CHAPTER 2

LITERATURE REVIEW

2.1 Quality

2.1.1 Quality Definition

Quality might have different meaning to everyone. Some equate quality to attainment of prescribed standards, some interpret it to represent customer needs, yet some take it as compliance with contractual requirements and specification. The International Organization for Standardization (ISO) formally defines quality as the 'total of characteristics of an entity that bear on its ability to satisfy stated or implied needs' (ISO, 1994a). Dr. J. M. Juran, an international authority in quality management, perceives quality simply as 'fitness for purpose'. Indeed, a product befitting its intended purpose would satisfy the user's need and expectations. The crucial point lies in making the purpose clear to all parties involved in the design and production (H.W.Chung, 1999).

It is even more difficult to define when quality in the construction field. First, the product is usually not a repetitive unit but a unique piece of work with specific characteristics. The construction product can be a section of a building, an entire building, or just a prefabricated component that ultimately forms part of a building. Secondly, the needs or requirements to be satisfied include not only those of the client but also the expectation of the community into which the completed building will integrate. The characteristics of quality; the construction time and cost of delivery are also important. All these should be properly addressed in designing the building and the outcome should be expressed unequivocally in drawings and specifications (Griffith, Alan, 1990).

The quality of building works is difficult to quantify since there are many construction practices cannot be assessed in numerical terms. ‘How good of the quality is good enough?’ are often a matter of personal judgment and consequently a subject of contention. If a building will function as intended for its design life, it is good quality. As a true quality of the building will not be revealed until completion, the notion of quality can only be interpreted in terms of the design attributes. It is fair to judge the quality of work by the degree of compliance with stipulations in the contract, not only the technical specifications but also the contract sum and the contract period. The client cannot but be satisfied if the construction is executed as specified, within budget an on time. Therefore, a quality product of building construction is one that meets all contractual requirements (including statutory regulations) at optimum cost and time (H.W.Chung, 1999).

2.1.2 Quality Control

Refer to the quality control; the activities that are carried out on the production line to prevent or eliminate causes of unsatisfactory performance. In most of the construction manufacturing industry, including production of ready-mixed concrete and fabrication of precast units, the major functions of quality control are control of incoming various materials, monitoring the processes of the production and testing of the finished product (H.W.Chung, 1999).

Before production is commenced, an assessment is made to achieve the needs of minimum quality to satisfy the requirements and consistently achieve that quality. A potential problem is preventing from developing into a real condition; the control mechanism then goes on to rectify the detected change.

In the building industry, contracts for construction and design to have separate practicing traditionally. The designer is also play the role of supervision of the construction works. The quality of the finished works is controlled by way of materials on site is judged by random testing and sampling; and before final acceptance, an overall inspection of the finished works is performed without exception. The major drawback of this ‘inspection system’ of quality control is that it identifies the mistakes after the event. Many building defects are covered up during subsequent construction and consequently the quality of the finished works cannot be assessed by final inspection. Defective building work is very difficult, if not impossible, to replace. The client is often left with the patched-up original which will be a source of trouble recur and huge expenditure in the years to come (H.W.Chung, 1999).

Regular supervision by the contractor's staff themselves is undoubtedly the key to quality. Organizational pressures and commercial that often favour speed at the expense of quality. Usually poor workmanship is condoned to keep up with expected productivity or just labour.

Therefore, to show commitment to quality, experience senior management of the company must provide adequate resources on site to avoid anybody taking short cut. Further, a comprehensive record of inspection process is essential to ensure that the intended verification is done; the extra efforts are managerial in nature and complementary to the operational techniques of quality control in assuring the product quality.

2.1.3 Quality Assurance.

Despite the much of site experience accumulated throughout the decades, client dissatisfaction and complaint against the contractor of building contracts still leads to10%. Defects occuring in construction are caused mostly by poor management and communication. It is preclusive to assume that mistakes occurring on site are actually happened on site. These wrong perceptions may be traced to retrieve the out-dated drawings (Kettlewell, 1990).

Consistent quality; can only be achieved when such avoidable mistakes are avoided in the first instance. Preventive measures must be taken to minimize the risk of managerial and communication problems. This is the basic concept of quality assurance.

The performance of an individual in an organization could affect the quality of the finished product directly or indirectly. Responsibility for quality therefore stretches from the chief executive officer right down to the person in-charge.

To practice quality assurance, an organization has to establish and maintain a quality management system usually abbreviated to quality system in its daily operation. A set of documented procedures for the various processes carried out by the organization would be a quality system contains. Operating a quality system does not replace the existing quality control functions, nor does it result in more inspection and testing; it just ensures that the appropriate type and amount of verification is performed when and where it is planned to be done. In fact, a quality system embraces quality control as its technical arm. (Dunston, I, 1993).

Therefore, prevention of quality deficiencies is oriented towards quality assurance. It aims at minimizing the risk of making mistakes in the beginning, thereby avoiding rectification or repair.

The processes of construction involve a variety level of education of professionals and tradesmen and wide range of skills. The environment is often exposed to aggressive elements where these processes are carried out. Under such condition, it is arguable standardization the procedures. Some contractors are trying to do some merely implant another layer of bureaucracy in the organization (Griffith, Alan, 1990).

A quality system may be set up to standardize these corporate procedures, with provision for preparation of a quality plan to cover the characteristics and specific requirement of a particular project.

2.1.4 Quality system

The organization carrying out the production must have some means to ensure that every time a process is performed the same control is exercised and the same method is adopted to maintain the consistency of product quality.

In according to ISO 1994a, a quality system is a framework for quality management; it embraces the ‘organizational structure, procedures, processes and resources needed to implement quality management’. The quality system of an organization clarifies the authorities and responsibilities of the staff and procedures. It regulates the conduct of verification activities.

Within the organization, providing assurance that quality control activities have been well-planned and carries out in full is the quality system. When it comes to the organizations outside, the quality system is an objective mock-up of the builder’s ability to produce building work to meet the customer’s requirements in a cost effective way (CIOB, 1987).

The quality system is to be fully documented with documentation usually in three tiers. The first tier document is the quality manual. It is to covers the International Standard requirements to which quality system is to conform. It also incorporates the quality policy and outline of the documentation’s structure if the quality system. The second tier documents consist of a number of quality procedures which are referred to by the quality manual. The third tier documents are supplemented by work instructions that define how the activities are performed (H.W.Chung, 1999).

2.1.5 Standard of Quality System

A quality system has to cover all the requirement and procedures leading to the completed product. The adequacy of a quality system can be judged.

In 1979 the British Standards Institution made a major contribution in this direction by issuing the three-part standard BS5750 (BSI,1979). This standard provided a comprehensive coverage of the key elements that were expected of a quality system.

The international Organization for Standardization (ISO) went one step further by developing a standard which would be internationally accepted. Indeed, compatibility of quality systems and mutual recognition of certification schemes are essential to further development of business in the global sense. Based on BS5750 and with input from some twenty countries, the Technical Committee ISO/TC 176 of this international body produced the ISO 9000 family of Standard in 1987.

In the industry of construction, ISO 9001 is suitable for those companies that are engaged in design and build projects. However, the majority of building contractors work to a design supplied by the architect/ engineer, and their quality system may be modeled on ISO 9002. In fact, ISO 9002 is a sub-set of ISO 9001 without the requirements on design control. The quality system of a building construction company should conform to either ISO 9001 or ISO 9002, depending on whether permanent works of design forms part of the company activities (H.W. Chung, 1999).

2.1.6 Process Control and Inspection/Testing

Construction processes, including precasting, prefabrication, erection of temporary works and installation of appliances, should be scheduled, identified and planned well before the construction commencement. This is normally done soon after the project is commissioned.

Process control is linked with inspection/testing. While process control prevents sidetracking of the established procedures, inspection/testing verifies that the required quality is obtained. To make process control effective, every witness point in an inspection and test plan should be observed, and work should not proceed beyond a hold point without approval by the authorized person (Donald Friedman, 2000).

The project quality plan should indicate the inspection and testing required for a project. On a construction site, testing and inspection is carried out at three stages:

a. on receipt of subcontracted or purchased items or service;
b. during a construction process in which an in-process check is conducted before proceeding to the next step; and
c. before final product delivery or handover of the finished works.

During construction, inspection and testing should be carried out progressively to ensure that any defective work is not built upon or hidden. The requirements for in-process inspection and testing are usually documented in the inspection and test plans (ITPs) which form part of the quality plan. An ITP lists is sequence the activities involved in a process, specifies the checks or tests to be performed and the acceptance criteria, indicates the hold points when verification of quality is a prerequisite to continuation of work, and identifies the authority of approval at each hold point. There are many construction and installation processes for which ITPs have to be prepared (Donald Friedman, 2000).

Inspection and testing of construction work is traditionally the responsibility of the architect/ engineer acting as the client's representative. In the spirit of quality assurance, inspection and testing is carried out mainly by the contractor. Nevertheless, the architect/ engineer can exercise control through the hold points and witness points of the ITPs. He may also retain the authority of approval at the hold points where appropriate.

Like the architect. Engineer, the contractor monitors the quality or subcontracted work through strategically located hold points. His inspection and test plan should appropriately interface with the subcontractor's if there is one.

Before handover of the finished works or part of it, the contractor always arranges for a final inspection in the presence of the architect/ engineer. The final check should include verification that all receiving and in-process verifications required by the quality plan have indeed been fully, correctly and satisfactorily accomplished. This is very important as it is often impossible to judge the quality of the finished product by final inspection alone.

Throughout a construction process, records of inspection and testing are to be maintained. This is conveniently achieved by signing off the inspection and test plan at the various hold/witness points by the designated inspector. Any other method of record keeping may be used provided that it shows clearly whether the respective stage of inspection and testing have been passed.

The test and inspection status is shown in the various inspection and test records. With building works, records inspection and testing in-process virtually become a register of the step-by-step works acceptance.

2.1.7 Measuring, inspection and test equipment

In building construction, equipment used for testing, measuring and inspection includes surveying instruments, should be maintained properly at regular intervals as recommended by the manufacturers respective. The equipment should be handled, preserved and stored in such a way as maintain accuracy and fitness for use.

2.1.8 Corrective and preventive action

With in-process inspection and testing properly and conscientiously performed, it should be able to discover any nonconformity as soon as it exists. The nonconforming work should be reviewed as soon as possible after it is detected. In the review process, the extent of nonconformance and its bearing on the quality of the finished works as a whole are evaluated. The review is conducted by a person who has executive power to take corrective action, this person is normally the project manager or the site agent, but for minor nonconformities the general foreman may act with delegated authority (Harrison, 1931).

If the nonconforming works is repaired, it should be re-inspected and/or tested. Records must be kept of any repair or concession granted. A non-conformance notice is generally issued to the subcontractor indicating the clause (s) of the subcontract violated and/or the specifications not satisfied, the suggested remedial measures and the deadline for implementation.

In the course of reviewing nonconforming work, or handling a client complaint, the situation leading to it and the cause of the incident are usually observed. A construction activity might have deviated from the contract approved drawings/specifications or the workmanship might have implied level of standard. Corrective action is necessary to eliminate the cause do as to avoid recurrence of the untoward event. This may involve amending a documented procedure or work instruction, providing additional resources or training the operational staff. In contemplating the appropriate action, account should be taken of the magnitude of the problem and the risks involved (Harrison, 1931).

Prompted by the actual nonconformity discovered, the investigation is usually extended to similar situations in which potential nonconformities exist. Appropriate steps have to be taken to prevent a possible problem developing into a real problem.

Corrective and preventive action should be implemented by the authorized person (s) following an established procedure. Such action may be immediate or long-term in nature. An immediate action is necessary to be applied to solve the problem. Its implementation is conveniently verified by signing off the nonconformance record. However, nonconforming work is often the result of contravention of certain documented procedure or inadequacy in the procedure itself. This can hardly be rectified without a long-term action involving equipment upgrading, staff training and changes to the working environment. Its effectiveness is monitored through the feedback of the functions concerned in due course (Harris. Samuel Y, 2001).

2.2 Causes and Agents of Deterioration

Building demands many skills in planning, design and construction, and the selection and use of many materials and techniques. After the building is completed, it has to meet various requirements, withstand the rigours of the climate and expected to last for many years, preferably with minimal maintenance. It is not surprising that defects and failure occur frequently. Provide consideration must be, therefore, at every building process stage, prolong the durability and reducing the incidence of defects of the building (Lee How Son, George C.S. Yuen, 1994).

2.2.1 Primary Causes

2.2.1.1 Design Deficiencies

Design is the pre-planning process of knowledgeably selecting materials and determining their relative positions in a construction to produce a building with predictable performance. To ensure predictable performance, the designer must possess a good understanding and knowledge to the material details, as well as of the interactions that building materials will have with their environment in service (Franey & Co, 1991).

According to Derek Miles (1976), many of the subsequent maintenance problems are directly attributed to decisions making at the design stage of the building. These decisions can be roughly classified into the categories.

2.2.1.2 Construction Faults

According to Richardson, Barry A. (2000), the site personnel can be just as guilty of promoting deterioration of buildings by bad workmanship, in adequate supervision and the substitution of poor fixings, materials or components. There is a constant need for stringent control of both the work on the site as well as the materials used for the construction in view of these problems.

2.2.1.3 Lack of Maintenance

According to Harry Wirks (1977), the long-term maintenance needs of the building often to be determined by the client's brief for a new building. The explanation should indicate possible changes in use, the future policy for operating, cleaning and maintaining the building as well as performance requirements.

The role of the designer includes that of providing advice to the client on maintenance matters so that performance and durability of the building itself, and of the fittings and equipment, can be enhanced.

Even after the building is completed, the effects of deterioration can be minimized by a serious commitment towards maintenance by the users of the building. For example, the failure to allocate sufficient financial resources for maintenance may have serious implications on the standard of maintenance for the property. Any delay in attending to the problem by indifferent users can also heighten the problem of deterioration. similarly, the use of inferior materials may accelerate the deterioration of the materials and increase maintenance costs.

2.2.1.4 Building Change of Use

Normally, a specific use would be created for a building. During the design period the designer will only make necessary provisions for that use. These provisions may be for space layout, floor loading requirements, acoustic standard, thermal transmission and type of finishes, services, fittings and equipment.

Serious defects arising from certain actions of the users of the building may sometimes occur even if these actions are within the original intended use of the building.

The problems are worsened if there is alteration or users change of use without the designers being consulted before handing over. For example, the implications upon space configuration, fire precautions and increased floor loading are not often appreciated.

2.2.1.5 Vandalism

Vandalism is happened by willful damage to the structure or building. It has its roots in the social fabric of the country. But other factors can increase the incidence of vandalism: lack of security, poor lighting arrangement, wrong choice of materials, poor space layout, and failure to promote awareness of social responsibility. Any action of vandalism will affect the appearance of the component or material and reduce its lifespan. The end result is higher maintenance costs.

2.2.2 Weathering Agents

2.2.2.1 Solar Radiation

According to Lee How Son and George C. S. Yuen (1994), solar radiation is received at the surface of the earth both directly and as diffused long-wave radiation, the intensity of solar radiation reaching the earth is lost because of reflection, scattering and absorption of the radiation by water vapour, ozone, air and duct particles.

Ultra-violet radiation is of shorter wavelength belonging to the region beyond the violet end of the visible spectrum, while infra-red radiation is of longer wavelength beyond the red end of the visible spectrum. Solar radiation affects building materials in two ways: photochemical reaction and thermal movement.

2.2.2.2 Wind

By the removal of part of building elements, wind can caused direct physical damage. Wind pressure varies according to the direction and intensity of the wind and affects the vertical, inclined and horizontal surfaces according to their locations. The consequent compression and suction forces may result in the loading or lifting or the structure. For these reasons, a careful study of the effects of wind on a building and the effects of adjacent buildings which can cause deviation of air currents becomes necessary during the design stage. The effects are more significant with increasing height and exposure of the building (Lee How Son and George C. S. Yuen, 1994).

2.2.2.3 Driving Rain

Raindrops tend to fall vertically, However, if there is a strong wind it will blow the drops along. Unfortunately, this seldom happens in practice and some consideration is necessary to establish the relationship between wind speed and rainfall..

Driving rain is rain carried along at an angle to the vertical by wind so that it impinges on the vertical surfaces of the building. The run-off from the vertical surfaces will increase the loads on any abutting horizontal or sloping surfaces unless the water is drained away separately.

2.2.2.4 Atmospheric Gases

Gases of atmospheric include oxygen, carbon dioxide, sulphur dioxide and ozone. The gases present to the formation of acid that attack certain building materials such as metals, concrete, other cementitious products and stones, in the presence of moisture.

Vast quantities of sulphur dioxide are given out by the burning of fuel in factories. This gas, together with other hydrocarbon emissions from power stations and other industrial pollutants form what is generally known as acid tain. Its injurious effects on building materials include erosion of limestones and brickwork and corrosion of metals.

The presence of carbon dioxide on the atmosphere is generally beneficial in reacting with lime products to form a protective carbonated layer. However, if carbonation is allowed to proceed as far as the reinforcement in concrete, for example, it can have serious consequences in causing the accelerated corrosion of the steel bars.

Oxygen can cause oxidation of organic materials such as paints, plasters and sealants, and is particularly severe on unprotected steelwork. Because of its high concentration in the air and its high reactivity, this gas is potentially the most damaging.

Ozone, which is an unstable modification of oxygen, is very much more reactive towards organic materials. Though ozone is present only in traces, it plays a major role in the degradation of rubber, mastics, bituminous compounds, paints and plastics, which can result in their embrittlement and eventual failure.

2.2.3 Chemical Agents

2.2.3.1 Corrosion

According to Lee How Son and George C. S. Yuen (1994), the instability of some metals result which tent to achieve a more stable state by forming with certain environmental elements such as air, water, soil and carbon dioxide; is considered as corrosion.

Electrolytic corrosion is sometimes referred to as electro-chemical corrosion and is the result of contact between two dissimilar metals or between a metal and a non-metal, the condition being that the second material should be more electro-positive than the material affected. The presence of moisture is essential for this form of attack, where the potential difference between the metals will set up a galvanic action.

2.2.3.2 Sulphate Attack

Sulphates are salts which are present in clay brick, gypsum products, industrial wastes, flue condensates and in some ground-waters naturally.

In persistently damp conditions, sulphates will react slowly with tricalcium aluminate (a constituent of Portland cement and hydraulic lime) forming a compound called calcium sulphoaluminate. This reaction causes the cement mortar or renders to expand and eventually disintegrate.

2.2.3.3 Crystallisation of Salts

Soluble salts may be present initially in certain building materials or may be conveyed into them by movement of moisture from the ground or adjoining materials. They may also be formed by the action of acid gases in the atmosphere on the constituents of building materials.

When moisture evaporates from the surface after gets into a material, the the salt in solution concentration increases until crystallises out. If this occurs within the pores of the surfaces layer and not on the surface, it may cause gradual erosion or flaking. On the surface it is referred to as efflorescence which causes some surface disfiguring only. If crystallization takes place below the surface, it can cause more serious problems.

2.2.4 Biological Agents

In carious part of a building, attacked by fungi, rodent, inserts, algae and plants may cause serious deterioration.

Rodents may cause considerable damage to timber and other organic material. Insect attack is generally confined to timber, but some other materials derived from organic fibres or pulp may also be affected.

Fungal attack occurs only in the presence of sufficient persistent moisture. Fungi are parasitic and attach themselves to surfaces which supply nutrients. Attention to the problem of moisture exclusion will take care of this cause of deterioration generally. When the risk cannot be totally eliminated by design, there remains the second line of defense of pre-treating all vulnerable materials with suitable fungicides.

Algae, being chlorophy-bearing, grow on walls of buildings to which they are transferred by wind as spores. Algal growths resemble dirt deposits on external paint surfaces and porous concrete. In the early stages of attack they can be washed off but moulds may penetrate and damage the films.

Plant life in the form of ivy, moss and lichens, if allowed to develop, will cause deterioration of the material surface and the jointing materials. The damage is done by the penetration of roots into crevices as they grow to extract moisture from the damp materials. In addition, lichens and mosses can produce acidic waste which can increase the problem of metallic corrosion, particularly of embedded components (Lee How Son and George C. S. Yuen, 1994)..

2.2.5 Mechanical Agents

Those which tend to impose a physical force on the building are mechanical agents. They can be permanent or static, such as ground pressure, or temporary and static such as a transient load. Eventually, the force of the mechanical agents can be dynamic.

The design of structural elements should take into account all the possible actions of predictable mechanical agents impinging on a building.

2.3 Diagnosis and investigation Techniques

Even with reasonable care and management at every stage of a building process, defects do occur. Some of these defects are manageable, particularly if they are localized; other defects are more serious, take a longer time to show up and usually need expert investigation. There is, therefore, it is necessary to understand the causes of the defects occur, what the immediate and long-term implications are, and what remedial works are necessary to restore, maintain or extend the function and safely of the building. Out of this need has arisen a relatively new discipline which is broadly described as ‘building diagnostics’ (David S. Watt, 1999).

2.3.1 What is Building Diagnostics?

A survey has been described as: ‘a comprehensive, critical, detailed and formal inspection of a building to determine its condition and value, often resulting in the production of a report incorporating the results of such an inspection’. Building diagnostic involves a process in which relevant experts investigate the existing condition of a building, carry out the necessary tests, evaluate the data collected, make recommendations professionally, and predict the future performance of the building. (Franey & Co, 1991).

It is clear that building diagnostic involves a wide range of disciplines experts, including structural engineers, architects, building surveyors and materials’ specialists. In addition, testing specialists experienced in the use of sophisticated instruments are also available to give support services when required.

2.3.2 Need for Building Diagnostics

According to Harris, Samuel Y (2001), the physical condition of the building may have affected in the whole life of a building, thus affecting its use continued. It is useful for an owner of building to know such occasions when to be occur so that he can call in relevant experts to arrest the problems in time.

Briefly, it is likely that a diagnostic assessment is required under the circumstances as follow:

1. Persistent Defects

The presence of defects such as deformations and cracks are common in most buildings. Most of these are minor and localized, and could be rectified by regular maintenance. However, if the cracks and deformations persist in a manner that appears become widespread or to worsen progressively, a building diagnostic assessment should be carried out thoroughly to determine the causes of defects and ensure the safety and long-term serviceability of the building.

2. Aging Structure

When a building ages, it may develop visually latent defects such as corrosion of steel reinforcement and decreasing concrete strength. Usually, tell-tale signs may be detected such as minor deformations or discoloration. Therefore, to determine the presence of hidden defects of an old building, it should be checked progressively.

3. Change of Use or Rehabilitation

If a building is being rehabilitated or the use to be changed is planned, a diagnostic assessment should be put into considered. Such an assessment will examine the suitability of the new usage, particularly with reference to the adequacy of structural members to take the new increased loads, if any. The assessment will also reveal the extent of rehabilitation work required for the new usage of the building.

4. Sale of Property

Whenever there is any resale of a building, a diagnostic assessment could be initiated by the following interested parties:

- The prospective purchaser who needs to know the condition of the building, be it a house, factory, office or shop.
- The vendor in order to inform to the purchaser the defects and rectification works, especially those works undertaken which are not available for inspection such as underpinning, alterations, damp-proofing or eradication of rot.
- The bank or financial institution that is processing the mortgage loan to the potential buyer. The report will enable the institution to have some knowledge about the condition of the existing building in order to approve the amount of the loan.

In addition, no responsible valuer should give a market valuation of the building without a thorough knowledge of its condition.

5. Budgeting Maintenance Costs

An assessment of the building will permit accurate budgeting of annual repairs and maintenance costs required as well as longer-term expenditure to up keep the building. This is particularly important with older buildings and when funds are difficult to secure.

6. Post-crisis Assessment

Severe events such as a fire or overloading can cause damage to structural members of the building. In such cases, it is imperative that an assessment of the structural integrity and safety of the building be conducted before any reinstatement work is done.

7. Satisfying Statutory Requirements

In many countries, mandatory inspection of certain types of buildings is required. The main objective of such compulsory inspections is to ensure that buildings are structurally sound and safe to be occupied of used. It is usual practice for commercial and industrial buildings to be subjected to more regular inspections than residential ones.

It is clear from the above reasons that the scope of a survey required in all building diagnostic assessments is related to the nature of the defect, the accuracy with which the causes of the defect need to be identified, and the main reason for wanting to know why the defect has occurred. At a very simple level, the diagnosis may be based on a survey that consists of no more than a thorough visual inspection (often called a reconnaissance survey). At the other extreme, it may be necessary to undertake extensive opening up, iste and laboratory tests and intensive data collection (called a detailed structural survey).

2.3.3 Approach to Diagnostic Assessment

In the normal approach, maintenance personnel would notice defects during their routine duties and alert the building owner. Depending on their training and experience, maintenance personnel could make some preliminary assessment as to the severity of the defects. If the defects are only minor, then a suitable repair contractor would be called in to rectify the defects. However, for major or recurrent defects such as excessive concrete spalling, severe cracking or serious water seepage, an independent building consultant should be engaged. For architectural defects, the consultant could be a building surveyor, architect or engineer experienced in such works. Sometimes a materials specialist could also give useful opinions. On the other hand, a professional engineer should be engaged for structural defects (Ben John Small, 1974).

The consultant would prepare an assessment programme, conduct a building diagnosis and recommend necessary remedies. In the case of architectural defects, the consultant could have basic instrumentation to conduct the diagnosis himself. But for structural defects, a diagnostic testing expert would usually be necessary to carry out tests on the member as part of the diagnostic programme. Once the data have been collected and collated, a proper report should be drawn up for the owner. In most cases, the consultant's service could be extended to include preparation of specification and tender documents, selection of repair contractors and supervision of the repairs (Mel A Sher, 1983).

2.3.4 Principle of Diagnosis

According to Eric Bird (1957), the diagnosis of building defects has often been compared with crime detection or even forensic medicine. During the process of investigation, clues are found which must be analyzed carefully; hypotheses have to be tested to determine which one best explains the causes of the defect. The whole process iterative; the more unusual or complex the cause, the more will be the need to go back and repeat some or all of the stages previously completed.

The investigation required for the diagnosis of the cause(s) if a building defect has to be carried out thoroughly and systematically. Some points worth nothing include the following:

- A list of the potential causes of a defect would be useful as a reference point to return to when unexplained symptoms are found or a diagnosis is challenged.
- Diagnosis must be done step-by step in a methodical manner. But it is essential to recognize that even the most obvious diagnosis may still lead to the wrong conclusion because the symptoms, the investigation and original assumption of potential causes may all be incomplete.
- In reality, defects are often caused by a combination of factors and seldom by s single factor. Some of these factors on their own may not require remedial works, but where they are attacking the material in combination, may need urgent attention. Diagnosis should not be geared to discovering a single cause for a defect.
- Sometimes the cost involved in determining all the possible causes of a defect may not be justified for various reasons. In this case, it may be more prudent to embark on a replacement of the damaged material than try to find our all the possible causes.

In spite of all the patience, inquisitiveness and caution shown by the investigator, common pitfalls still exist that could lead to the wrong diagnosis of building defects. For example, inadequate or wrong information, inaccurate ‘as built’ drawings and outdated records could all mislead the investigator into the wrong diagnosis of a certain defect.

2.3.5 Client’s Instructions

According to Dan Browne (1974), before undertaking a survey it is imperative that the purposes, nature and scope of the survey be ascertained. An exchange of letters with the client or the holding of a series of discussions will often be needed.

The client’s requirements can range from the survey of a specific defect, such as a leaking basement, to a full survey of the whole building to assess its structural integrity.

In order to prevent misunderstanding, care must be exercised at this stage to advise the client of the limitations of access and the problems connected with the inspection. For example, it a large multi-storey commercial building is involved, the client must be aware of the cost incurred in inspecting each and every part of the building. It may be more suitable to select sample floors or units to reduce the time spent and, hence, make the fees more acceptable.

Immediately after agreement is reached, the surveyor or other investigator should follow this up by confirming in writing all relevant and important aspects such as:

- Purpose of survey, that is, whether a structural survey, valuation, redevelopment feasibility or any other survey is required.
- Agreed date of commencement of survey and expected date of completion.
- Statement of surveyor's intentions covering a range of relevant matters which include extent of inspection of building; extent of opening up of structure; any limitation of liability by surveyor; enquiries to be made to statutory authorities; and basis of calculation of professional fees and other reimbursements.

2.3.6 Process of investigation

According to Franey & Co (1991), Having established the purpose and extent of the investigation and agreed on a basis for professional fees, to make sure that the investigation/inspection process can progress without causing inconvenience to the building occupants, a plan of necessary action has to be done. This process normally entails several steps.

1. Preliminaries

One important component of preliminary work needed is a documentation survey during which existing information on the building structure and the maintenance records may be obtained from design and as-built drawings, specifications, adjacent buildings, suppliers' records, contractors' test records during construction , records of defects and repairs, past and present usage of the building, loadings and subsequent alterations, if any. This historical overview of the design, construction and maintenance of the building may be a very tedious exercise, but nevertheless a very essential one.

2. Visual Inspection

On-site investigation should begin with a careful scrutiny of the building, relying mainly on normal human sensory perceptions such as hearing, sight, smell and touch. It is at this stage that many of the basic tools such as hammer, scrapers, magnifying glass, mirrors and binoculars are used. Graphic and photographic records may also be made of critical members for further analysis. Conduct interviews with occupants and maintenance personnel for obtaining the additional information.

From the inspection visually, valuable information may be obtained relating to signs of material deterioration, workmanship and structural serviceability. It is important that the surveyor or engineer doing the survey be knowledgeable in these areas.

The visual inspection is and essential step of the investigation process, leading to the selection of other subsequent testing methods. If no defects are detected or suspected, confirmatory tests could be carried out more economically on critical locations only.

3. Testing and Monitoring

There is a wide range of testing techniques available to suit the purpose and may be decided upon after the visual inspection has been completed. These techniques include:

- Non-destructive and semi-destructive methods.

- Chemical and physical analysis of materials.
- Destructive tests.

For large buildings involving thousands of structural elements, testing must be selective. It is neither economical nor necessary to test every member. Critical zones or members could be sampled for testing purposes. Where no specific problem has been identified, a sufficient number of elements could be selected according to a statistical sampling technique in order to give a measure of confidence in the results obtained. An optimal number can be determined to give reliable results at a reasonable cost.

A combination of non-destructive and destructive methods should be used together to achieve more consistent and accurate results. The choice of testing method will be influenced by the costs of the test and the extent of testing needed for the purpose. Accessibility must also be included, together with the safety of site personnel, the occupants and general public.

Monitoring is a useful method of assessing the movement of building structures over a period of time and this can be done by measuring the widths of fractures or by taking vertical alignment readings of the structure with a theodolite from a datum position. Monitoring is time-consuming. The state of the building and the needs of the client must be considered before using them.

4. Exploratory Works

The skills and techniques of removing blockages or obstructions for a closer inspection of deeper parts is known as exploratory works.

These include excavation works to reveal the depth, size and condition of foundations to expose structural parts. In every case, damage will be caused and high costs may be incurred. They should generally be regarded as last resorts in elucidating causes and only employed where everything else has failed.

Identifying particular locations for removal or excavation requires careful planning to reduce the costs. In some cases, exploratory instruments will assist in reducing disturbance to a minimum.

2.3.7 Surveying Equipment

The surveyor requires certain items of equipment for use during his survey. The choice of equipment needed would depend to a large extent on the preference of the individual surveyor and the nature of the survey as instructed by the client.

1. Basic Equipment

General-purpose or basic equipment is required for recording data, marking measurements, making observations and simple opening up of a construction. The list includes the following:

a) Recording instruments and Stationery

b) Measuring Dimentions

c) Access and Inspection

d) Testing and Sampling

e) Protection Equipment

2. Specialized Equipment

Specialized equipment would be needed where more accurate measurements and extensive opening up for observation and/or laboratory testing are required. Most of these items of equipment require trained personnel in their operation.

a) Damp Diagnosis

b) Visual Inspection Probes

c) Non-destructive tests

2.3.8 Sources of Information

The information needed in all diagnostic work should aim, first and foremost, to provide the surveyor or other investigator with relevant data relating to the actual materials and details that were used during construction, as well as the actual conditions to which the materials and the elements of which they form part have been exposed during and after construction (Ivor H, Seeley, 1985).

The sources of information from which the data have to be collected can be wide and varied. For example, the information can be recorded, oral, from observation, published of from test results.

The main sources of information and the data they are likely to provide are as follows:

1. Drawings and Specifications

All drawings and specifications, including those produced by the consultants, specialists and sub-contractors, and used during the construction should provide data on the details of construction and materials used. But these documents do not necessarily include all the revisions made during construction.

2. Site Notes, Minutes and Reports

Apart from giving information on modifications made during construction, site notes, minutes and reports also give information regarding difficulties encountered during construction; the precautions taken to protect the materials, the quality of workmanship achieved as well as the building subsequently from the weather.

3. Maintenance Records and Manuals

These documents contain reasonably accurate details of the construction, alterations and additions, maintenance, replacements and repairs. More importantly, the records should also contain materials used in cleaning and redecoration, and the history of all defects in the building.

4. Interviews

Interviews conducted by the surveyor or other investigator with any party connected with the construction, design, use of the building and maintenance can provide valuable information on a number of aspects regarded with a defect. But such information should be treated with some caution because the party providing the information may not always be impartial.

5. Inspection

Inspection of the defect obviously provides the most important information, for it is during this process that the investigator uses his keen sense of observation, making use of sight, hearing, smell or touch. The observations made during the inspection usually have to be compared with other data collected by other means.

6. Published Information and Research Reports

There is a wealth of information available form many institutions noted for their research work. These organizations include both publicly and privately funded ones, for example, universities, polytechnics and trade associations.

7. Test Results

Test and measurements of properties of materials may include moisture determination, chemical analyses of the composition of samples, and physical analyses related to structural properties and resistance to water or frost. Other readings taken on the site that may assist the surveyor in his diagnosis of the defect may be those of temperature of air or surfaces, relative humidity of the air, rate of ventilation and movement of cracks.

2.3.9 Reports

A report is a written documents produced after some investigations to meet the client's requirements. The methods employed in the preparation of the report will depend considerably on the surveyor's own knowledge and experience. But there are a few points to note in writing a technical report.

First, the report must be simple, clear and concise. At the same time it must be technically accurate. The report should also be presented in a logical way and be written in a style that maintains continuity and is easy to follow.

2.3.10 Recommending Remedies

The interpretation of repair will be made on the individual circumstances that prevail in each case. Renewal is the reconstruction of the entirety. Repair is the restoration by the replacement or renewal of subsidiary parts.

Any repair will include some renewal. This may occur because of the extension of the repair beyond the boundary of the actual damage, or due to the replacement of defective material, when only a part is damaged. It is a question of degree as to whether the repair has become renewal or improvement. (Franey & Co, 1991).

The remedial work could be divided in to a few of general categories as follow:

1. Replacement of Parts

This should be the first consideration to give a permanent repair. However, the lack of suitable compatible materials, high costs or other difficulties may give rise to problems to make this recommendation unattractive. Sometimes there is no other alternative but to use this method in spite of the difficulties. For example, preserving the character and appearance of older buildings provides some incentives to carry out replacement of certain parts using limited resources of skilled operatives.

2. Patching up

This recommendation is very often accepted due to apparent lower costs. But it always be considered as a temporary solution and employed only where the building has a limited functional or economic life and when more extensive rehabilitation or improvement works are planned in the near future.

3. Complete Renewal

This last recourse is the most economical solution for buildings with a longer life, and the process can either involve removing existing parts for the entire area or providing a complete coverage over existing areas depending on adequate fixing facilities being possible.

In any one of these alternative courses of action, the faults need to be properly corrected to prevent a repetition of the same defects and only machines, components and techniques which are well ~ and tested should be used.

2.4. Finishes and Decorations

Despite development in building technology, building defects of the non-structural type are still common. Every year, a lot of money is spent on rectifying defects in finishes. These defects arise from errors in design or construction, many of which could have been avoided if proper and closer supervision had been enforces during the design and construction stages. Other causes include the varying site conditions, occupational use of buildings, lack of maintenance, and climatic effects on the finishes and decorations.