar aggregate' bond and reduce the strength. Salinity causescorrosion of reinforcing bars as well as deterioration of concrete.

(iv) Quality of supervision:

Construction work should be carried out as per the laid down specification.

Adherence to specified water-cement ratio controls strength, permeability, anddurability of concrete. Insufficient vibration may result in porous and honeycombined concrete, whereas excess vibration may cause segregation.

(v) Deterioration due to corrosion:

- Spalling of concrete cover
- Cracks parallel to the reinforcement
- Spalling at edges
- Swelling of concrete
- Dislocation
- Internal cracking and reduction in area of steel reinforcement.

6. Explain the various categories of inspection based on method and interval . (April/May 2017)

Inspection to be carried out during construction of structure.

Inspection of Buildings Under Construction are required for a variety of purposes,including statutory requirements, which will dictate the frequency and scope ofinspection and reporting format, and these must be agreed between the professionaland the client.

Foundation stage	
Boundaryclearances	• setbackstoallrelevantallotmentboundariesandother buildingsandstructures
Excavationoffoundationmaterial	• dimensionsofexcavations • profileofsoilexcavated • bearingsurfacesofexcavations
Compactionoffillmaterial	• levelofcompaction • retentionofcompactedfill
Reinforcementofslabandfootingsystem	• typeandplacementofsteelreinforcing • sizeandgaugeofreinforcingsteel • locationanddimensionoflapstoreinforcementsteel.
Slab Stage	
Termitemanagementsystem	• locationandtypeofphysical andchemicalbarriers • protectionofpenetrations throughfootingor slabelements.
Floorlevels	• finishedslablevels toestablishheights abovefloodlevels,buildingheightor toaccommodatedrainagerequirements.
Frame Stage	
Floor framing and flooring	• membersizes andspacings • diaphragmbracingandblocking • water proof/resistantflooringtowet areas.
Roofand ceilingframing	• membersizes andspacings • cross-bracing andtie-down • point-loads supported • locationandfixingoftruss binders • battenfixingandjointlocation(sheetroofs).

Inspection to be carried out after construction of structure.

Atthecompletionofallaspectsofthework the following inspection need to be carried out.

Final Stage	
Siteworks and drainage	• drainagecomplieswith buildingdevelopment approvaland sitefacilitates drainawayfromthedwellingandprotectadjoiningproperties fromstormwaterrun-off • drainageofretainedearthincludingbatters donotimpactonthedwellingor adjoiningproperties

	• surface and roofwaterdischarges toanapproveddischargepoint • finishedgroundlevelsadjacenttothedwellingaregradeda way • requiredfinishedslabheights aboveexternalgroundlevel.
Termitemanagementsyste ms	• sub-floor termite shieldsandother elements ofphysical andchemicalbarriers • exposed slabedges • termitemanagementsystemnotices inrequiredlocations.
Damp andweatherproofing	• weatherproofcoatingtoexternalfaceofsingle-leaf masonrywalls • flashingtowall/roofjunctions • locationandspacingofweepholestocavitymasonrywalls • flashingtodoor andwindow openings for sheet-cladexternalwalls.
Firesafety	• hearth constructionaroundfree-standingor openfireplace • terminationheightofchimney • fire-ratedconstruction • constructionrequirements for bushfireproneareas • operationandlocationofsmokealarms.
Health andamenity	• ceilingheightstostairs,habitableandnon-habitablespaces light transmissionareas. • naturalandmechanicalventilation ofrooms constructionofsanitarycompartments
Safemovement and access	• balustradestostairs,balconies,decks, windows andpath ofaccesstoa buildingetc • constructionofstair risers andgoings • constructionoflandings andthresholds.
Constructionofwetareas	• water resistantandwaterproofconstructiontowet areas • treatmentofwallfloor junctions.
Glazing	• locationandtypeofglassinaccordancewith buildingdevelopmentapproval • locationandtypeofglass for energyefficiencyrequirements.
Sub-floorventilation	• locationandspacingofsub-floor ventilation • areaofventilationopenings

	• ventilationopenings tosub-floor internalwalls • sealed impervious membrane over groundinexcessivelydamp areas • groundgrading. •
Energyefficiency	• energyefficientlightingandhotwater supplysystems installed. • energyefficiencyrequirements as per buildingdevelopment approval.
Water savings measures	• rainwater tanks or greywater treatment plantsinstalledinaccordancewith QueenslandDevelopmentCodeMP4.2 • water conservationmeasures—showerheads,aerators,taps.

7. Distinguish between repair and rehabilitation?(April/May 2017)

Repair	Rehabilitation
The repair of concrete structures may vary between a cosmetic treatment and total replacements. By a proper investigation and well designed equipment. Tools and materials can be reinstated economically, an appropriate repair method can be selected depending upon the cause and extent of damage, importance of the structural elements, and its location.	Support the structural members properly as required. Remove all cracked, spalled and loose concrete. Clean the exposed concrete surface and steel reinforcement. Providing additional reinforcing bars, if the loss in reinforcement is more than 10%.

8. Illustrate the deterioration mechanism (April/May 2019)

Different defects can be involved in the **deterioration of concrete**. The following review provides a brief summary on the most common defects observed in the

existing structures. Normally, one or a number of these defects can be seen in structures; therefore, it is necessary to identify them properly. One needs to understand these different defects properly in order to get more realistic evaluation of the structure.

SCALING

Scaling is referred to the loss of the surface portion of concrete (or mortar) as a result of the freezing and thawing (OSIM, 2008). It is a physical action that usually leaves the aggregates clearly exposed.

Scaling happens when the hydraulic pressure from water freezing within concrete exceeds the tensile strength of concrete. Scaling is more common in non-air-entrained concrete, but can also occur in air-entrained concrete in the fully saturated condition.

DISINTEGRATION

Disintegration is the physical deterioration (such as scaling) or breaking down of the concrete into small fragments or particles.

It usually starts in the form of scaling. It may be also caused by de-icing chemicals, sulphates, chlorides or by frost action.

EROSION

Erosion is the deterioration of concrete surface as a result of particles in moving water scrubbing the surface.

When concrete surface is exposed to the water-borne sand and gravel, the surface gets deteriorated by particles scrubbing against the surfaces. Flowing ice particles can also cause the problem. It is an indicator of poor durability of concrete for that specific exposure.

CORROSION OF REINFORCEMENT

Corrosion is the deterioration of steel reinforcement in concrete. Corrosion can be induced by chloride or carbonation. The corrosion can result in cracking in the concrete cover, delamination in concrete decks, etc.

When the concentration of chloride ions above the surface of reinforcement reaches the threshold limit (which is the amount required to break down the passive film) corrosion begins. The volume of resulting material (rust) is 6-7 times, which increases the stress around the rebar, and causes fracture and cracking. The cracks extend to the surface of concrete over time; that is when we can visually see the sign of rust over the surface of concrete.

Structural Effects of Corrosion

DELAMINATION

"Delamination is defined as a discontinuity of the surface concrete which is substantially separated but not completely detached from concrete below or above it." Delamination is often identified by the hollow sound by tapping or chain dragging of concrete surface.

The corrosion of reinforcement and subsequent cracking of the cover can cause delamination. When the rebar have small spacing, the cracking extends in the plane of the reinforcement parallel to the exterior surface of the concrete.

SPALLING

Spalling can be considered an extended delamination. In fact, when the delamination continues, the concrete fragments detach from a larger concrete mass.

If delamination is not repaired on time, the progress of damages as a result of external loads, corrosion, and freezing and thawing can break off the delaminated pieces.

ALKALI-AGGREGATE REACTIONS

It is the internal cracking of concrete mass as a result of a chemical reaction between alkalis in the cement and silica in the aggregates. The AAR/ASR cracking are very famous for their crack patterns.

The alkalis in the cement can react with the active silica in the aggregates to form a swelling gel. When this gel absorbs water, it expands, and applies pressure to surrounding environment which makes the concrete crack.

CRACKING OF CONCRETE

A crack is a linear fracture in concrete which extends partly or completely through the member.

Some people believe that concrete is born with cracks; that its ingredients, and how it is produced - from the batching plant to pouring, setting, and curing - is influenced by so many factors that cracking of concrete does not come as a big surprise; and to a great extent, that might be true. Cracking of concrete can happen in different stages: It can happen before hardening of concrete, and it can happen in an old concrete structure:

9. **Explain in detail the six facets of maintenance?**

(a) **Emergency maintenance:** Necessitated by unforeseen breakdown ofdrainage or damage caused by natural calamity like fire, ·floods, cyclone,earthquake etc.

(b) **Condition based maintenance** (i.e.) work initiated after due inspection.

(c) **Fixed time maintenance:** Activities repeated at prederminend intervalsof time.

(d) **Preventive maintenance:** This is intended to preserve by preventingfailure and detecting incipient faults (work is done before failure takesplace)

(e) **Opportunity maintenance:** Work done as and when possible within thelimits of operational demand.

(f)**Day to day care** and maintenance.

(g) **Corrective maintenance:** This is the usual or common method to carryout repair and rehabilitation when an item falls below the, level of anacceptable standard. This is called corrective maintenance, e.g., corrosionmaintenance, repair of cracks, etc.

(h) **Shutdown maintenance:** Thorough overhaul and maintenance afterclosing a facility.

(i) **Improvement plans:** This is essentially maintenance operation wherein the weak links in the original construction are either replaced by new partsor strengthened.

10. What is maintenance? Explain the facets and importance of maintenance with various inspection procedures?

Maintenance is the act of keeping something in good condition by- checking or repairing it regularly. Maintenance is preventive in nature, Activities include inspection and works necessary to fulfill the intended function or to sustain original standard of service.

<u>Facets of maintenance:</u>

The two facets of maintenance are

(i)<u>Prevention</u>which include emergency maintenance, fixed time maintenance,condition based maintenance, preventivemaintenance, opportunity maintenance, day to day care maintenance, corrective maintenance, shutdown maintenance etc.,

<u>(ii) Repair</u>referring to modification of a structure partly or wholly which is damaged in appearance or serviceability.

<u>IMPORTANCE OF MAINTENANCE:</u>

The following are the advantages of good maintenance.

- Improves the life of structure.
- Improved life period gives better return on investment.
- Better appearance and aesthetically appealing.
- Better serviceability of elements and components.
- Leads to quicker detection of defects and hence remedial measure.
- Prevents major deterioration and leading to collapse.
- Ensures safety to occupants.
- Ensures feeling of confidence on the user.
- Maintenance is a continuous cycle and involves every element of buildingscience

.

11. What is time based maintenance?

Time-based maintenance is maintenance performed on a calendar schedule. This means that time is the maintenance trigger for this type of maintenance. Time-based maintenance is planned maintenance. This means that it can be used with both preventative maintenance and predictive maintenance strategies. A maintenance plan for a piece of work is put together that needs to be performed regularly. An example is the maintenance that is done on an air-conditioner every year before summer. With the maintenance plan in place, the maintenance is performed each time the calendar rolls over the specified number of days.

Advantages:

Easy to implement, no condition monitoring needed.

Decision variable: Time (T).

Maintenance is performed when the unit reaches age T.

A time-based maintenance plan must comprise the following parts, in order for it to be scheduled:

(i) Scheduling data &Scheduling parameters

The maintenance of scheduling parameters is dependent on the maintenance plan type.

(ii) Maintenance cycle

The maintenance cycles and packages contain the time or performance condition when maintenance must be performed.

(iii) Maintenance strategy

A maintenance strategy defines the rules for the sequence of planned maintenance work. It contains general scheduling information, and can therefore be assigned to as many maintenance task lists (PM task lists) and maintenance plans as required.

(iv) Maintenance item(s)

A maintenance item describes which preventive maintenance tasks should take place regularly at a technical object or a group of technical objects.

12. What is condition based maintenance?

Condition-based maintenance (CBM), shortly described, is maintenance when needarises. This maintenance is performed after one or more indicators show that equipment is going to fail or that equipment performance is deteriorating.

Condition-based maintenance was introduced to try to maintain the correct equipment at the right time. CBM is based on using real-time data to prioritize and optimize maintenance resources. Observing the state of the system is known as conditionmonitoring.

Secondly, introducing CBM will invoke a major change in how maintenance is performed, and potentially to the whole maintenance organization in a company.

CBM has some **advantages** over planned maintenance:

- Improved system reliability
- Decreased maintenance costs
- Decreased number of maintenance operations causes a reduction of human error influences

Its **disadvantages** are:

- High installation costs, for minor equipment items often more than the value of the equipment
- Unpredictable maintenance periods cause costs to be divided unequally
- Increased number of parts (the CBM installation itself) that need maintenance and checking

13. Explain the classification of maintenance?

Daily Routine Maintenance:

• Basically an inspection oriented and may not contain action to be taken.

• Help in identifying major changes, development of cracks, identifying new cracks etc.

• Inspection of all essential items by visual observation.

• Check on proper function of sewer, water lines, wash basins, sinks etc.

• Check on drain pipes from roof during rainy season.

Weekly Routine Maintenance:

• Electrical accessories.·

• Cob webs cleaning

• Flushing sewer line

• Leakage 0; water line.

Monthly Routine Maintenance:

• Cleaning doors, windows, latches etc.

• Checking septic tank/sewer.
• Observation for cracks in the elements.
• Cleaning of overhead tanks.
• Peeling of plaster, dampness, flour cracks

Routine maintenance:

• Attending to small repairs and white washing
• Painting of steel components exposed to weather.
• Check of displacements and remedial measures.

Maintenance operations require different approaches for different elements of the structure.

1.Those which should last the life of the structure without requiringattention.
Ex: foundations.

2. Those where improvements and sustained operation level is possible by the replacement of small parts at more or less regular intervals, like waterproofing of roof.

3. Those components which are subject: to wear and tear due to human or mechanical or natural agencies, like flooring.

4. Those components which are proved obsolete as a result of technological advances or to cater to changing tastes of user like sanitary fittings.

5. Those components which are exposed to weather and other natural deteriorating agents.

These operations may involve tackling the following:

- Structural repairs
- Electrical wiring
- Plumbing - water supply - sanitation
- Finishes on floors and walls
- Roof terrace
- Service platform / verandah
- Lifts
- Doors, windows and other elements.

14. Elaborate on the scope and objectives of investigations?

The **scope of investigation** of a defect is dependent primarily on the amountof money and effort that can be spent on it. The scope is further related to:

- Nature of the defect
- The accuracy with which causes of defect needs to be identified
- The main reason for the defect investigation (such as remedial workrequired).

The scope of investigation becomes wider with uncommon defects and requirements of greater accuracy.

Purpose/ Objectives of Investigations:

Before taking up investigations for assessing the causes of deterioration ofbuilding structures/services, it is necessary to understand reasons for carrying outsuch investigations. The purposes for investigation are:

(i)Legal: Commission of enquiries are normally appointed to go into thereason of such deterioration and failures. The emphasis is on 'who' ratherthan on "what" went wrong. But more often the aim of theseinvestigations is to find out the "Culprit". If deaths have occurred dueto deterioration/failure, these investigations become part of criminalprocedures also.

(ii)Insurance Surveys: Many times important works under construction areinsured against "Contractor's All-Risk (CAR) Policies", Centering,form-work, and works under water are insured by the contractors againstfailure risks. Even Architects and Consultants like "ProfessionalIndemnity Insurance" to. protect themselves against claims from theclients by insuring their design. Here again the investigations concentratemore on Assessment of damages including damages in terms of money.

(iii)Structural Failures: These investigations are primarily done to find outscientifically what went wrong with regard to design andconstruction and to pinpoint the cause of deterioration.

15. Explain the different common defects in concrete structures with their causes and effects?

Common building defects and their symptoms

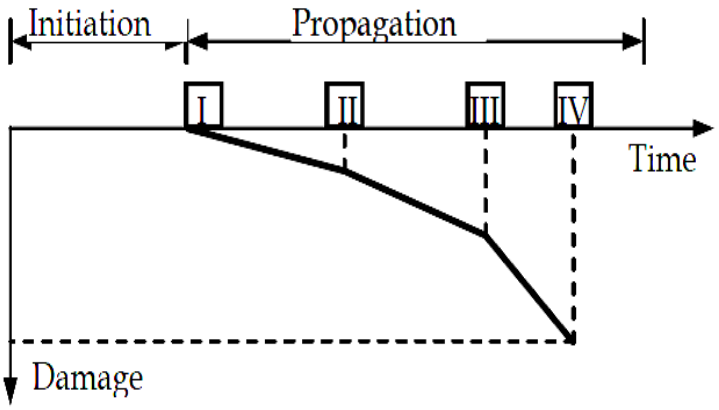
Common Defects	Symptoms/Phenomenon	Possible Causes
efective concrete **i)** spalling or loose plaster in ceilings	Surface with water/rust staining, •waterleakage•Patterned cracking, •Bulging, falling off of concrete patches with reinforcementexposed, •often rustyfalling off of plaster/tiles	Defective concrete as a result of ageing is commonly found in old buildings. Persistent water leakage may affect the steel reinforcement. Weak concrete caused by the use of salty water in concrete mix, or overloading are also common causes in spalling
/ater seepage from **ii)** external wall, window, roof, or from ceiling	/ater staining, Peeling off of paint or wall paper• Water dripping• Growth of fungus• Defective concrete, plaster or tiles• Rust staining•	External water seepage could be due to a variety of reasons including cracks on external wall, honey comb concrete, defective sealant at window, defective waterproofing membrane at roof, defective external water and drainage pipes, etc
tructural cracks in(**iii)**walls	racks that penetrate through finishes into the concrete or bricks, •Long, continuous cracks across width of wall, •Diagonal cracks at corners of window or door, •Cracks with rust staining	Structural cracks may be caused by many factors, e.g. excessive movement of the building structure, unwanted ground settlement, serious overloading, weaknesses caused by corrosion/deterioration of materials, or damage by accidents, or poor design/ construction, etc. Detailed investigation must be carried out to identify the cause(s) which must be removed or rectified before the cracks are repaired

on-structural cracks **v)**usually in plaster or other finishes with cement sand rendering as base)	airline cracks multi-directional cracks (shrinkage cracks)Cracks between panel walls and structural elements e.g. brick wall and beams/columns	Cosmetic shrinkage cracks in plaster or other forms of finishes will affect the appearance only and do not pose any safety concern. They are small hairline cracks developed within the finishes layer not penetrating down to the reinforced concrete structure
efective external wall **(vi)**finishes/mosaic tiles/ceramic tiles/stone cladding/curtain wall	ebonding of finishes/tiles from wall Structure resulting in "hollow sound" when tapped with a hammer racking of wall surfaces Bulging with hollow base Falling offCracks Loosening of parts	The defects could be due to ageing, structural movements, defective workmanship during installation, thermal movement, defective or missing expansion joints, damage by external factors (e.g. falling objects during typhoon), ingress of water into the gap between the finishes or tiles and the structure, etc.

16. With a graph explain the service life behavior of a concrete structure with respect to maintenance.

Service life models

The service life of concrete structures is commonly modeled as a two stage process,defined respectively as the "initiation" and the "propagation" stage (see Figure). Manystudies have already been performed based on these processes over the last decades.The limit state functions (critical failure modes) will be developed basedon these physical models.



I. Initiation
II. Cracking
III. Spalling
IV. Collapse

Initiation Period:

The initiation period is a period during which chloride ingress occurs into the concretecover until, eventually, depassiviation takes place and rebar corrosion starts. Once corrosion of a rebar in concrete has been initiated, phenomena may occur such asreduced rebar cross-section, deterioration of concrete cover, cracking and spalling ofconcrete, loss of steel-to concrete bond, etc.

If corrosion proceeds at a sufficiently high rate,all of these phenomena may negatively affect performance and eventually structuralcapacity. Actually, corrosion takes place during the whole propagationperiod. Initiation of rebar corrosion itself does not necessarily represent an undesirablestate, but without initiation the probability of these negative phenomena is absent. This iswhy in many service life approaches, initiation is taken as an indicator of the need to carryout maintenance; usually preventive maintenance is sufficient to secure all required levelsof performance.

Propagation period:

After the initiation of corrosion the propagation begins and this period has two distinct processes. One is that the corrosion flows an electrochemical process

and the other is the physical process due to which damage to concrete occurs. During the propagation period the corrosion progress at a rate depending on the availability of oxygen and moisture.