Subject : Maintenance and rehabilitation of structure

“Unit- 2 Repair Strategies ”

1. Unit-II Repair Strategies

- Learning Out Come:
- Explain distress diagnostic techniques
- Carry out inspection and evaluation of damaged structure.
- Topic and Subtopics:

1. Causes of distress in structures
2. Construction and design failures
3. Condition assessment and distress-diagnostic techniques
4. Inspection and evaluating damaged structure.

Distress Structure:

When a **structure** or a member is subjected permanently to some unforeseen stresses exceeding its load-bearing capacity, the **structure** may be termed as having a defect. This may be due to various reasons excess loading, change in pattern of loading and use, bad materials used in **construction**, effect of environment, etc.

A structure is said to be distressed when it looses its load carriying capacity and strength

- Before attempting any repair procedure, it is necessary to have a planned approach to investigate the condition of concrete and reinforcement. While the diagnosis of damage or deterioration in some cases is reasonably straightforward, it may not be so in many cases. Particularly difficult are cases in which the causes and effect phenomenon cannot be readily explained or when prognosis in terms of long-term performance of restored structure is to be made

This will require a thorough technical inspection and an understanding of the behavior of the structural component, which is being repaired. Inspection calls for detailed mapping of affected areas, documentation of type and location of symptoms and their history and photographic evidences.

It may also include the environmental factors, which are likely to accelerate the damage process. Existence of concealed ducts, water lines, wet areas require special attention. Some areas impose severe limitations on access to damaged areas. A comprehensive inspection data helps in making an effective strategy for repair and rehabilitation.

MAIN CAUSES OF SUCH DISTRESS IN BUILDINGS:

(I) CAUSES OF DESTRESS IN STRUCTURE:

- One or more of the factors listed below may cause distress in buildings/Structure
- Deficiencies in design
- Poor detailing of reinforcement in RC structural members and joints
- Poor quality of construction
- Corrosion of reinforcement due to aggressive environment.
- Inadequacies in the structural system to resist lateral forces due to natural hazards like cyclones and earthquakes.

- Settlement or differential settlement of foundation
  Extreme and unforeseen loading
  Poor material and workmanship
  Inspection and maintenance
  Unpredictable causes

CAUSES OF DISTRESS AND DETERIORATION OF CONCRETE:

- Following are the main causes of distress and deterioration of concrete:

1. Accidental loadings
2. Chemical reaction

- Acid attack
- Alkali – carbonate rock reaction
- Miscellaneous chemical attack
- Aggressive- water attack
- Alkali-silica reaction
- Sulfate attack

3.Construction error

4.Corrosion of embedded metals

5. Design errors

- Inadequate structural design
- Poor design details

6. Erosion

- Abrasion
- Cavitation

7. Freezing and thawing

8. Settlement and movements

9. Shrinkage

- Plastic shrinkage
- Drying shrinkage

10. Temperature changes

- Internally generated
- Externally generated
- fire

- 11. Weathering

CONSIDERATION FOR REPAIR STRATEGY:

- The following points should be considered in the condition survey report before arriving at the repair strategy.
- Identification of the cause of distress in the structure is the fundamental to carry out very carefully.
- Systematic documentation of all observations made during preliminary inspection is essential for arriving at an effective and economical solution for repair.
- Accessibility to the areas identified for repair needs consideration.
- Available space and accessibility will determine the selection of repair method and repair strategy.
- The prioritization of repairs and their sequencing are important components for deciding the repair strategy.

- Safety measures to prevent any immediate major mishap shall be prescribed.
- Major repair procedure may demand propping the structural members to relieve a part or full component of the load acting on the member. If the building requires extensive propping, vacating, the building may become the pre-requisite.
- Depending upon the scope of repair work, the repair strategy has to suit the on-going activities in the building.
- Availability of services of experienced rehabilitation engineer/consultant.
- The report should also include requirements on safety measures to be adopted during execution of repair jobs.

Objectives of Repair strategies:

A repair procedure may be selected to accomplish one or more of the following objective:

1. To increase strength or restore load carrying capacity.
2. To restore or increase stiffness.
3. To improve functional performance.
4. To provide water tightness.
5. To improve appearance of concrete surface.
6. To improve durability.
7. To prevent access of corrosive materials to reinforcement.

CONSTRUCTION AND DESIGN FAILURE:

- The followings are the defficiencies which results construction and design failure of structure**.**

(a) Construction errors:

Poor construction practices and negligence can cause defects that lead to the cracking and deterioration of concrete.

The common construction errors are:

1. Use of inferior quality construction materials, i.e. cement, sand, aggregate, reinforcements. Etc.
2. Use of wastewater or saline water in construction.
3. Adding more water to concrete to improve its workability. Addition of water increases w/c ratio resulting in shrinkage cracks and reduction in strength.
4. Poor proportion (grading) of concrete ingredients

5. Poor mixing of concrete
6. Batching of concrete by volume using mortar pans
7. Insufficient compaction of concrete, resulting in honeycombing and porosity.
8. Dropping concrete from height resulting in segregation.
9. Insufficient reinforcement in slab, beam, column, etc., using rusted re bars.
10. Improper location of reinforcing steel.
11. Hooks, bends, overlap, concrete cover to reinforcing are not proper.
12. Formwork props not resting on hard base may settle down resulting in Settlement of the structural member.
13. Premature removal of formwork props.

14. Using props of insufficient strength.

15. Construction joints, expansion joints, contraction joints, etc. are not properly provided.

16. Improper curing of concrete, brickwork, etc. resulting in shrinkage cracks.

17. Segregation of concrete during transportation.

18. Settlement of foundation constructed on soil of low bearing capacity.

19. After concreting in hot weather or direct sun, if concrete surface is not covered.

20. In case of brick masonry.

- Bricks are not soaked in water before use in masonry.
- In the masonry, if brick layers are laid with frog on downside .
- Joints of masonry are not properly filed with mortar.
- Excess quantity of brick bats is used.
- Compressive strength of bricks is less than 7 N/mm*. and water absorption is more than 25%.

(b) Design deficiencies:

- Design deficiencies can be broadly categorized into two types:

    1. Inadequate structure design.
    2. Poor design detailing.

1. **Inadequate structural design:**

The common errors of structural design are:

- Error in load calculations.
- For the design of foundation, SBC of soil assumed without conducting plate load.
- Design not conforming to IS: 456-2000 and IS 1893-1987 guidelines.
- Load transfer path in the structure is not properly understood by the designer.
- Design with many cantilevers and projected balconies.

- Shear wall is not designed in the multistory framed structure.
- In the ground floor storey for parking only columns are provided without walls, resulting in ‘soft storey’.
- Stiffness of the structures in both directions is different, resulting in ‘torsion’ during earthquake.
- In one story, if some of the columns become ‘shot columns’, they attract larger lateral load.
- Lack of knowledge of using structural design software like STADD PRO, ETAB, STRUD, etc.

2. Poor design detailing:

- Detailing of reinforcement is equally important as structural design. Sometimes a structure may fail due to poor detailing, though the design is proper.

Some of the detailing errors are:

- Abrupt changes in section.
- Insufficient reinforcement at re-entrant corners and opening.
- Inadequate provision for deflection.
- Inadequate expansion joints.
- Material incompatibility.
- Error in showing one way / two -way slab in the drawing.

- Bent up bars are not properly shown.
- In beams, spacing of vertical stirrups is wrongly shown, i.e. shown 250 mm c/c instead of 150 mm c/c.
- Similarly in columns spacing of lateral ties is wrongly shown.
- Hooks for lateral ties and vertical stirrups are shown 90 degree instead of 135 degree.
- Ductile detailing is not done as per IS : 13920
- This lead to

1. Leakage through joints
2. Inadequate drainage
3. Inefficient drainage slopes
4. Unanticipated shear stresses in piers, columns and abutments etc.
5. Incompatibility of materials of sections
6. Neglect in design

CONDITION SURVEY/ASSESSMENT OF BUILDINGS:

- Building condition surveys are carried out on all building types; institutional, commercial as well as housing.
- It is the examination of building, its components and materials quality for the purpose of identifying and defining area of destress.
- Condition Survey is an inspection of a building or other structure, at a certain date, to determine its state of repair and may requirements for maintenance.
- A building condition survey may be described as a survey to collect information about the condition of the buildings for a defined purpose. Condition is the criteria by which the buildings to be judged.

- The main purpose is to briefly describe how to carry out the *condition assessment of buildings* before taking up repair and upgrading work. This will determine whether a distressed building should be demolished to *build back better* or whether it will be cost-effective to either repair or retrofit it, in the context of overall safety.
- Condition may be interpreted broadly. Typical condition issues include the following :

a) State of repair or disrepair;

b) Physical state and need for maintenance;

c) Existence of components

d) Health and Safety

e) Fitness for purpose.

f) Capacity to meet regulatory requirements;

g) Capacity to meet performance requirements

- A Condition Survey provides an assessment of physical property conditions.
- The survey should identify deficiencies, and maintenance issues including, but not limited to structural, mechanical, electrical, plumbing, fire protection, site layout, site utilities, storm water management, soil erosion and life safety systems.
- To facilitate an informed decision-making process, a Condition Survey should result in a clear understanding of the current condition of operating systems by a Client.

- Ref. QproQ Engineering, Inc. Civil/Structural Engineers

For assessment of damage of a structure the following general considerations have to be take account.

1) Physical inspection of damaged structure.
2) Presentation and documenting the damage.
3) Collection of samples and carrying out tests both in situ and in lab.
4) Studying the documents including structural aspects.
5) Estimation of loads acting on the structure.
6) Estimate of environmental effects including soil structure interaction.
7) Diagnosis.

8) Taking preventive steps not to cause further damage.

9) Retrospective analysis to get the diagnosis confirmed.

10) Assessment of structural adequacy.

11) Estimation of future use.

12) Remedial measures necessary to strengthen and repairing the structure.

13) Post repair evaluation through tests.

14) Load test to study the behavior.

15) Choice of course of action for the restoration of structure.

CONDITION SURVEY/ASSESSMENT:

OBJECTIVES:

Main objective of condition assessment is to place the building into one of the following three categories:

A. Building has not shown any signs of distress and it satisfies all the safety and serviceability requirements according to relevant Codes of practice, hence no action is needed towards retrofitting.

B. The building is seen to be deficient (or distressed) but it can be repaired and strengthened to satisfy the caudal safety requirements or performance criteria set by the user.

C. The building is badly damaged. It is to be demolished and a new building may be built, build back better.

- ***Main steps of condition assessment will be***

a) To record the damage if any, and find out the causes for distress

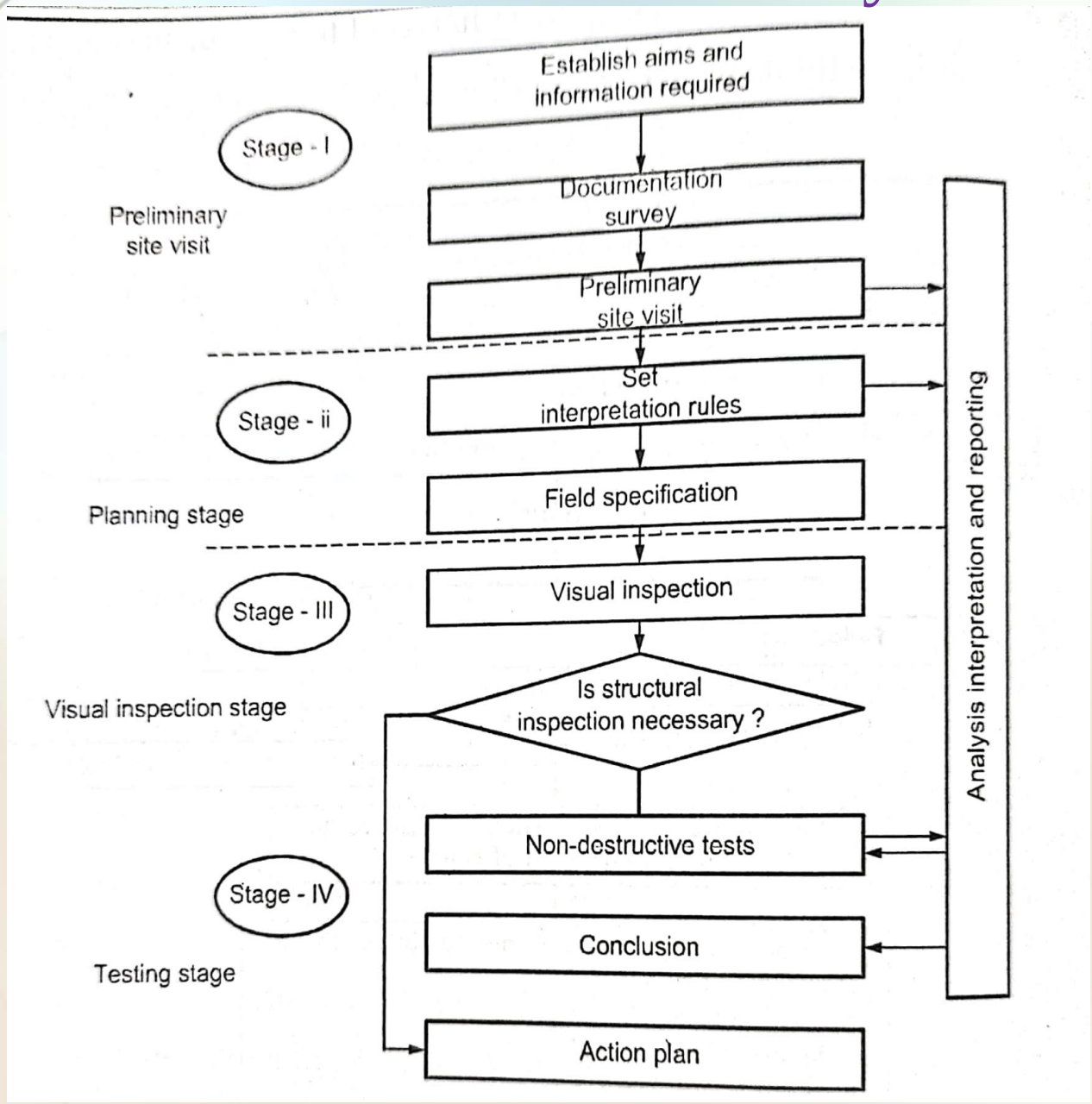
b) To assess the extent of distress and to estimate the residual strengths of components and the system including the foundation.

c) To plan the rehabilitation and retrofitting/strengthening of the building.

- **Stages of condition survey:**

1. Preliminary Inspection
2. Planning stage
3. Visual inspection
4. Field and laboratory testing

Process of condition survey



METHODOLOGY FOR CONDITION ASSESSMENT:

Condition assessment and evaluation is generally carried out in two levels:

(i) Preliminary Inspection:

A preliminary Condition Survey entails the review of existing documentation such as construction drawings, specifications, reports and calculations. During a preliminary Condition Survey, the Engineer(s), along with a person such as a Building Supervisor, should visually inspect the site and building system(s). Photographs and video are useful to illustrate deficiencies that may be found during the on-site inspection. After documenting the existing conditions, the Engineer(s) should analyze the collected data and summarize the findings and recommendations in a brief report.

- If requested by the Client, an opinion of probable construction cost can be included with the report. After a preliminary Condition Survey is completed, a detailed Condition Survey may be requested to gather and document additional detail that will be necessary to prepare renovation drawings, upgrade operating systems, and/or negotiate a property purchase or sale.

1.Preliminary Inspection

- Objectives and Information of Preliminary Inspection:
- Objectives :

(i) To collect necessary information for a thoughtful planning

- Background history of a distressed structure
- Details of earlier repairs, if any
- Safety requirements
- Extent and quantum of survey work
- Time needed for survey work
- Tool and equipment for sampling and field testing

(ii) To advise the owner /client for immediate safety measures, to alert any mishap endangering life and structure

(iii) To define the scope of work of field investigation in consultation with client.

Basic information to be collected in preliminary inspection:

- Period of construction
- Design details and drainage, structural & architectural drawing
- Specifications of materials
- Foundation details, soil condition
- Exposure conditions of structure
- Structural changes made, if any
- Use of structure
- Details of earlier repairs, if any
- Details of previous investigation
- Apparent cause of distress
- Photograph of distressed parts of structure, etc.

2. Planning stage:

- Planning stage involves:

a) Preparation of field documents

b) Grouping of structural members

c) Classification of damage

(a) Preparation of field documents:

- Objectives of survey
- Scope of work
- Method of survey
- Laboratory/field tests to be conducted
- List of tasks and their sequence
- Floor plans based on measurements
- Worksheet and tables for recording all information ,test result etc.
- Maintenance and repair record
- Photocopies of available drawings

Worksheet:

- Worksheets are documents in the form of floor plans, charts, statistical formats etc. to record relevant data, observations, quality, type and extent of damage etc.
- Floor plan with suitable grid pattern should be prepared to identify various structural members i.e. Beam, column, slab, wall, projection, chajjas etc.

(b) **Grouping of structural members:**

- Grouping as per type and similarity of exposure condition
- e.g.

1. External beam/ columns and Internal beam/ columns – severity of environmental attack
2. In external column- Corner or projected -more exposure
3. Different protective finishes- plaster, timber, aluminium etc.
4. Dampness effect - in or around toilet area

(c) Classification of damage:

Based on preliminary data and site visit ,the rehabilitation engineer should interpret the rule and subdivide the repair or damage classification as under.

(c) CLASSES OF DAMAGE AND REPAIR CLASSIFICATION:

CLASS OF DAMAGES	REPAIR CLASSIFICATION	GENERAL OBSERVATIONS ON THE CONDITION OF CONCRETE	REPAIR REQUIRMENT
Class O	Cosmetic	Only final finishes disfigured. No structural distress observed	Redecoration, if required
Class 1	Superficial	Final finishes/ skin alone damaged. No structural cracks observed. Carbonation depth not yet reached reinforcement level.	Super facial repair of slit damage to nonstructural finishes
Class 2	Patch repair	Minor structural cracks observed depths reached reinforcement level.	Nonstructural or minor structural repair limited to crack, selling, restoring the lost cover concrete, if any, due to corrosion of reinforcement carbonation resistance surface protective coating, short create or other repair material reinforced with nominal like steel fabric.
Class 3	Principle repair	Spelling of cover concrete major structural cracks including cracking along reinforcement due to corrosion or otherwise leading substantial reduction of load carrying capacity	Strengthening repair reinforced concrete in accordance with the load carrying requirement of the member concrete strength may be extremely low and reinforcement diameter might have been significant reduced requiring check by reason procedure

3. Visual Inspection:

- A through visual inspection leads to proper approach to be adopted during investigation. It determine the number of field and laboratory tests required to be carried out.
- **The visual inspection shall cover:**

1. The recording of
   - Areas of high distress and Exposure conditions of various distressed areas
   - Cracks width , location and pattern
   - Spalling of concrete, abrasion/erosion, efflorescence
   - Leakage/seepage and dampness locations, joints
   - Excessive deflection, sinking of column
   - Failure of beam-column junction

- Conditions of fixtures
- Abnormal vibrations in structure, if any
- Service area- Stair case, lift, water supply & drainage line
- Metal corrosion, color, texture and rust dtains
- Algae, fungus growth and their locations
- Photographic records

2. Identifying the areas of immediate concern

4. Field and Lab Tests:

A number of non-destructive, partially destructive and destructive techniques for assessment of concrete structure and to predict the cause of deterioration of the concrete in the existing structures These NDT techniques can be broadly classified into following four groups:

1. Strength Tests :

- Schmidt Hammer Test
- Ultrasonic Pulse Velocity
- Pull out and Pull off Tests
- Break off
- Core Test
- Windsor Probe
- Pulse Eco Technique

2. Chemical Tests

- Carbonation test
- Suphate Determination Test
- Chloride Determination Test
- Thermoluminescence Test
- Thermo gravimetric analysis Test
- Differential Thermal analysis
- Dilatometric Test

3. Durability Tests

- Corrosion Tests
- Absorption and Permeability
- Test for Alkali Aggregate Reaction
- Abrasion Resistance Tests
- Rebar Locator Test

4. Performance and Integrity Tests

- Infrared Thermography Test
- Radar Test
- Radiography and Radiometry Tests
- Acoustic Emission
- Optical Fibre Test
- Impact Echo Tests
- Load Testing test
- Dynamic Response
- X-Ray Diffraction

(ii) **Detailed condition survey:**

- In a detailed Condition Survey, on-site interviews, maintenance history review, review of local municipal records, code compliance research, testing of operating systems, design and performance criteria definition, load capacity calculations and preparation of schematic drawings are generally areas addressed in the findings and recommendations report.

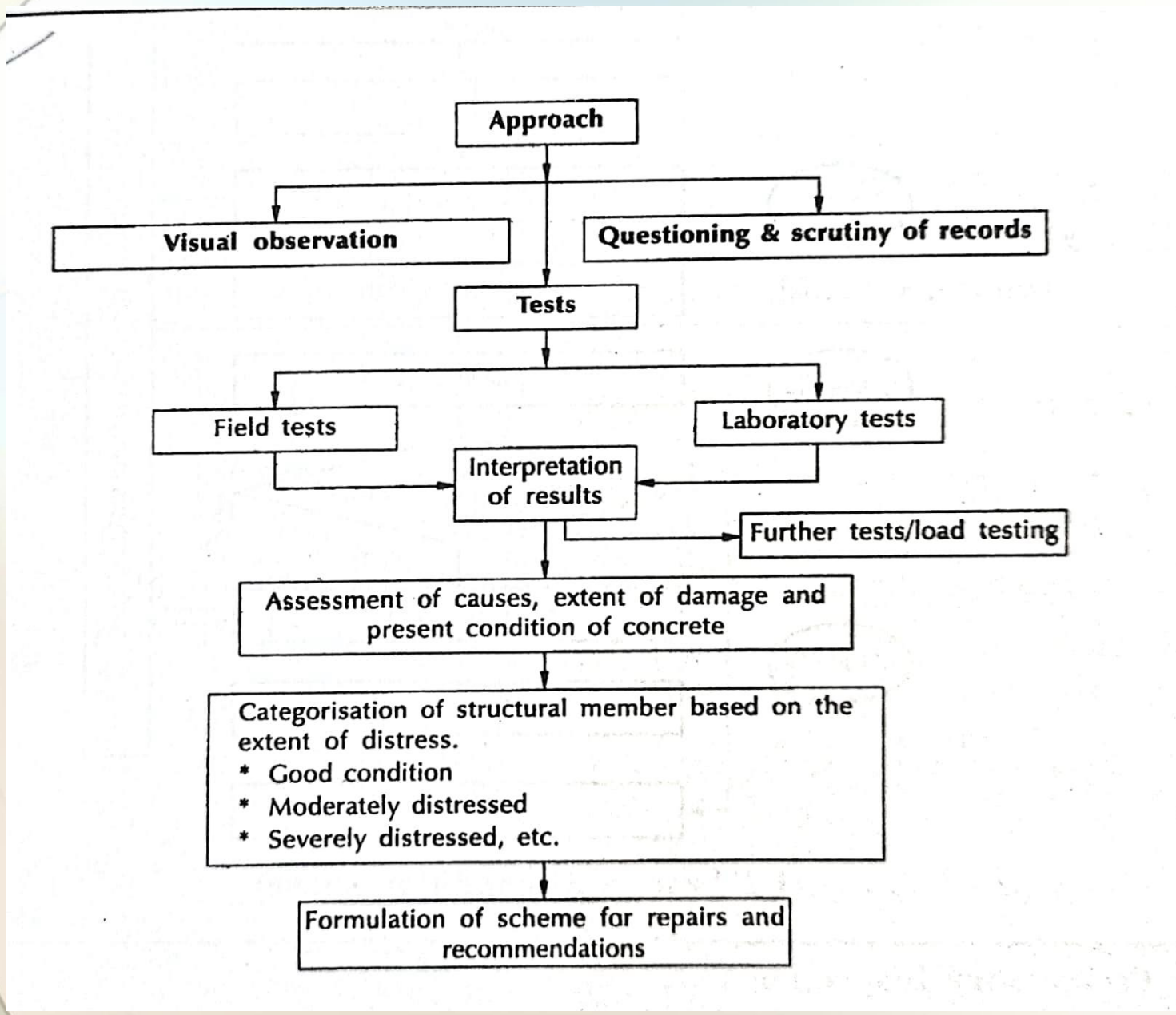
EVALUATION PROCESS:

1. Evaluation approach:

The first step is to evaluate the current condition of the concrete structure. This evaluation may include:

- Review of available design and construction documents.
- Structural analysis of the structure in its deteriorated condition.
- Review of records of any previous repair work accomplished.
- Review of maintenance records.
- Visual inspection.
- NDT and core testing. Laboratory analysis of concrete samples

General approach for pre repair evaluation of distressed concrete



Thank you…