ROHINI COLLEGE OF ENGINEERING AND TECHNOLOGY
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Department of Civil Engineering

COURSE MATERIAL

Course Name : REPAIR AND MAINTENANCE OF BUILDING

1. Importance of Maintenance:-

1. Improve the life of structure

2. Improved life period gives better return on investment

3. Better appearance and aesthetically appealing

4. Better serviceability of elements and components

5. Leads to quicker detection of defects and hence remedial measures

6. Prevents major deterioration and leading to collapse

7. Ensures safety to occupants

8. Ensures feeling of confidence on the user

9. Maintenance is a continuous cycle involves every element of building science

namely, Structural

Electrical wiring

Plumbing-water-supply-sanitation

Finishes in floors and walls

Roof terrace

Service platform/verandah

Lifts

Causes of Deterioration

a) Design and construction Flows

Design of concrete structures governs the performance of concrete structures. Well-designed and detailed concrete structure will show less deterioration in comparison with poorly designed and detailed concrete, in this similar condition. The beam-column joints are particularly probe to defective concrete, if detailing and placing of reinforcement is not done properly.

b) Environmental effects

Micro-cracks present in the concrete are the source of access of moisture and atmospheric carbon-di-oxide into the concrete, which attack reinforcement and react with various ingredients of concrete. In aggressive environment, concrete structures will deteriorate faster and strength/life of concrete structures will be severely reduced.

c) Usage of poor Quality Material

Quality of materials to be used in construction, should be ensured by means of various tests, as specified in the IS codes. Alkali-aggregate and Sulphate attack results in early deterioration.

Clayed materials in the fine aggregates may weaken the mortar-aggregate bond, and reduce the strength.

d) Quality of Supervision

Construction work should be carried out as per the specifications. Adherence to specified water-cement ratio controls strength, permeability and durability of concrete. Insufficient vibration may result in porous and honey-combed concrete, whereas excess vibration may cause segregation.

e) Deterioration due to Corrosion

- ✓ Spalling of concrete cover
- ✓ Cracks parallel to the reinforcement
- ✓ Spalling at edges
- ✓ Swelling of concrete
- ✓ Dislocation

Definition of deterioration/Decay

Deterioration or decay is the development of defects in a structure that may be due to natural causes of ageing. If deterioration is not checked or is allowed to occur, decomposition of materials results and replacement becomes the only solution. The rate of deterioration depends on the resisting capability of materials.

2. FACTOR CAUSING DETERIORATION, THEIR CLASSIFICATION

The different factors giving rise to the deterioration are classified as follows:

1. Human factors
2. Chemical factors
3. Environmental factors
4. Miscellaneous factors

1. Human Factors

Most of the deterioration of structures is caused by human factors. This can be either due to a lapse in the construction phase or due to misuse of the building by its occupants or due to improper and inadequate maintenance of the building.

Following are the human factors causing the deterioration of the structure :

1.Use of bad quality building materials.

2.Improper execution during construction.
3.Failure to supervise during construction.
4.Lack of awareness of factors that cause deterioration.
5.Failure to perform ongoing maintenance.
6.Lack of awareness of service requirements among users.
7.Failure to establish a maintenance standard that is acceptable.
8.Inadequate planning, budgeting and allocation of funds for maintenance activities.
9.Have an occasional approach to repairs with a negative attitude of waiting until emergency measures are required.
10.Flagrant misuse of buildings, facilities, finishes, etc.

2. Chemical Factors

Chemical reactions are caused by the interaction of certain materials with the surrounding environment. This leads to dissolution, softening or discoloration of the material or components. Corrosion is the result of chemical reactions of materials with air and water in the environment.

2. **Environmental factors**

Environmental factors refer to the exposure of building components such as sun, wind, rain, ground salts etc.

The various environmental factors causing the deterioration of Buildings are :

(i) Atmospheric Moisture:

Atmospheric moisture is regarded as the principal-agent causing the deterioration of the structures. Moisture is always present in the atmosphere and when the surface temperature falls, condensation can occur. Water frozen in the pores of materials can cause spalling of the surface, cracking or disintegration.

(ii) Temperature effects:

The temperature change causes temperature stress in the material of the structure. These stresses cause breakage and failure of the building material.

(iii) Gaseous Pollutants of Air:

Increasing pollution is also a major contributor to structural damage. SO_2 is the most aggressive gaseous pollutant which causes corrosion of some metals and causes some stones to blister and spall. CO_2 also forms a weak acid, capable of slowly eroding limestone. The extent of carbonation in concrete has a marked influence on the corrosion rate of steel.

(iv) Solid contaminants:

Environmental pollution in the form of solid contaminants also has an adverse effect on buildings deterioration. Dirt also contains some soluble salts. it absorbs water from the atmosphere and accelerates the corrosion rate of metals and the deterioration of some stone surfaces. The dirt also contains some soluble salts. It. absorbs water from the atmosphere and accelerates corrosion rate of metals and deterioration of some stone surfaces.

(v) Groundwater and Salts:

The salts present in the groundwater rise in solution through capillary action. Upon evaporation of water, salts accumulate on the surface and cause damage to the building. This usually causes flaking and deterioration of building surfaces and finishes. More seriously if magnesium sulphate is present in groundwater. Rendering and masonry surface discoloration may occur. Acidic groundwater can cause concrete to disintegrate.

(vi) Biological Agencies:

Some building materials are affected by biological agencies like algae, mosses, termites etc. Termite attacks on the wood are very prominent.

4. Miscellaneous Factors

The following are the miscellaneous factors causing deterioration of the structures :

(i) Poor construction materials:

Use of substandard construction materials, inadequate inspection of materials, poor on-site storage facilities for construction materials and inconsistent mixing of materials on site are the factors responsible for the deterioration of buildings at a later stage.

(ii) Poor design:

Poor and faulty design lead to more immediate deterioration of structures.

(iii) Poor workmanship:

Poor workmanship is a major factor that affects the durability of the structure. Include, Failure to understand/follow exactly the specifications and drawing, Lack of skilled labour, Lack of supervision during construction, Failure to replace the defective work noticed if any and Over-emphasis on quantity rather than the quality of construction.

(iv) Misuse of buildings:

This includes the use of buildings for which it is not designed. The condition of the building can deteriorate due to open misuse of the building, its fittings, furnishings etc.

Deterioration Of Construction Materials

It is necessary to understand the effect of various agencies causing deterioration of building materials to take proper protection against these agencies.

The choice of building material depends upon,

(i) Ability to withstand the effects of climate.
(ii) Ability to accomplish designed tasks.
(iii) Reaction with the surrounding material.
(iv) Ease of maintenance and replacement.
(v) Overall economic acceptability.

The effects of different agencies of degradation on different building materials are as follows:

1. BRICKS

Generally, bricks have good durability. The most common effects of weathering on bricks are :

- Efflorescence (deposition of white powdery materials causing disfigurement of bricks).
- The spalling of the external surfaces.
- Change in appearance.

2. TIMBER:

The following are the effects on the durability of timber:

- Timber decays as a result of the destructive action of 'fungi' (called dry rot) growing on it.
- Dry rot requires a moisture content of about 20% and spreads very rapidly.
- Insect infestation (i.e. beetles, termites) destroys timber used in buildings.
- Exposure to natural weathering agents such as rain, wind and temperature contribute a lot to the fast decay of timber.

The following steps are taken to avoid deterioration of timber :

Proper seasoning of timber (reduction of moisture content to optimum levels is done to make it last longer.

Preservatives are used to preserve the timber from decaying. Such treatment is done to ensure a long, trouble-free life of the timber.

3. CONCRETE: Effects of deterioration of concrete

Concrete is a relatively durable material but its durability is affected due to the following factors :

(i) Freezing and thawing: Water entering the pores (voids) of concrete freezes in cold climates. An increase in the volume of water on freezing results in Agencies Causing Deterioration disintegration of concrete. Concrete located in exposed conditions is more susceptible to such attacks.

(ii) Sub-soil salt attack: The water-soluble sulphates in soil when it comes in contact with concrete causes its expansion, spalling and disintegrations. The extent of damage to concrete will depend upon the amount and types of sulphate present in the groundwater and the quality of concrete.

(iii) Alkali-aggregate reactions: Silica present in aggregates reacts with the alkalis of cement in the presence of water and causes expansion and subsequent damages to concrete.

(iv) Corrosion of steel: Corrosion of steel bars in R.C.C. structures reduce the durability of concrete in contact with steel bars. Rusting of steel bars causes spalling and cracking of concrete. Deterioration is aggravated in case the concrete is the permeable or concrete cover to steel reinforcement is inadequate.

Effect of deterioration of concrete can be controlled by the following steps :

(i) Using optimum water-cement ratio.

(ii) Using sound and fresh cement.

(iii) Using durable, densely graded and non-reactive aggregates.

(iv) Using proper batching and mixing equipment and methods.

(v) Providing thorough and uniform compaction.

(vi) Providing proper curing.

4. METALS:

The metals used in buildings have good durability. The durability of metals is affected by corrosion. Corrosion is a complex electrochemical reaction. It is aggravated by the presence of dissolved atmospheric gaseous pollutants, dirt and admixtures. The risk of corrosion increases when the metal comes into contact with other building materials such as brick or plaster.

Mild steel used extensively in building construction, is rarely exposed, but has a protective coating of paint, bitumen, or is surrounded by other materials, usually RCC. Protective coatings reduce the rate of corrosion. RCC In the member, it is the solid cover that breaks down first.

Therefore, R.C.C. In steel cover. The structure should be in accordance with the risk of the structure to the environment. Only when the steel is heavily corroded can we see both broken concrete and fabricated steel.

The cast iron pipe buried in the ground also gets rusted, but the rusty part remains in its place and does not deteriorate and acts as a protection against further corrosion. Many cast iron pipes buried under the ground last for a very long time in the field. Steel pipes don’t last that long.

5. PAINTS

Paint is a coating of coloured liquids applied to the surface of finished parts of a building, which are drying. Forms an impervious coat and protects surfaces from the effects of atmospheric agencies, corrosion of wood and metal corrosion and also serves as a decorative surface.

The following defects are observed in painting due to various agencies of deterioration :

(i) Blistering: This is due to the trapping of water vapour behind the painted surface. This forces the paint into little bubbles or blisters.

(ii) Fading: When the painted surface is exposed to direct sunlight, gradual fading of colour due to loss of brightness of pigment occurs.

(iii) Blooming: This is the development of dull patches due to the presence of moisture or dialling of the surface glossy coat.

All other defects in paints are due to the following reasons :

(a) Use of poor material: All the paints should be selected of good quality in relation to their exposure condition and backing material.

(b) Application on the damp surface: Dampness breaks down the adhesion of the paint with the surface of the component causing flaking and cracking from the surface.

(c) Poor workmanship: It is one of the main causes of paint wear and blemishes. Poor workmanship can be attributed to incorrect, inadequate or non-existent surface preparation. Over-thinning of paint Improper brush selection, poor brushing technique and failure to apply the specified number of coats can result in tarnishing of the paint.

6. PLASTICS

A wide range of plastics is used in buildings. Polyvinyl chloride (PVC) has wide applications. Plasticized PVC is widely used as a floor covering, false ceilings under pitched roofs. Rigid aplastic PVC, a covering membrane in flat roofs and plastic membranes for waterproofing, is primarily used for domestic soil and vent systems.

Rainwater drainage. Wall cladding. Ducting etc. Expanded PVC is also available for thermal insulation Glass-reinforced plastics (GRP) are also used for structural purposes.

Special plastics are used for large drainage chambers, plumbing, drainage fittings and wall ties. Foamed plastic provides the cellular material used for thermal insulation.

The following defects are observed in plastics :

- Shortwave solar radiation degrades plastics due to changes and changes in surface appearance.
- In general, the effect of moisture is very small, but it can reduce the bond strength between the glass fibre and polyester resin.
- The breakdown of polyethene in cold water tanks is due to the use of oil-based joint compounds.
- PVC and polycarbonate have high thermal expansion. Unless properly allowed, movement of PVC gutters and downpipes can lead to joint failure and leakage.
- Plastics tend to creep under constant load and require special precautions when the stress is high.

7. STONES:

Natural stones are classified as belonging to one of the three main groups-igneous, sedimentary or metamorphic.

The following deterioration is observed in natural stones due to various weathering agencies :

1. The atmospheric pollution causes the deterioration of limestones and sandstones. If wetting and drying are frequent due to rainfall, the surface of the stone gets slowly eroded.
2. Frost may also attack some limestones.
3. Marble is attacked by sulphuric gases.
4. Slates are used for roofing, cladding and D.P.C. Roofing slates are exposed to the most severe conditions and can be affected by sulphuric gases.
5. One major cause of damage in all types of stones can be the corrosion of embedded fixtures. Rusting of iron and steel cramps and dowels cause extensive damage to limestones and sandstones.

3. INVESTIGATION AND DIAGNOSIS OF DEFECTS IN BUILDING

As buildings become old, their structural conditions deteriorate, causing concerns of irreparable damage and structural safety. To address these concerns of aged buildings, regular inspection and condition assessment for the purpose of building diagnosis are required. The inspection may consist of visual inspection, crack mapping, deflection measurement, settlement measurement, and observations of signs of water leakage and steel corrosion, whereas the condition assessment generally comprises of taking samples for materials testing, in situ measurement of temperature, moisture, half-cell electrical potential, vibration and delamination, and occasionally even continuous monitoring. However, in Hong Kong, not all of the test and measurement methods are accredited and often different laboratories/personnel follow different practices. Finally, building diagnosis has to be performed to make a judgment on the overall structural condition in terms of expected residual life and the repair needed. This requires good knowledge of structural engineering, materials and testing. Hence, building diagnosticians should be recognized as professionals of a special discipline, but this is not happening yet.

Building Inspection Visual inspection is the prime step of building inspection. Before the visual inspection, the building and structural plans, and the construction and maintenance records of the building should be obtained for preliminary study. During the visual inspection, particular attention shall be paid to additions and alterations (whether legal or illegal), the inspector should also identify the structural components and non-structural components, observe the presence of cracks, record any signs of water leakage and steel corrosion, tap at plasters, tiles and concrete surfaces to detect delamination, check the straightness of structural members to detect excessive deflection, and check the inclination of the building using a plumb line. All the observed defects should be marked on drawings for detailed desk top study together with the building and structural plans. At this stage, it may be necessary to liaise with the building owner for more information. In order to avoid missing out traits and information that are important to the ensuing investigations, the first visual inspection must be led by an experienced professional.

Following the first visual inspection and the desk top study, further field investigation is required including crack mapping, measurements of deflection, settlement and inclination, locating the possible sources of water leakage and a more thorough survey of the identified defects. Some non-destructive test methods may be used fora quick and preliminary appraisal. These include: covermeter survey of concrete cover to steel rebars, ultrasonic pulse velocity tests for detecting voids and defects in concrete, rebound hammer tests for rough estimation of concrete strength, impact echo test for detecting delamination, infrared thermography for remote detection of delamination and/or water leakage, and surface penetration radar for detecting internal cracks and defects etc. An account of non-destructive testing and evaluation of concrete structures was presented by Maierhofer et al. Brief description of these non-destructive test methods is given in the following. Building Diagnostic Techniques

Covermeter Survey

The working principle of covermeter is based on electromagnetism. Electric current in the coil winding of the probe generates a magnetic field which propagates through the concrete and interacts with any metal buried therein, such as reinforcing steel. The interaction causes a secondary magnetic field to propagate back to the probe where it is detected by another coil, or in some instruments by modifying the primary field. The signal received will increase with increasing rebar size and decrease with increasing rebar distance (concrete cover). By making certain assumptions about the rebar and specifically by assuming the presence of only one rebar within the primary magnetic field, the instrument can be calibrated to convert the intensity of signal to distance and hence the cover thickness. Reference is made to British Standard BS 1881 Part 204 for the guidelines of conducting cover-meter survey. However, if there is more than one rebar within the range of the primary field, the instrument will receive a greater signal and indicate a shallower cover than the true cover. Some manufacturers claim that the size of the reinforcing bar may be determined by the use of spacer blocks and associated in-built mathematical processing. Such methods work satisfactorily only where a single rebar is present within the range of the probe. Therefore, the accuracy of covermeter is mainly affected by grouped reinforcing bars of unknown bar sizes.

Ultrasonic Pulse Velocity

Test In the ultrasonic pulse velocity test, the time of travel of an ultrasonic pulse through the concrete structure is measured and the pulse velocity is determined by the relation: pulse velocity = distance/time. As void and defects in the concrete prevent direct passage of ultrasonic pulse owing to the existence of concrete-air inter faces, the ultrasonic test can reveal internal defects of concrete such as the presence of honey combing at the interior. Besides, as there is positive relationship between wave velocity and elastic modulus, as well as between elastic modulus and strength, the ultrasonic velocity is able to reflect the concrete strength. Reference can be made to British Standard BS EN 12504 Part 4 and American Standard ASTM C597 for the guidelines of conducting the ultrasonic pulse velocity test.

Rebound Hammer Test

Rebound hammer test, or Schmidt hammer test, is a simple method to estimate the in situ concrete strength. Guidelines for conducting the rebound hammer test can be referred to British Standard BS EN 12504 Part 2. The hammer measures the rebound of a spring loaded mass impacting against the surface of the concrete. The rebound hammer has an arbitrary scale ranging from 10 to 100. Empirical correlation was established between concrete strength and the rebound number. It should be noted that the surface for testing should be grinded flat and smooth. When conducting tests, the hammer should be held at right angles to the surface, because the rebound reading can be affected by the orientation of the hammer. When used on the underside of a suspended slab, gravity will increase the rebound distance of the mass (vice versa for a test conducted on the top surface of a floor slab). Each rebound hammer should be calibrated before use. The major drawback of rebound hammer test is the limited accuracy. Even for calibrated hammers, the error of test could be about 15 %; whereas for uncalibrated hammers, the accuracy is much worse and the error can reach 30 %.

Impact Echo Test

In the impact echo test, a short-duration mechanical impact, produced by tapping as mall steel sphere against the concrete surface, generates low-frequency stress waves (up to about 80 kHz) that propagate through the structure and are reflected by flaws and/or external surfaces. Multiple reflections of these waves within the structure excite local modes of vibration, and the resulting surface displacements are recorded by a transducer located adjacent to the impact. The piezoelectric crystal in the transducer produces a voltage proportional to the displacement, and the resulting voltage-time signal (called a waveform) is digitized and transferred to the memory of a computer, where it is transformed mathematically into a spectrum of amplitude versus frequency. The dominant frequencies, which appear as peaks in the spectrum, are associated with multiple reflections of stress waves within the structure, or with flexural vibrations in thin or delaminated layers. The fundamental equation of impact-echo is: depth of flaw = wave speed/frequency/2. The frequency is obtained from the test as the dominant frequency of the signal, whereas the wave speed should be measured prior to the test. Guidelines of conducting the impact echo test can be referred to ASTM C 1383.

Infrared Thermography

The use of infrared thermography (or abbreviated as IRT) in structural damage assessment is one of the broad applications of thermal imaging. Thermo graphic camera detects radiation in the infrared range and produce images of the radiation. At the surface of concrete structure, regions with moisture trapping, water leakage, concrete spalling, debonding of tiles, etc. emit different amount of infrared radiation, and show up in the thermographic image by their different temperature transmittance. The procedures to conduct IRT can be referred to the specific test manual. The main features of IRT are: free of contact by remote sensing, full-field examination of large areas, poses no requirement of human accessibility, generation of real-time images for rapid detection, compatibility with digital post-processing, and ability of radiation to penetrate mist. On the other hand, the limitations of IRT include:

(1) the test is qualitative rather than quantitative;

(2) only the surface is measured but not the interior;

(3) for delamination failure, the thickness of delamination cannot be assessed;

(4) the surface temperature can be altered by human activities and climatic factors such as rain and wind;

(5) the test is interfered by reflected solar radiation, external shadings, shadows cast by nearby structures, and radiation from surroundings;

(6) thermal radiation is obstructed by the presence of objects between the camera and detected surface;

(7) test results are affected by the thickness of rendering and services buried in the structure;

(8) accuracy deteriorates with distance due to attenuation of thermal radiation;

(9) viewing at large angle of elevation introduces distortion to the image; and

(10) difficulty in the interpretation of test results arose from noise and variation in emissivity.

Carbonation Test

The carbonation test is to determine the carbonation depth. A phenolphthalein solution is sprayed onto freshly exposed concrete surface (as phenolphthalein is insoluble in water, ethanol is employed as the solvent). The solution turns pink when pH > 8.6, and remains colourless when pH ≤8.6. The carbonation depth is measured as the average depth of the colourless region, in which the alkalinity had been neutralized by carbonation. Specification of the carbonation test was published by the Hong Kong Housing Authority . It should be noted that as de-passivation of steel can take place at pH below 10.5, the carbonation test does not fully reflect the extent of possible steel corrosion.