

MAINTENANCE MANAGEMENT, REPAIRS, RETROFITTING AND STRENGTHENING OF BUILDINGS

5.1 MAINTENANCE MANAGEMENT

Maintenance management of building is the art of preserving over a long period what has been constructed. Whereas construction stage lasts for a short period, maintenance continues for comparatively very large period during the useful life of building. Inadequate or improper maintenance adversely affects the environment in which people work, thus affecting the overall output and also the overall service life of the building. In the post construction stage the day to day maintenance or upkeep of the building shall certainly delay the decay of the building structure. Though the building shall be designed to be very durable it needs maintenance to keep it in good condition.

5.2 TERMINOLOGY

For the purpose of this Section, the following definitions shall apply.

Maintenance: The combination of all technical and associated administrative actions intended to retain an item in or restore it to a state in which it can perform its required function.

Maintenance Management: The organization of maintenance within an agreed policy. Maintenance can be seen as a form of 'steady state' activity.

Building Fabric: Elements and components of a building other than furniture and services.

Building Maintenance: Work undertaken to maintain or restore the performance of the building fabric and its services to provide an efficient and acceptable operating environment to its users.

Housekeeping: The routine recurring work which is required to keep a structure in good condition so that it can be utilized at its original capacity and efficiency along with proper protection of capital investment, throughout its economic life.

Owner: Person or body having a legal interest in a building. This includes freeholders, leaseholders or those holding a sub-lease which both bestows a legal right to occupation and gives rise to liabilities in respect of safety or building condition.

In case of lease or sub-leaseholders, as far as ownership with respect to the structure is concerned, the responsibility of structure of a flat or structure on a plot belongs to the allottee/lessee during the leasehold.

Confined Space: Space which is inadequately ventilated for any reason and may result in a deficiency of oxygen, or a build-up of toxic gases, e.g. closed tanks, sewers, ducts, closed and unventilated rooms, and open topped tanks particularly where heavier than air gases or vapors may be present.

Provisions of Sec 8.1 and 8.2 of Chapter 8 Part 6 shall apply for detailing of reinforced concrete members, in general. For reinforced concrete structures, subject to earthquake loadings in zone 2 and zone 3, special provisions contained in Sec 8.3 of this chapter shall apply.

5.3 BUILDING MAINTENANCE

5.3.1 General

Any building (including its services) when built has certain objectives and during its total economic life, it has to be maintained. Maintenance is a continuous process requiring a close watch and taking immediate remedial action. It is interwoven with good quality of housekeeping. It is largely governed by the quality of original construction. The owners, engineers, constructors, occupants and the maintenance agency are all deeply involved in this process and share a responsibility. Situation in which all these agencies merge into one is ideal and most satisfactory.

There are two processes envisaged, that is, the work carried out in anticipation of failure and the work carried out after failure. The former is usually referred to as preventive maintenance and the latter as corrective maintenance. The prime objective of maintenance is to maintain the performance of the building fabric and its services to provide an efficient and acceptable operating environment to its users.

Maintenance in general term can be identified in the following broad categories.

- a) Cleaning and servicing — This is largely of preventive type, such as checking the efficacy of rain water gutters and servicing the mechanical and electrical installations. This covers the house keeping also.
- b) Rectification and repairs — This is also called periodical maintenance work undertaken by, say, annual contracts and including external re-plastering, internal finishing etc.
- c) Replacements — This covers major repair or restoration such as reproofing or re-building defective building parts.

5.3.2 Factors Affecting Maintenance

Maintenance of the buildings is influenced by the following factors:

- a) Technical factors — These include age of building, nature of design, material specifications, past standard of maintenance and cost of postponing maintenance.
- b) Policy — A maintenance policy ensures that value for money expended is obtained in addition to protecting both the asset value and the resource value of the buildings concerned and owners.
- c) Environmental — All buildings are subject to the effects of a variety of external factors such as air, wind precipitation, temperature etc. which influence the frequency and scope of maintenance.

The fabric of building can be adversely affected as much by the internal environment as by the elements externally. Similar factors of humidity, temperature and pollution shall be considered. Industrial buildings can be subject to many different factors subject to processes carried out within. Swimming pool structures are vulnerable to the effects of chlorine used in water.

- d) User — The maintenance requirements of buildings and their various parts are directly related to the type and intensity of use they receive.

5.3.2.1 Influence of design

The physical characteristics, the life span and the aesthetic qualities of any building depend on the considerations given at the design stage. All buildings, however well designed and conscientiously built, will require repair and renewal as they get older. However, for better performance of the building envelop, the following are the ways to minimize troubles at the later stage:

- a) Minimize defects during construction and design,
- b) Detail and choose materials during construction so that the job of maintenance is less onerous

In addition to designing a building for structural adequacy, consideration shall also be given to environmental factors such as moisture, natural weathering, corrosion and chemical action, user wear and tear, pollution, flooding, subsidence, earthquake, cyclones etc.

5.3.3 Maintenance Policy

The policy shall cover such items as the owner's anticipated future requirement for the building taking account of the building's physical performance and its functional suitability. This shall lead to decisions regarding:

- a) the present use of the building anticipating any likely upgrading and their effect on the life cycles of existing components or engineering services; and
- b) A change of use for the building and the effect of any conversion work on the life cycles of existing components or engineering services.

5.3.4 Maintenance Work Programmes

The programming of maintenance work can affect an owner or his activities in the following ways:

- a) Maintenance work shall be carried out at such times as are likely to minimize any adverse effect on output or function and with due consideration to the comforts of the occupants and public and Third Party stakeholders.
- b) Programme shall be planned to obviate as far as possible any abortive work. This may arise if upgrading or conversion work is carried out after maintenance work has been completed or if work such as rewiring is carried out after redecoration.
- c) Any delay in rectifying a defect shall be kept to a minimum only if such delay is likely to affect output or function. The cost of maintenance increases with shortening response times.
- d) Maintenance work, completed or being carried out shall comply with all statutory and other legal requirements.

5.3.5 Maintenance Guides

An owner responsible for a large number of buildings has to established procedures for maintenance. When an owner is responsible for the maintenance of only one building or a small number of buildings, the preparation of a guideline manual tailored to suit each particular building, can offer significant advantages. Such a manual shall take into account the following:

- a) type of construction and residual life of the building, and
- b) environment and intensity of use (see 5.3.2).

The guide shall form part of a wider manual covering operational matters.

5.3.6 Planning of Maintenance Work

Work shall take account of the likely maintenance cycle of each building element and be planned logically, with inspections being made at regular intervals. Annual plans shall take into account subsequent years' programmed to incorporate items and to prevent additional costs. It shall be stressed that the design of some buildings can lead to high indirect costs in maintenance contracts and therefore, careful planning can bring financial benefits. Decisions to repair or replace shall be taken after due consideration.

5.3.7 Feed Back

Feed back is normally regarded as an important procedure of providing information about the behaviour of materials and detailing for the benefit of the architect and engineer designing new buildings, which will result in lessening maintenance costs. It is an equally valuable source of information for the persons responsible for maintenance. Every maintenance organization shall develop a sample way of communicating its know-how, firstly for benefit of others in the organization and secondly for the benefit of the building industry as a whole. There shall be frank and recorded dialogue on an on-going basis between those who occupy and care for buildings and those who design and construct them.

Feedback shall aim at the following:

- a) User satisfaction,
- b) Continuous improvement, and
- c) Participation by all.

The information on feed back can be obtained from the following:

- a) Occupants,
- b) Inspections,
- c) Records, and
- d) Discussions.

5.3.8 Means of Effecting Maintenance

Some maintenance work will be carried out by the occupier of a building or by the occupier's representative. In the case of leasehold or similar occupation not all maintenance shall be the responsibility of occupier. The regular maintenance shall be clearly mentioned in the tenancy agreement. Responsibility of common areas shall be clearly defined.

Maintenance work sub-divided into major repair, restoration, periodical and routine or day-to-day operations will be undertaken by one of the following:

- a) Directly employed labour,
- b) Contractors, and
- c) Specialist contractors under service agreement or otherwise.

The merits of each category for typical maintenance work must be considered because optimum use of resources appropriate to tasks in a given situation is an important element of policy.

The success of contracting out depends on the nature of the services, conditions in which contracting is undertaken (the tendering process), how the contract is formulated and subsequent monitoring of service quality. The important consideration in the decision to contract out is whether a contractor can ensure a socially desirable quantity and quality of service provision at, a reasonable cost to the consumers.

5.4 ACCESS

5.4.1 General

All maintenance activities including any preliminary survey and inspection work require safe access and in some situations this will have to be specially designed. Maintenance policy, and maintenance costs, will be much influenced by ready or difficult access to the fabric and to building services. Special precautions and access provisions shall also need to be taken for roof work or for entry into confined spaces such as ducts or voids.

5.4.2 Access Facilities

Permanent accessibility measures shall be provided at the design stage only for all the areas for safe and proper maintenance. It is a matter on which those experienced in the case of the building can make an important contribution at design stage in the interest of acceptable maintenance costs.

A wide variety of temporary access equipment shall appropriately be provided for maintenance work, ranging from ladders to scaffoldings or powered lift platforms.

Wherever possible it is better to provide permanent access facilities such as fixed barriers, ladders, and stairways. When such permanent access facilities are provided necessary arrangement shall be included in maintenance plans for their regular inspection, maintenance and testing.

All personnel employed for carrying out maintenance shall be provided with the necessary protective clothing and equipment and instructed in its use.

When physical access is not possible in situations such as wall cavities, drains etc, inspections shall be made with the aid of closed circuit television or optical devices such as endoscopes.

5.4.3 Access to Confined Spaces

5.4.3.1 Ventilation

Good ventilation shall be necessary in order that maintenance work can be carried out safely. This is especially important in confined spaces. When the normal ventilation is inadequate it shall be supplemented by temporary and forced ventilation installations. These shall provide general and spot ventilation as appropriate.

Special precautions need to be taken when entering a confined space. Such confined spaces shall be adequately ventilated and trapped gas removed, particularly before being entered, to ensure that they are free from harmful concentrations of gases, vapors other airborne substances and that the air is not deficient in oxygen.

5.4.3.2 Lighting

Good lighting is necessary in order that maintenance work can be carried out satisfactorily. This is particularly important in confined spaces. When the normal lighting is inadequate it shall be supplemented by temporary installations. These shall provide general and spot illumination as appropriate.

5.5 RECORDS

5.5.1 General

Good records can save owners and users/occupiers much unnecessary expense and reduce potential hazards in exploration work when faults arise.

5.5.2 Use of Building Records

All personnel involved in the maintenance of the building shall be made aware of the existence of the building records.

Known hazardous areas shall be explicitly marked on the records as well as being marked on site and shall be pointed out to such personnel together with any system of work adopted for use in such areas.

Records are of value only if they are kept up to date and arrangements for this shall be included in any provision that may be made for records.

Records shall be readily accessible for use and the place of storage shall take into account the form of the records and the conditions needed to keep them from damage of any kind. It is recommended that a duplicate set of records is kept in a secure place other than building itself and is kept up to date.

Following shall be typical contents of the maintenance records:

- a) A brief history of property, names and addresses of consultants and contractors.
- b) Short specifications, constructional processes, components, material finishes, hidden features, special features etc.
- c) "As built" plans and as subsequently altered with sections, elevations and other detailed drawings.
- d) Foundation and structural plans/sections such as concrete reinforcement drawings.
- e) Detail specification of all materials incorporated, for example, concrete mix, species and grades of timber etc. Potentially hazardous materials and types or methods of construction that under some circumstances may become hazardous shall be identified.
- f) Information on housekeeping and routine maintenance with details of internal and external surfaces and decorations, schedule of cleaning, inspection and maintenance.
- g) Means of operating mechanical, electrical and plumbing installations.
- h) Description of renovations, extensions, adaptations and repair to each element.
- i) All plant, machinery and propriety articles including manufacturers trade literature and instructions for installation, use and maintenance.
- j) Methods of work used in construction such as assembly of prefabricated units.

- k) All information related to fire such as:
 - i. Location and service arrangements of all fire alarm and call points;
 - ii. Location and service arrangements of all extinguishers, hose reels and other fire fighting installations;
 - iii. Location of all fire compartment walls, doors, floors and screens;
 - iv. Location of all areas of exceptional fire hazard;
 - v. Fire escape routes;
 - vi. Details of application of any fire protection treatment; and
 - vii. Location details and description of any installation for smoke control or protection of escape routes.
- l) There shall be a wall chart showing at a glance the various operations which have to be undertaken. Line drawings of buildings are always to be there.
- m) Records of security measures shall be known to Authorized personnel only.
- n) Where no records exist, information shall be slowly built up as it becomes available during the course of maintenance work.
- o) Use of computers for storing information shall be compulsory.

5.5.3 Mechanical Records

5.5.3.1 Documentation

Documentation shall record the following as installed:

- a) the location, including level if buried, of all public service connections (for example, fuel gas and cold water supplies) together with the points of origin and termination, size and materials of pipes, line pressure and other relevant information;
- b) the layout, location and extent of all piped services showing pipe sizes, together with all valves for regulation, isolation and other purposes as well as the results of all balancing, testing and commissioning data;
- c) the location, identity, size and details of all apparatus and all control equipment served by, or associated with, each of the various services together with copies of any test certificates for such apparatus where appropriate. The information with respect to size and details shall be presented in schedule form;
- d) the layout, location and extent of all air ducts showing dampers and other equipment, acoustic silencers, grilles, diffusers or other terminal components. Each duct and each terminal component shall be marked with its size, the air quantity flowing and other relevant balancing data, and
- e) The location and identity of each room or space housing plant, machinery or apparatus.

5.5.3.2 Drawings

Drawings shall record the following as installed:

- a) detailed general arrangements of boiler houses, machinery spaces, air handling plants, tank rooms and other plant or apparatus, including the location, identity, size and rating of each apparatus, The information with respect to the size and rating can be presented in schedule form;
- b) isometric or diagrammatic views of boiler houses, plant rooms, tank rooms and similar machinery, including valve identification charts. It is useful to frame and mount a copy of such drawings on the wall of the appropriate room, and
- c) comprehensive diagrams that show power wiring and control wiring and /or pneumatic or other control piping including size, type or conductor or piping used and identifying the terminal points of each.

5.5.4 Electrical Records

Documentation shall record the following including locations, as installed:

- a) main and sub main cables, showing origin, route, termination, size and type of each cable; cables providing supplies to specialist equipment, for example, computers, shall be identified separately; and
- b) lighting conduits and final sub circuit cables, showing origin, route, termination and size of each, together with the number and size of cables within each conduit. The drawings shall indicate for each conduit or cable, whether it is run on the surface or concealed, for example, in a wall chase, in a floor screed, cast in-situ, above a false ceiling etc.

These drawings shall also indicate the locations of lighting fittings, distribution boards, switches, draw-in-boxes and point boxes, and shall indicate circuitry:

- a) Location and purpose of each emergency lighting fitting including an indication of the circuit to which it is connected;
- b) single and three phase power conduits and final sub circuit cables showing locations of power distribution boards, motors, isolators, starters, remote control units, socket outlets and other associated equipment;
- c) Other miscellaneous equipment, conduits and cables;
- d) Lightning conductor, air terminals, conductors, earth electrodes and test clamps;
- e) Location of earth tapes, earth electrodes and test points other than those in(f); and
- f) Cables providing earth circuits for specialist equipment, for example computers, shall be identified separately,

Documentation shall also include, when applicable.

- a) Distribution diagrams or schedules to show size, type and length (to within 1 m) of each main and sub main cable, together with the measured earth continuity resistance of each;
- b) Schedule of lighting fittings installed stating location, manufacturer and type or catalogue number together with the type or manufacturer's reference, voltage and wattage of the lamp installed;
- c) Schedule of escape and emergency lighting fittings installed stating location, manufacturer, type or catalogue number together with the type or manufacturer's reference, voltage and wattage of the lamp installed. For battery systems the position of the battery, its ampere hour rating and battery system rated endurance in hours shall be stated;
- d) Records of smoke detectors, sprinklers, fire precautions;
- e) Incoming supply details; the type of system, voltage, phases, frequency, rated current and short circuit level, with the details of the supply protection and time of operation as appropriate;
- f) Main switchgear details; for purpose made equipment this shall include a set of manufacturers' drawings and the site layout;
- g) Transformer, capacitor and power plant details; the leading details shall be given, for example, for transformers the V.A rating, voltages and type of cooling; and
- h) Completion certificate, according to the Bangladesh Electricity Act.

5.6 INSPECTIONS

5.6.1 General

Regular inspections are actual part of the procedures for the maintenance of buildings. They are needed for a variety of purposes and each purpose requires a different approach if it is to be handled with maximum economy and efficiency. A more detailed inspection covering all parts of a building is needed to determine what work shall be included in cyclic and planned maintenance programme.

5.6.2 Frequency of Inspection

Inspection shall be carried out at the following frequencies:

- a) *Routine* — Continuous regular observations shall be undertaken by the building user as part of the occupancy of building. Feedback resulting from this type of observation shall be recorded in record book.
- b) *General* — Visual inspections of main elements shall be made annually under the supervision of suitably qualified personnel at appropriate times.
- c) *Detailed* — The frequency of full inspection of the building fabric by suitably qualified personnel shall not normally exceed a 5 year period.

5.6.2.1 Inspection schedule

The preparation of a specific inspection schedule shall be formulated at the beginning. Once prepared, it shall be used for subsequent inspections.

5.6.3 Inspection of Engineering Services

Engineering services generally have a shorter life expectancy than building fabric and because of their dynamic function shall be subjected to more frequent inspections and maintenance.

Inspection of services shall be carried out for three purposes as follows:

- a) to check if maintenance work is required,
- b) to check if maintenance work is being adequately carried out, and
- c) for safety reasons to comply with statutory requirements and if required, with recommendations of other relevant organizations.

The frequency of inspections for purpose

- a) will depend upon types of plant and system manufacturer's recommendations and subjective judgment. Frequencies for purpose
- b) shall be carried out on an annual basis.

5.6.3.1 Method of inspection

The limited life of building services means it is important to record their residual life so that their replacement can be budgeted for, and inspection methods shall be arranged accordingly.

A checklist of items of plant to be inspected shall be considered. Detailed specifications of how inspections shall be carried out are necessary because a simple visual inspection is unlikely to show whether plant is operating correctly and efficiently.

Inspections frequently necessitate the use of appropriate instruments by competent persons. An example of this is the inspections carried out to check compliance with statutory requirements.

When instruments are used it is important that adequate training is provided in the use of the instruments and the interpretation of the results.

Records of all inspections shall be kept in suitable locker.

5.7 MAINTENANCE OF ELECTRICAL APPLIANCES

5.7.1 Planning of Maintenance Work

If the authorized person has complete knowledge of the electrical appliances to be worked upon, then safety will be more assured. If the person attending to the job is not technically competent to handle the job then more careful planning is required before hand.

Repetitive nature of jobs involves little or no pre-planning whereas infrequent nature of jobs shall need careful planning even if the person attending the job is technically competent.

Planned routine maintenance will facilitate continued safe and acceptable operation of an electrical system with a minimum risk of breakdown and consequent interruption of supply.

As far as the electrical equipments/ installations are concerned, it is not possible to lay down precise recommendations for the interval between the maintenance required. The recommendation for frequency of maintenance in this regard from the manufacturer is more relevant. The manufacturer shall be requested to specify minimum maintenance frequency under specified conditions. These intervals depend greatly upon the design of the equipment, the duty that it is called on to perform and the environment in which it is situated.

Following two types of maintenance are envisaged.

5.7.1.1 Routine maintenance

Routine maintenance of the electrical equipments goes along with the regular inspections of the equipments. Inspections shall reveal the undue damage and excessive wear to the various components. Examination of the equipment shall reveal any need for conditioning of the contact system, lubrication and adjustment of the mechanisms.

5.7.1.2 Post fault maintenance

When there is a breakdown in the system and certain parts are identified for the replacement and then the maintenance/repair of the defective part away from the operating environment is covered under post fault maintenance.

5.7.1.3 Guidelines for the Maintenance of Electrical Appliances

Uninterrupted and hazard free functioning of the electrical installations are the basic parameters of maintenance. The equipment shall be restored to correct working conditions. Special attention shall be paid to the items and settings that might have been disturbed during the operational phase. Loose and extraneous equipment or wiring gives rise to potential safety hazards. All covers and locking arrangements shall be properly checked and secured to achieve original degree of protection.

Guidelines to be followed for the maintenance of electrical equipments to ensure their smooth functioning are given in Appendix 7.A.

5.8 OPERATING AND MAINTENANCE MANUALS

The engineering services within buildings frequently are dynamic, involving complex systems of integrated plant items. Operation of such plant can require detailed knowledge and direction. Maintenance can also require extensive information to be available. It is, therefore, important to have suitable operating and maintenance manuals to provide the necessary guidance. These shall be included as part of the contractual requirements for new installations and shall ideally be prepared as reference documents for existing installations where no such information exists.

For details on labor management concerning building maintenance, reference shall be made to good practice.

For details on financial management concerning building maintenance, reference shall be made to good practice.

5.9 PREVENTION OF CRACKS

Cracks in buildings are of common occurrence. A building component develops cracks whenever stress in the component exceeds its strength. Stress in a building component could be caused by externally applied forces, such as dead, imposed, wind or seismic loads, or foundation settlement or it could be induced internally due to thermal movements, moisture changes, chemical action, etc.

Cracks could be broadly classified as structural or non-structural. Structural cracks are those which are due to incorrect design, faulty construction or overloading and these may endanger the safety of a building. Extensive cracking of an RCC beam is an instance of structural cracking. Non-structural cracks are mostly due to internally induced stresses in building materials and these generally do not directly result in structural weakening. In course of time, however, sometime non-structural cracks may, because of penetration of moisture through cracks or weathering action, result in corrosion of reinforcement and thus may render the structure unsafe.

Vertical cracks in a long compound wall due to shrinkage or thermal movement is an instance of non-structural cracking. Non-structural cracks, normally do not endanger the safety of a building, but may look unsightly, or may create an impression of faulty work or may give a feeling of instability. In some situations, cracks may, because of penetration of moisture through them, spoil the internal finish, thus adding to cost of maintenance. It is, therefore, necessary to adopt measures of prevention or minimization of these cracks.

For complete details on causes and prevention of non-structural cracks, reference shall be made to good practice SP 25:1984 'Handbook on causes and prevention of cracks in buildings'.

5.10 REPAIRS AND SEISMIC STRENGTHENING OF BUILDINGS

5.10.1 Non-structural/Architectural Repairs

The buildings affected by earthquake may suffer both non-structural and structural damages. Nonstructural repairs may cover the damages to civil and electrical items including the services in the building. Repairs to non-structural components need to be taken up after the structural repairs are carried out. Care shall be taken about the connection details of architectural components to the main structural components to ensure their stability,

Non-structural and architectural components get easily affected/dislocated during the earthquake. These repairs involve one or more of the following:

- a) Patching up of defects such as cracks and fall of plaster;
- b) Repairing doors, windows, replacement of glass panes;
- c) Checking and repairing electric conduits/ wiring;
- d) Checking and repairing gas pipes, water pipes and plumbing services;
- e) Re-building non-structural walls, smoke chimneys, parapet walls, etc;
- f) Re-plastering of walls as required;
- g) Rearranging disturbed roofing tiles;
- h) Relaying cracked flooring at ground level; and
- i) Redecoration — whitewashing, painting, etc.

The architectural repairs as stated above do not restore the original structural strength of structural components in the building and any attempt to carry out only repairs to architectural/non-structural elements neglecting the required structural repairs may have serious implications on the safety of the building. The damage would be more severe in the event of the building being shaken by the similar shock because original energy absorption capacity of the building would have been reduced.

5.10.2 Structural Repairs

Prior to taking up of the structural repairs and strengthening measures, it is necessary to conduct detailed damage assessment to determine:

- a) the structural condition of the building to decide whether a structure is amendable for repair; whether continued occupation is permitted; to decide the structure as a whole or a part require demolition, if considered dangerous;
- b) if the structure is considered amendable for repair then detailed damage assessment of the individual structural components (mapping of the crack pattern, distress location; crushed concrete, reinforcement bending/yielding, etc). Non-destructive testing techniques could be employed to determine the residual strength of the members; and
- c) to work out the details of temporary supporting arrangement of the distressed member so that they do not undergo further distress due to gravity loads.

After the assessment of the damage of individual structural elements, appropriate repair methods are to be carried out component wise depending upon the extent of damage. The repair shall consist of the following:

- a) Removal of portions of cracked masonry walls and piers and rebuilding them in richer mortar. Use of non-shrinking mortar will be preferable.

- b) Addition of reinforcing mesh on both faces of the cracked wall, holding it to the wall through spikes or bolts and then covering it, suitably, with cement mortar or micro-concrete.
- c) Injecting cement or epoxy like material which is strong in tension, into the cracks in walls.
- d) The cracked reinforced cement elements shall be repaired by epoxy grouting and could be strengthened by epoxy or polymer mortar application like shotcreting, jacketing, etc.

5.10.3 Seismic Strengthening

The main purpose of the seismic strengthening is to upgrade the seismic resistance of a damaged building while repairing so that it becomes safer under future earthquake occurrences. This work shall involve some of the following actions:

- a) Increasing the lateral strength in one or both directions by increasing column and wall areas or the number of walls and columns.
- b) Giving unity to the structure, by providing a proper connection between its resisting elements, in such a way that inertia forces generated by the vibration of the building can be transmitted to the members that have the ability to resist them. Typical important aspects are the connections between roofs or floors and walls, between intersecting walls and between walls and foundations.
- c) Eliminating features that are sources of weakness or that produce concentration of stresses in some members. Asymmetrical plan distribution of resisting members, abrupt changes of stiffness from one floor to the other, concentration of large masses and large openings in walls without a proper peripheral reinforcement are examples of defects of this kind.
- d) Avoiding the possibility of brittle modes of failure by proper reinforcement and connection of resisting members.

5.10.4 Seismic Retrofitting

Many existing buildings do not meet the seismic strength requirements of present earthquake codes due to original structural inadequacies and material degradation due to time or alterations carried out during use over the years. Their earthquake resistance can be upgraded to the level of the present day codes by appropriate seismic retrofitting techniques, such as mentioned in 5.10.3.

5.10.5 Strengthening or Retrofitting Versus Reconstruction

Replacement of damaged buildings or existing unsafe buildings by reconstruction is, generally, avoided due to a number of reasons, the main ones among them being;

- a) higher cost than that of strengthening or retrofitting,
- b) preservation of historical architecture, and
- c) maintaining functional social and cultural environment.

In most instances, however, the relative cost of retrofitting to reconstruction cost determines the decision. As a thumb rule, if the cost of repair and seismic strengthening is less than about 50 percent of the reconstruction cost, the retrofitting is adopted. This shall also require less working time and much less dislocation in the living style of the population. On the other hand reconstruction may offer the possibility of modernization of the habitat and may be preferred by well-to-do communities.

Cost-wise the building construction including the seismic code provisions in the first instance, works out the cheaper in terms of its own safety and that of the occupants. Retrofitting an existing inadequate building may involve as much as 4 to 5 times the initial extra expenditure required on seismic resisting features. Repair and seismic strengthening of a damaged building may even be 5 to 10 times as expensive. It is, therefore, very much safe as well as cost-effective to construct earthquake resistant buildings at the initial stage itself according to the relevant seismic codes.

5.11 MAINTENANCE MANUAL

The Consultant/Engineer shall prepare a Maintenance Manual prior to handing over of the competed project and furnish this to the EMPLOYER, which must contain following items:

- a) As-built drawings for the completed project;
- b) Sources of all items of work including materials, furnishes equipments and fixed furniture, containing names and addresses of suppliers, catalogue numbers, technical information & specifications and warranty documents for respective items.
- c) Frequency of routine Preventive Maintenance and the procedure thereof, including information on available local and foreign after-sales service sources.
- d) Corrective Maintenance procedure and sources of available