Module 1:
Introduction of Building Pathology, Diagnosis, Prognosis and Appraisal; Initial Case Studies; and Types of Deterioration of Structural Components.

A lecture by
Ir. Jeffery Pirah

About the Speaker

Ir. Jeffery Pirah (MIEM, P.ENG, MBA)
www.alamegakonsult.com
www.malaysiaconstructionservices.com

Resident Engineer

- Projek Pembaikan / Menaik-taraf Jeti-Jeti Penumpang dan gunasama Di Dermaga Merdeka, Wilayah Persekutuan Labuan (2008)
- Cadangan kerja-kerja kecemasan untuk kerja-kerja pembaikan bagunan sekolah di Sekolah Menengah Kebangsaan Elopura (Bestari), Sandakan, Sabah (Perolehan Darurat AP 173.2) (2010)

Appraisal Engineer

- Desktop studies and Structure Appraisal Report for Cadangan Kerja-Kerja Kecemasan (AP 173.2) untuk Kerja-Kerja Pembaikan Struktur Bangunan Sekolah Menengah Kebangsaan Putatan, Kota Kinabalu Sabah (2011)
- Desktop Studies and Structure Appraisal Report for Segama and Kinabatangan Bridge for Pan Borneo Road Project (2018)
- Statistical Analysis for Kerja-Kerja Pengujian Bahan 5 Buah Sekolah di Daerah Semporna, Sabah (2016)
- Desktop Studies and Appraisal Report for PETRONAS Menara Building Integrity Report, Kota Kinabalu, Sabah (2014)

Ir. Jeffery Pirah (MIEM, P.ENG, MBA)

www.alamegakonsult.com
www.malaysiaconstructionservices.com

Appraisal Engineer

- Desktop Studies and Appraisal Report for the Upgrading for Dialysis Center for Hospital Papar, Sabah (2014)
- Desktop Studies and Appraisal Report for SMK Agaseh, SMK Penangah and SK Pekan, Sabah (2014)
- Desktop Studies and Appraisal Report for Kinabalu International School Building Integrity and Post-earthquake Report, Kota Kinabalu (2015)
- Desktop Studies and Appraisal Report for Jesselton Condominium Building Integrity and Post-earthquake Report, Kota Kinabalu (2015)
- Desktop Studies and Appraisal Report for Klinik Gigi HQE Integrity Report, Kota, Kota Kinabalu (2017)
- Desktop Studies and Appraisal Report for SESB building Integrity Report, Labuan (2017)
- Desktop Studies and Appraisal Report for Maybank Jalan Pantai, Kota Kinabalu (2017)
- Desktop Studies and Appraisal Report for Maybank Jalan Perpaduan, Kota Kinabalu (2016)
- Desktop Studies and Appraisal Report for proposed reconstruction of Masjid Ar-Rahman, Ranau (2018)
- Desktop Studies and Appraisal Report for Ticketing Building Jesselton Point, Kota Kinabalu (2017)

Ir. Jeffery Pirah (MIEM, P.ENG, MBA)

www.alamegakonsult.com
www.malaysiaconstructionservices.com

Appraisal Engineer

- Desktop Studies and Appraisal Report for Cadangan Kerja-Kerja Pembaikan Struktur dan Sistem Pembangunan di Sekolah Menengah Kebangsaan Agama Ranau (Lama) Secara Reka dan Bina (2013)
- Design Change Marine Foundation for Seaweed Research Center at Semporna, Sabah (2013)
- Desktop Studies and Appraisal Report for PUSPAKOM Kota Kinabalu, Sabah (2013)
- Desktop Studies and Appraisal Report for SMT Likas Kota Kinabalu, Sabah (2014)
- Desktop Studies and Appraisal Report for Fully-in Hotel, Kota Kinabalu, Sabah (2014)
- Desktop Studies and Appraisal Report for structural repair work for SMK Kunak Jaya, Sabah (2017)
- Desktop Studies and Appraisal Report for Obtaining Certificate of Fitness for Labuan Shipyard and Engineering (2018)

Learning Modules

Learning Module for Today

Module	Subjects
Module 1	**Module 1: Introduction of building pathology and forensic, initial case studies, and the specifications involved in JKR Standard and British Standard mainly on concrete.** •Introduction to building pathology and forensic – Definitions, Issues lead to structural failure, Building failures in Sabah, Forensic - A requirement, Parties involved for government project, Basic in desktop studies and conducting appraisals •Concrete Structures - Engineering properties of structural materials , Structural concrete codes and standards, Method of analysis, Critical characteristics of concrete structures, Testing of Materials and Structures, Types and causes of nonperformance and failure •Steel Structures - Engineering properties of structural materials, Structural steel codes and standards, Method of analysis, Critical characteristics of steel structures, Testing of Materials and Structures, Types and causes of nonperformance and failure •Timber Structures - Engineering properties of structural materials, Structural codes and standards, Method of analysis, Critical characteristics of structures, Testing of Materials and Structures, Types and causes of nonperformance and failure

Learning Modules for the Future

Module	Subjects
Module 2	**Module 2: Introduction to design load & tolerances, and desktop studies** •Introduction design loads and tolerances - Design Load based on UBBL, Design Load based on British Standard, Design Load based on Euro codes, Building/Construction tolerances and dimensioning, Assigning loads using finite element analysis software, SLS tolerances based on BS8110 and BS5950, Building forensic Desktop Study, Durability literature and specifications •Desktop Study simulation
Module 3	**Module 3: Introduction to general failures of structures, symptoms & mapping works, and types of testing for concrete and steel structures.** •Introduction - General failures of structures, Behavior of Concrete, Causes of corrosion and deterioration, Controlling corrosion and protection •Appraisals - Appraisal of Existing Steel Structures, Steel-reinforced Concrete Structures Assessment •Analyses - Assessing and Analyzing Symptoms, Conducting a Structural Defect Mapping •Structural Integrity Investigation - In situ sampling and testing, Determination of structural integrity, Laboratory testing and sample analysis •Exercise - On-field mapping simulation and recommended type of testing
Module 4	**Module 4: Introduction to concrete strength analyses & correlation methods, concrete design mix, and structural repair & rehabilitation principals and methods** •Introduction - Concrete strength , Practical analyses for concrete strength •Design Mix - Concrete mix design, Practical design for normal concrete and high strength concrete •Principal and methods in structural repair and rehabilitation - Principals and methods in structural repair and rehabilitation (continued) and, application (exercise) based on findings and analyses

Literatures

Why Building Failed

Structural integrity and failure is an aspect of engineering which deals with the ability of a structure to support a designed load (weight, force, etc...) without breaking, and includes the study of past structural failures in order to prevent failures in future designs.

Structural integrity is the ability of an item—either a structural component or a structure consisting of many components—to hold together under a load, including its own weight, without breaking or deforming excessively. It assures that the construction will perform its designed function during reasonable use, for as long as its intended life span. Items are constructed with structural integrity to prevent catastrophic failure, which can result in injuries, severe damage, death, and/or monetary losses.

Why Building Failed

Structural failure refers to the loss of structural integrity, or the loss of load -carrying capacity in either a structural component, or the structure itself. Structural failure is initiated when a material is stressed beyond its strength limit, causing fracture or excessive deformations; one limit state that must be accounted for in structural design is ultimate failure strength. In a well- designed system, a localized failure should not cause immediate or even progressive collapse of the entire structure.

Most building defects are avoidable; they occur, in general, not through a lack of basic knowledge but by non-application or misapplication of it. Such knowledge seems to become mislaid from time to time. Certain fundamental properties of materials, such as their ability to move through changes in temperature and moisture, seem to be overlooked and a rash of difficulties occurs.

Why Structure Repair or Rehabilitation is important?

To ensure robustness and reliability of the structure

To increase strength and rigidity of the structure

To prolong the serviceability and stability of the structure

To cater change of function(s) of the structure

It is the rule or regulation. Part of the renovation submission for high risk committee to review.

Since the end of 2013, the Local Gov. & Housing Ministry instruct local authorities to inform building owners of more than 5-storey and more than 10 years old to have structural integrity inspected once every 10 years.

The Need for Repair or Rehabilitation Arises when

- Determine financial security against an intended loan or mortgage or change of ownership
- Provide confidence for a potential purchaser or tenant
- Determine stability and risk of failure
- Establish liability for disrepair or dilapidations
- Diagnose defects when symptoms appear, determine the effectiveness of past repairs
- Determine levels of disrepair in advance of legal proceedings
- Provide a basis for planned repair

The Cost of Structure Repair

Country	New structure works	Maintenance and repair works	Total construction works
Japan*	52,5 trillion Yen (83%)	10,7 trillion Yen (17%)	63,2 trillion Yen (100%)
Korea*	116,8 trillion Won (85%)	21,1 trillion Won (15%)	137,9 trillion Won (100%)
France*	85,6 billion Euro (52%)	79,6 billion Euro (48%)	165,2 billion Euro (100%)
Germany*	99,7 billion Euro (50%)	99,0 billion Euro (50%)	198,7 billion Euro (100%)
Italy	58,6 billion Euro (43%)	76,8 billion Euro (57%)	135,4 billion Euro (100%)
UK*	60,7 billion Pounds (50%)	61,2 billion Pounds (50%)	121,9 billion Pounds (100%)
Switzerland**	29,1 billion Francs (62%)	17,9 billion Francs (38%)	47,0 billion Francs (100%)

Notes: (*) All the figures are for Year 2004, *except for Italy Year 2003.* (**) Year 2009

Table 1.1: Maintenance and repair works in different countries

The Cost of Structure Repair

JPN Sarawak received RM202.52 Million for schools maintenance. Out of 1452 Schools, 388 schools are in extremely bad shape.

Federal Gov. Allocate RM262.6 Million to execute 19 school structure repair work since 2009. 8 out of 18 cost RM99.4 Million (Star, 2012)

On the 1st Nov 2018, Datuk Seri Maximus Ongkili queried the Minister of Education on the status of repair and reconstruction of poor school for Sabah and Sarawak that cost around RM1billion in the Dewan Rakyat.

During 2015 earthquake, 33 schools are affected – minor cracks (no integrity issues). However, reports mentioned cracks aggravated ever since – SMK Taun Gusi.

Parties Involved in Structure Repair

Government, Agencies and Local Authorities

Owner, Tenants, Habitants or Dwellers, and Users

Investigation Bodies, Investigation Firms, Engineers

Insurance Companies, Law Firms, other beneficiaries

Third Parties

Definitions – Building Pathology

It is therefore comprehensive in scope, covering the investigative process from initial manifestation of the defect through to rectification and monitoring. Generally this term is related to illness; however, it may also be used to mean material and product alterations, extending also to treatment, prophylaxis and restoration procedures.

In medical terms “pathology” has specific meanings as when:
• it refers to diseased conditions in relation to their determining causes (pathogenesis)
• it concerns macroscopic and microscopic alterations caused by such diseased conditions (anatomy and pathological histology)
• it refers to general pictures of a disease (special pathologies), both medical and surgical.

Definitions – Building Pathology

A systematic study of diseases with the aim of understanding their causes, symptoms and treatment. It is by necessity, an interdisciplinary approach and requires a winder recognition of the ways which buildings and people respond and react to each other.

It is a term used to describe the holistic approach to understand building. It is based that to repair and maintain a building effectively, a detailed understanding is required of how it was designed, constructed, used and changed, and how the particular environmental, material and structural conditions have affected it.

Definitions – Building Pathology

The definition of building pathology given by the *Association d'Experts Européens du Bậtiment et de la Construction* (AEEBC, 1994) draws attention to three separate, though interrelated, areas of concern:

- identification, investigation and diagnosis of defects in existing buildings;
- prognosis of defects diagnosed, and recommendations for the most appropriate course of action having regard to the building, its future and resources available; and
- design, specification, implementation and supervision of appropriate programs of remedial works; monitoring and evaluation of remedial works in terms of their functional, technical and economic performance

Definitions – Conservation, Preservation

In the structural concrete Model Code revision, currently undertaken by the *f´ed´eration internationale du b´eton (fib),* it is suggested that these activities be encompassed by the convenient umbrella term “Conservation of Structures”. Conservation would also include inspection, condition assessment, and regular maintenance activities for structures.

Conservation is an approach where there is something of historic or aesthetic merit to be kept, but there can be change, as long as new insertions are in keeping or enhance that which is existing. It is a living and developing situation.

Preservation: “activities performed on bridge elements or components that aim to prevent, delay, or reduce deterioration.

Definitions - Others

•Upgrading: Upgrading is defined as “modifications to an existing structure to improve its structural performance” in ISO 13822: Basis for design of structures – Assessment of existing structures.
•Assessment: set of activities performed in order to verify the reliability of an existing structure for future use.
•Inspection: on-site non-destructive examination to establish the present condition of the structure.
•Maintenance: routine intervention to preserve appropriate structural performance.
•Rehabilitation: work required to repair, and possibly upgrade, an existing structure.
•Repair: improve the condition of a structure by restoring or replacing existing components that havebeen damaged.

Structure elements should satisfy

strength – ability to sustain loads without undue distortion or failure

stability – ability to remain balanced

rigidity – ability to resist deformation under load (also referred to as stiffness)

equilibrium – ability to achieve a balance of forces (static or dynamic equilibrium)

robustness – ability to perform adequately for intended purposes

serviceability – ability to function to satisfaction of occupants

What is a Building Defect?

A defect may be considered to be a failing or shortcoming in the function, performance, statutory or user requirements of a building, and might manifest itself within the structure, fabric, services or other facilities of the affected building.

The severity of a building defect and the associated levels of damage, deterioration or decay currently present or expected to affect the building and its occupants are similarly related to the perceptions and expectations of the owner and occupier, and to various other stakeholders with interests in the well-being of the property.

defect, or the action required to reduce or remove its effect on the building, will typically be ranked according to a predetermined set of priorities for repair, maintenance or other works to improve either performance or capability

Nature of Building Defects

Agents	Acting outside the building		Acting inside the building	
	Atmosphere	Ground	Occupancy	Design consequences
Mechanical agents				
Gravitation	Snow and rainwater loads	Ground and water pressure	Live loads	Dead loads
Forces and imposed or restrained deformations	Ice formation pressure, thermal and moisture expansion	Subsidence, slip	Handling forces, indentation	Shrinkage, creep, forces and imposed deformations
Kinetic energy	Wind, hail, external impacts, sand-storm	Earthquakes	Internal impacts, wear	Water hammer
Vibration and noises	Wind, thunder, aeroplanes, explosions, traffic, machinery noises	Traffic and machinery vibrations	Noise and vibration from music, dancers, domestic appliances	Services noises and vibrations
Electromagnetic agents				
Radiation	Solar radiation, radioactive radiation	Radioactive radiation	Lamps, radioactive radiation	Radiating surfaces
Electricity	Lightning	Stray currents	–	Static electricity, electrical supply
Magnetism	–	–	Magnetic fields	Magnetic fields
Thermal agents	Heat, frost, thermal shock	Ground heat, frost	User-emitted heat, cigarette	Heating, fire

Contd.

Nature of Building Defects

Agents	Acting outside the building		Acting inside the building	
	Atmosphere	Ground	Occupancy	Design consequences
Chemical agents				
Water and solvents	Air humidity, condensations, precipitations	Surface and ground water	Water sprays, condensation, detergents, alcohol	Water supply, waste water seepage
Oxidising agents	Oxygen, ozone, nitrous oxides	Positive electrochemical potentials	Disinfectant, bleach	Positive electrochemical potentials
Reducing agents	–	Sulphides	Agents of combustion, ammonia	Agents of combustion, negative electrochemical potentials
Acids	Carbonic acid, bird droppings, sulphuric acid	Carbonic acid, humic acids	Vinegar, citric acid, carbonic acid	Sulphuric acid, carbonic acid
Bases	–	Lime	Sodium, potassium, ammonium hydroxides	Sodium hydroxide, cement
Salts	Salty fog	Nitrates, phosphates, chlorides, sulphates	Sodium chloride	Calcium chloride, sulphates, plaster
Chemically neutral	Neutral dust	Limestone, silica	Fat, oil, ink, neutral dust	Fat, oil, neutral dust
Biological agents				
Vegetable and microbial	Bacteria, seeds	Bacteria, moulds, fungi, roots	Bacteria, house plants	–
Animal	Insects, birds	Rodents, termites, worms	Domestic animals	–

Desktop Studies and Appraisals

Definitions – Appraisal

The term describes the process of assessing the actual condition of a structure in relation to its use (whether an existing use, or a proposed change of use) in order to determine whether the structure can sustain that use.

Whatever the reason for the appraisal, it involves the building pathology approach to determine structural adequacy. As such, the finding from the appraisal may be that the structure is satisfactory and requires no intervention in order to fulfill its future use.

Alternatively, repair, strengthening or alteration may be necessary. As these actions will cost money and take time, it is clear that the appraisal has a pivotal role in deciding the structure's future – or indeed in deciding whether it has one

The Need for an Appraisal

An appraisal may be necessary for one of a number of reasons, which can broadly be grouped under two headings. One is establishing the construction, condition and behaviour of the structure as existing, with a view to continued use unchanged.

The second is establishing the status quo as a preliminary to a change in use or other alteration to the existing structure. Building pathology is at the core of the task in all cases.

In practice, the appraisal appointment and brief would often come from an agent acting for the relevant party, such as a solicitor or surveyor.

Preparing for an Appraisal Brief

The brief for the appraisal must be clear in its aims and scope, and should give the reason(s) for the appraisal's being undertaken. It is also essential to give an adequate description of the structure(s) to be appraised. Nowadays, it is customary for such work to be put out to tender, often competitively, and so the bidders should be given as much information as possible to allow the submission of a realistic price and programme.

Wherever possible, bidders should be given the opportunity to visit and inspect the structure so that they can assess for themselves how the work is to be done, and reflect this in a realistic bid price.

Inspection Preparation for Tenderers

•What access will be permitted internally (e.g. all spaces, typical rooms only, removal of finishes for inspection only, ditto with permission to take samples for testing)?
• What means of access will be permitted internally (steps, ladder, platform, scaffolding, especially for high spaces)?
• What access will be permitted externally (e.g. all facades, selected ‘easy-access’ locations only, removal of finishes for inspection only, ditto with permission to take samples for testing)?
• What means of access will be permitted externally (steps, ladder, platform, scaffolding, rope access, mobile access platform)?
• Who is to provide the means of access?
• Who is to pay for providing the means of access?
• Who is to make good areas where sampling or other work has taken place?
• Who is to pay for this?

Planning the Appraisal

It is recommended that appraisal work should generally be undertaken in the following order

- Initial inspection and appraisal;
- urgent action;
- information gathering, research and documentary review;
- detailed investigation;
- assessment of structural condition;
- consideration of work needed;
- reporting and recommendations.

The recommendations may include, in particular:

- further investigations, including load testing.

Preliminary Site Visit

The purpose of a preliminary site visit or reconnaissance is to inform the surveyor about the nature and likely extent of the survey and what additional considerations need to be taken into account when confirming and undertaking the survey

- Make contact with occupants, neighbours and others
- familiarisation of layout (e.g. dead areas, ducts, flues)
- confirm security arrangements
- Available safe access to all parts of the building
- Establish nature and extent of services
- Agree nature and extent of opening up and moving of contents
- Establish boundaries, easements and rights of way
- Assess need for specialised survey services (e.g. M&E)
- Assess need for specialised investigative equipment
- Take photographs and sketches as a record for later survey

Desktop Studies

Research undertaken as part of a survey should be appropriate for its purpose and aim to inform the surveyor about issues concerning location, site, construction, use and occupation of the building. Key issues might include:

- Determining whether the building and/or site is legally protected (e.g. listed, scheduled or in a conservation area)
- Establishing former uses (e.g. potential hazards)
- Establishing site conditions (e.g. flooding, clay subsoils)
- Establishing earlier programmes of repair and/or maintenance
- Ascertaining development policies with local authorities (e.g. structure and local plans)

Desktop Studies – Background Info

- National and local repositories (e.g. National Monuments Record, Sites and Monuments Records, Historic Environment Records)
- Libraries and museums
- Published material (e.g. historical and trade directories, construction texts, topographical studies)
- Archive material (e.g. title maps, deed plans, rate books, census returns, local estate archives)
- Graphic material (e.g. drawings, paintings, engravings, postcards, terrestrial and aerial photographs)
- Cartographic material
- On-line support services or internet news archive

Desktop Studies – Documentations

- Design and procurement documentation (e.g. permissions and consents, contracts, drawings, schedules, specifications, minutes of meetings, correspondence)
- Reports (e.g. surveys, health and safety files, access audits, heritage impact assessments)
- Agreements and guarantees
- Agents' particulars
- Documents of ownership (e.g. freehold, leasehold, mortgages)
- Maintenance and service charge agreements
- Maintenance and operating manuals
- Legal documents
- Utility service bills
- Listed building and scheduled monument descriptions & curtilage
- Conservation area boundaries
- Descriptions and map for sites

Desktop Studies – Oral & Anecdotal Info

- Owners and occupiers (past & present)
- Building staff (e.g. cleaners, caretakers)
- Grounds staff (e.g. gardeners)
- Users
- Adjacent owners and users
- Third parties (if any)

Inspection or Survey

The inspection or survey of a building is a complex task made up of a number of discrete and interwoven activities that provide information on which to make an assessment of its condition and fitness for purpose as prescribed by relevant documents or individual need.

A building survey will draw on a surveyor's skills of observation and judgement, knowledge derived from training and continuing professional development, practical experience, familiarity with the type of property or particular defect, and an inquiring mind. The surveyor should be competent to perform the required service(s) and clear as to the precise purpose and extent of the survey. Explicit instruction, briefing and documentation are, in this respect, essential.

Personal safety and comfort is also an important consideration, and the hazards that can arise when inspecting or surveying a building.

Writing Appraisal Report

The purpose of a report is to bring together all relevant information derived from the preliminary site visit, background research, and inspection or survey, and ‘communicate to the client the implication of the building’s condition’. The importance of a report, both as a record of condition and as a guide for decisions or actions, cannot be understated.

The relevance of what is seen during a survey, and the consequences for the owner or client, must be carefully considered, as it is not enough simply to describe the defects without explaining their significance. Assessing the risk of a particular defect will therefore require a thorough understanding of the building, and of the needs and expectations of the client.

Writing Appraisal Report

Options will therefore need to be considered and evaluated, ranging – in the case of a single defect – from simple palliative measures (low cost, high risk) to complex repair or replacement (high cost, low risk).

For certain complex or important buildings it may be necessary to bring together a team of experts, who will inspect, assess and report on individual parts under the control of project leader.

Historic structure reports, which are an initiative based on a detailed interdisciplinary survey of an individual historic building prior to its reuse or refurbishment, offer a useful model for understanding the history, fabric and needs of a particular building.

Content of an Appraisal Report

General information
Name and address of clients, property address and/or Ordnance Survey national grid reference, date(s) of survey weather conditions at time of survey, purpose and scope of survey, tenure and occupancy

General description
description of property, accommodation, outbuildings and parking, approximate age, orientation, location and amenities, summary of construction and materials

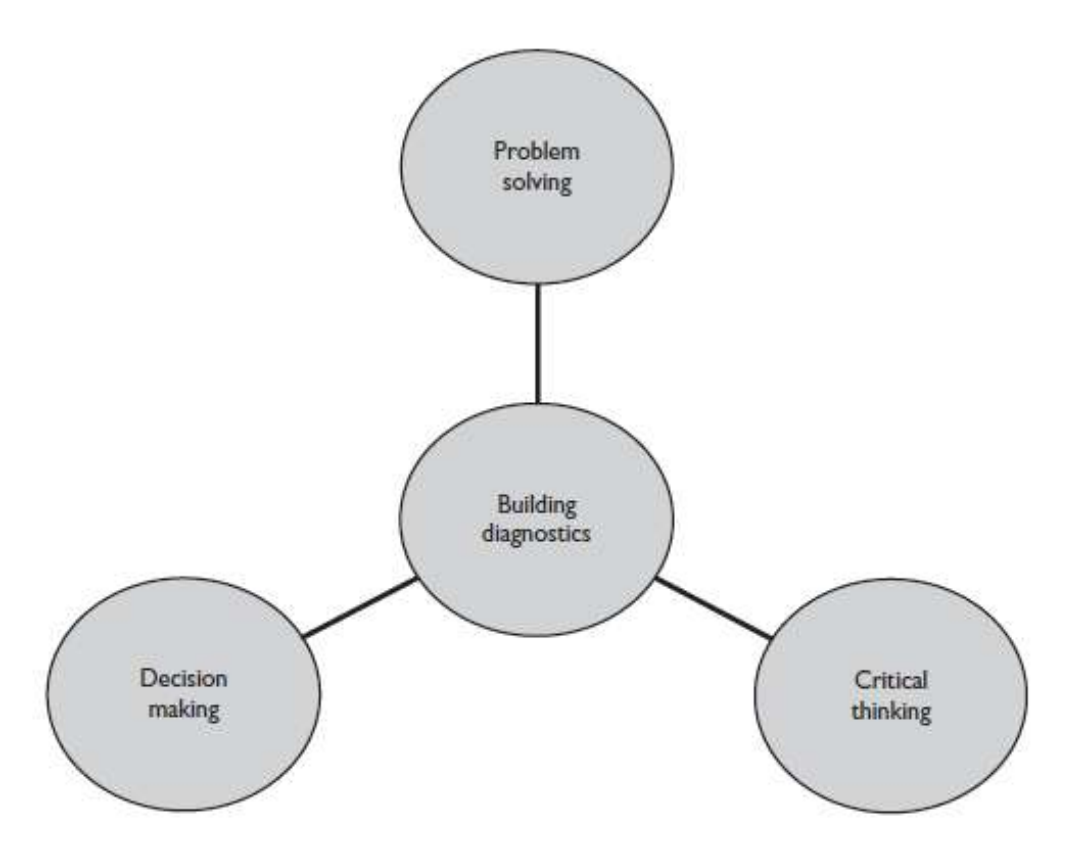
Content of an Appraisal Report

External and internal condition (incl. building services and site)
general condition, deterioration in relation to age, description of defects, appropriateness of use, adequacy of maintenance and general care, major problems and defects

Further advice
specific requirements (e.g. fire precautions, security precautions), need for further investigations or monitoring, matters to be checked by legal advisers, matters that might materially affect value, recommendations and priorities for work, building insurance, open market value

Diagnosis and Diagnostics

Building diagnostics is the branch of Building Pathology that deals with methodologies and techniques for determining the condition, internal environment and performance of property.



Defect Diagnosis

Defects may be obvious and readily determined on examination of the building or particular element of construction, or be present in such a form or location that simple detection is not always possible.

Hidden defects may remain undetected for many years, and cause serious damage. The detection and diagnosis of such latent defects requires all the skills of the surveyor and may require detailed investigation including the use of nondestructive survey techniques, material testing, measurement, monitoring or opening up of the building fabric.

Defect Diagnosis

Where such symptoms are complex or conflict with other available information, the surveyor may need to adopt a more scientific approach to diagnosis. In this, a particular line of reasoning or investigation is tested against known or assumed facts so that it might be proved or rejected in favor of another. Such an approach is based on a number of stages:

- observations – observe and record visible symptoms
- theories – develop theories based on observations
- questions – define a set of questions to differentiate between theories tests
- analysis – analyse and interpret results
- conclusions – match diagnosis to symptoms and results
- feedback – redefine questions as required to support new information and prognosis
- action – develop appropriate course of action

Defect Diagnosis – 5 Main Information

To judge the severity of a defect.

To judge the cause of a defect.

To predict the subsequent course and prognosis of a defect.

To estimate the likely responsiveness to therapy in the future.

To determine the actual response to therapy at the present.

Defect Diagnosis - Questions Posed

Symptoms

- How does the defect manifest itself?
- Do the symptoms change (e.g. with weather conditions) or are they constant?
- Are the symptoms getting worse?

Investigation

- What is the extent of the defect and could it affect other parts of the building?
- Are the symptoms relevant to one or more possible defects?
- Could the cause of the defect be remote from the symptom?

Diagnosis

- What is the cause of the defect?
- Can the defect be attributed to two or more causes?
- Is the defect static or progressive?
- Is further action required to diagnose the defect?

DENT Problem Solving Process

Key stages	*Actions*
Define	• Carefully define the problem. • Detect/discover any anomalies. • Cue acquisition – of possible defect source or agencies involved.
Explore	• Hypothesis generation. • Devise a list of knowledge of the problem. What do we know? What do we don't know? Is this defect analogous to any past problem? • What core building concepts may apply to this problem?
Narrow	• Cue interpretation of evidence. • After developing a list of hypotheses, sort them, weed them and rank them. List the type of data required to test each hypothesis. Give priority to the simplest, least costly tests. It is easier to get information on the condition of a building than it is to get from sophisticated laboratory tests on materials.
Test	• Hypothesis evaluation. • When you encounter data that confirm one of your hypotheses draft a technical report giving an explanation of your solution and justify it using the available evidence. • If all your possible solutions are eliminated, begin the cycle again: define, explore, narrow, test.

Defect Prognosis

The prognosis of defects requires consideration of various factors concerning the condition and use of the building, and, in particular, demands a detailed understanding of the cause and severity of the defect, and an awareness of how it might advance over time.

As with diagnosis, the prediction or forecasting of defects and the consequences of neglect are assessed on the basis of a logical series of questions and answers, which are made with regard to what is seen or can reasonably be inferred during or following a survey

Defect Prognosis – Typical Questions

- Will the defect progress further?
- How rapidly will further deterioration take place if no remedial action is taken?
- Will the stability of the building or well-being of the occupants be seriously threatened?
- If so, when will the situation become critical?
- Are any immediate safeguarding works necessary (e.g. temporary works, hoardings, debris netting)?
- What are the short-,medium-and long-term consequences (e.g. structural stability, health and safety, finance, occupation) of doing nothing?
- What is the most appropriate cause of action (e.g. replacement, repair, maintenance)?

Defect Prognosis – Typical Questions

Future of the building:

- Is the building or the part affected by the defect nearing the end of its useful life?
- If so, is it worthy of retention?
- If the building is not worthy of retention and is nearing the end of its useful life, is it appropriate to undertake temporary or palliative action rather than an expensive permanent repair?
- Are major alterations or demolition planned that would render any repairs valueless?
- Could the repair incorporate features not only to remedy the defect, but also enhance the performance of the element or component concerned (e.g. increased natural ventilation, thermal insulation)?

Defect Prognosis – Typical Questions

Needs of the occupants:

◦ Can occupants remain safely in occupation during works?

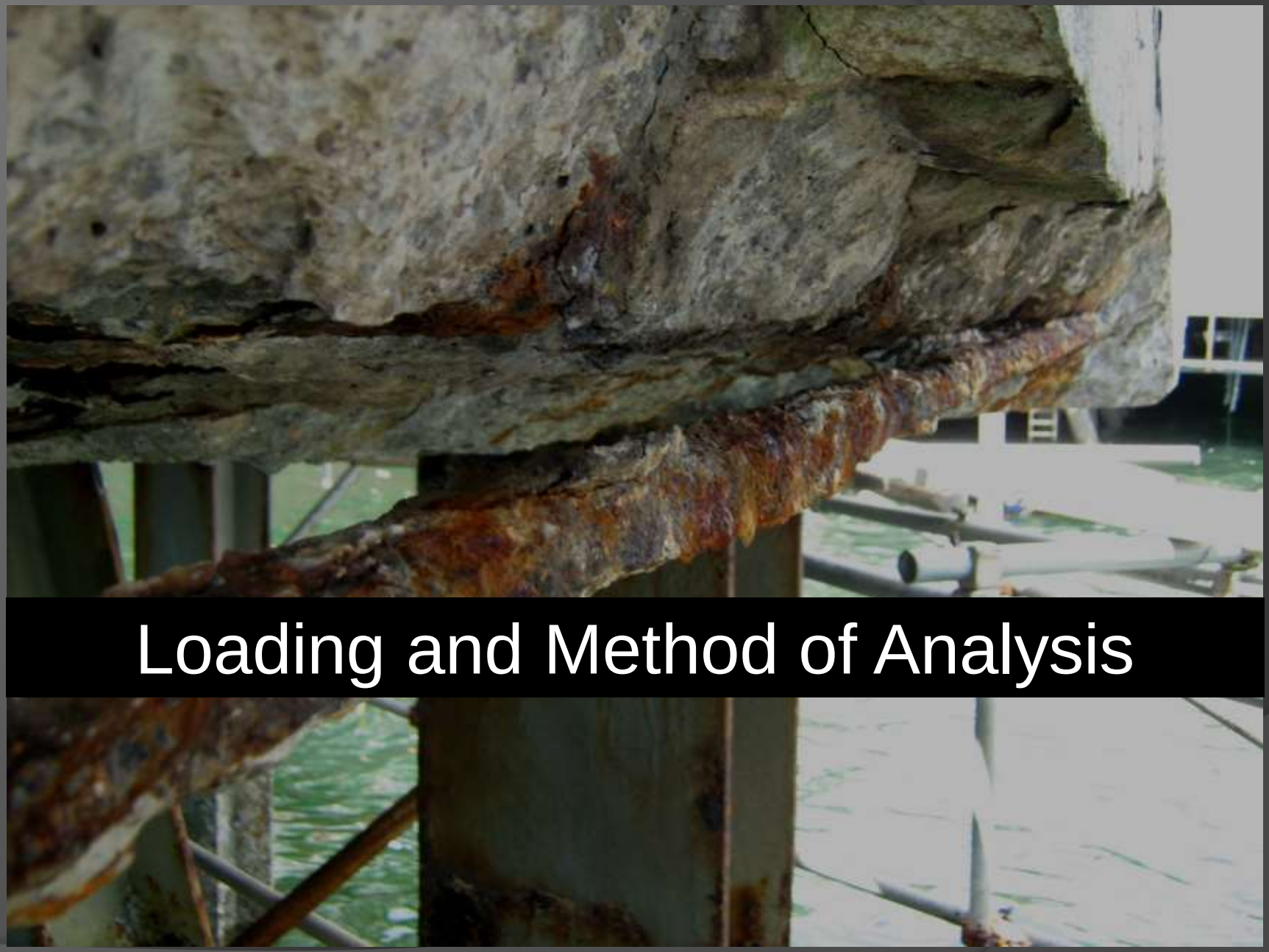
◦ Will the works adversely affect activities or sensitive contents?

◦ Will they need to be decanted and to where?

Client's resources:

◦ What funds are available for remedial works?

◦ If funding is limited, will a cheap holding operation be appropriate until funds are available for a more permanent remedy?



Loading and Method of Analysis

Code of Practice for Loading

Code of Practices for loading are important as parts of the analysis parameters. There are several codes which are essential, namely;

MS 1553: Code of Practice on Wind Loading For Building Structure (Substituting BS6399 Part 2
MS EN 1992-1-1: Malaysia National Annex to Eurocode 2: Design of Concrete Structures, Part 1-1: General Rules and Rules for Buildings
MS EN 1998-1: Malaysia National Annex to Eurocode 8: Design of Structures for Earthquake Resistance, Part 1: General Rules, Seismic Actions and Rules for Buildings
BS 6399: Loading for buildings. Code of practice for dead and imposed loads – Part 1
BS648: Weights of Building Materials

Methods on Structural Analysis

There are several methods on Structural Analysis, generally by using manual calculation or finite element analysis software.

Structural analysis is the determination of the effects of loads on physical structures and their components. Structural analysis employs the fields of applied mechanics, materials science and applied mathematics to compute a structure's deformations, internal forces, stresses, support reactions, accelerations, and stability. The results of the analysis are used to verify a structure's fitness for use, often precluding physical tests. he results of such an analysis typically include support reactions, stresses and displacements. This information is then compared to criteria that indicate the conditions of failure.

Methods on Structural Analysis

There are three approaches to the analysis:
a) the mechanics of materials approach (also known as strength of materials),
b) the elasticity theory approach (which is actually a special case of the more general field of continuum mechanics),
c) and the finite element approach.

The first two make use of analytical formulations which apply mostly to simple linear elastic models, lead to closed-form solutions, and can often be solved by hand. The by and finite element approach is actually a numerical method for solving differential equations generated by theories of mechanics such as elasticity theory and strength of materials.

Concrete Structures

Engineering properties of Structural Materials

The determination of the properties and physical condition of structural concrete may be required to provide an indication of its condition. Observed problems in the structure may indicate areas requiring investigation. Commonly measured properties and physical conditions are defined and discussed in this Section.

Absorption
Acidity
Air Content
Carbonation
Cement Content
Chemical Content
Chloride Content

Engineering properties of Structural Materials

The determination of the properties and physical condition of structural concrete may be required to provide an indication of its condition. Observed problems in the structure may indicate areas requiring investigation. Commonly measured properties and physical conditions are defined and discussed in this Section.

Creep
Density
Elongation
Moisture Content
Permeability
Proportion of Aggregate
Soundness
Cement/Water Ration

Critical Characteristics

The followings are critical characteristics associated with design for ultimate limit state (ULS) rather than just serviceable limit state (SLS).

Compressive Strength
Modulus of Elasticity
Modulus of Rupture
Pullout Strength
Splitting Tensile Strength
Tensile Strength

Structural Concrete Codes & Standards

- British Standard BS1881: Testing Concrete
- British Standard BS8500: Concrete – Complementary British Standard to BS EN 206-1
- British Standard BS8110: Structural Use of Concrete
- British Standard BS (MS) EN 206: Concrete
- British Standard BS (MS) EN 12390: Testing Hardened Concrete
- British Standard BS EN 12504: Testing Concrete in Structure. NDT
- British Standard BS (MS) EN 13791: Assessment of in-situ Compressive Strength in Structures and Precast Concrete Components
- Malaysia Standard MS 1242: Assessment of in-situ compressive strength in structures and precast concrete components - Complementary guidance to that given in MS EN 13791

- *British Standard BS5328: Concrete; Superseded by BS EN 206
- *Malaysia Standard MS1195 Part 1; Withdrawn

Testing of Materials and Structures

Based on BS 1881 Part 201, there are 23 types of non-destructive methods of test for hardened concrete.

Resonant Frequency, Ultrasonic Pulse Velocity, Dynamic Response
Electromagnetic cover
Resistivity Measurement
Half-Cell Potential
Radiography, Radiometry, Radar
Neutron Moisture Measurement, Thermography
Initial Surface Absorption, Surface Permeability
Maturity Measurement
Surface Hardness, Internal Fracture, Strain Measurement
Screed test, Pull-out Test, Pull-off Test, Break-off Test
Penetration Resistance, Depth of Carbonation
Acoustic Emission

Testing of Materials and Structures

Based on BS 1881 Part 201, Table 1 – Suitability of Non-Destructive Test Method as a guideline.

Table 1 — Suitability of non-destructive test methods

Methods[a]	Test situation					
	Quality control	Investigation of standard of workmanship	Control of formwork removal, pre-stress release or load application	Comparative survey of quality of concrete in the structure	Investigation of potential durability	Investigation of fire, frost, chemical attack or similar
Pull-out test (cast-in insert)	X		X			
Pull-out test (drilled hole)	X		X	X		X
Internal fracture	X		X	X		X
Break-off test	X		X			
Pull-off test	X		X	X		
Penetration resistance	X		X	X		
Surface hardness	X		X	X	X	
Screed test	X			X	X	
Dynamic response	X	X		X		
Ultrasonic pulse velocity measurement	X	X	X	X	X	X
Acoustic emission		X			X	
Electromagnetic cover measurement	X	X			X	

Testing of Materials and Structures

Based on BS 1881 Part 201, Table 1 – Suitability of Non-Destructive Test Method as a guideline.

Radar		X		X		
Radiography		X				X
Radiometry	X	X		X		
Neutron moisture measurement				X	X	
Depth of carbonation				X	X	X
Initial surface absorption				X	X	
Surface permeability					X	
Resistivity measurements				X	X	
Half-cell potential measurements					X	
Strain measurements		X	X	X	X	X
Thermography					X	X
Maturity measurements			X			
Resonant frequency	X					

[a] Subject to the practical limitations outlined in section 2.

Testing of Materials and Structures

Based on BS 1881 Part 201, Table 2 – Summary of Principal Test Methods and relevant Parts as reference

Table 2 — Summary of principal test methods

Method	Clause number	Principal reference	Principal applications	Principal properties assessed	Surface damage	Type of equipment	Remarks
Pull-out test (cast-in insert)	2.18	BS 1881-207[a]	Quality control (in situ strength)	Strength related	Moderate/ minor	Mechanical	Preplanned usage, surface zone test
Pull-out test (drilled hole)	2.18	BS 1881-207[a]	In situ strength measurement	Strength related	Moderate/ minor	Mechanical	Drilling difficulties on vertical surfaces or soffits, surface zone test
Internal fracture	2.17	BS 1881-207[a]	In situ strength measurement	Strength related	Moderate/ minor	Mechanical	High test variability, surface zone test
Break-off test	2.20	BS 1881-207[a]	In situ strength measurement	Flexural tensile strength	Substantial/ moderate	Mechanical	High test variability, substantial damage
Pull-off test	2.19	BS 1881-207[a]	In situ strength measurement	Direct tensile strength	Moderate/ minor	Mechanical	Care needed with adhesive, surface zone test
Penetration resistance	2.21	BS 1881-207[a]	In situ strength measurement	Strength related	Moderate/ minor	Mechanical	Specific calibrations required, limits on minimum member size, surface zone test
Surface hardness	2.15	BS 1881-202 (supersedes BS 4408-4)	Comparative surveys	Surface hardness	Very minor	Mechanical	Greatly affected by surface texture and moisture, surface test unrepresentative on concrete more than 3 months old, strength calibration affected by mix properties
Initial surface absorption	2.8	BS 1881-208[a] (supersedes BS 1881-5)	Surface permeability assessment	Surface absorption	Minor	Hydraulic	Difficult to standardize in situ moisture conditions and to obtain watertight seal to surface, comparative test
Surface permeability	2.9	(11)	Surface permeability assessment	Surface permeability	Minor	Hydraulic	Surface zone test, water or gas
Resistivity measurements	2.3	(6)	Durability survey	Resistivity	Minor	Electrical	Surface zone test, related to moisture content, indicates probability of reinforcement corrosion in zones of high risk
Half-cell potential measurements	2.4	(9)	Survey of reinforcement corrosion risk	Electrode potential of reinforcement	Very minor	Electro-chemical	Cannot indicate corrosion rate
Thermography	2.11	(16)	Structural integrity survey and void location	Surface temperature differences	None	Infra-red radiation detection	Extraneous temperature effects have to be excluded, temperature differentials small, shortage of data and development
Maturity measurements	2.10	(14)	In situ strength development monitoring	Maturity	Minor	Thermo-sensitive chemical or electronic	Preplanned usage, specific calibration required

Testing of Materials and Structures

Based on BS 1881 Part 201, Table 2 – Summary of Principal Test Methods and relevant Parts as reference

Table 2 — Summary of principal test methods

Method	Clause number	Principal reference	Principal applications	Principal properties assessed	Surface damage	Type of equipment	Remarks
Screed test	2.16	(21)	Quality control of screeds	Surface soundness	Minor	Mechanical	Sand/cement screeds only, cannot be used if screed over soft material
Ultrasonic pulse velocity measurement	2.13	BS 1881-203[a] (supersedes BS 4408-5)	Comparative surveys	Elastic modulus	None	Electronic	Two opposite smooth faces preferably needed, strength calibration affected by moisture and mix properties, some surface staining possible
Acoustic emission	2.23	(34)	Monitoring during load testing	Internal crack development	None	Electronic	Increasing load required, not fully developed for site use
Dynamic response techniques	2.14	(20)	Pile integrity	Dynamic response	None	Mechanical/ electronic	Cannot yield bearing capacity
Electromagnetic cover measurement	2.2	BS 1881-204[a] (supersedes BS 4408-1)	Location of reinforcement	Presence of embedded steel	None	Electro-magnetic	Affected by magnetic aggregates and unreliable for congested steel
Radar	2.12	(19)	Location of voids or reinforcement	Internal interfaces	None	Electronic	Experience limited, procedures under development
Radiography	2.5	BS 1881-205[a] (supersedes BS 4408-3)	Location of voids or reinforcement	Relative density	None	Radioactive source or generator	Extensive safety precautions, limit on member thickness
Radiometry	2.6	(3)	Quality control	Density	None	Radioactive source or generator	Safety precautions and limit on member thickness for "direct" method, "backscatter"method is surface zone test
Neutron moisture measurement	2.7	(3)	Comparative moisture content	Moisture content	None	Nuclear	Surface zone test, calibration difficult
Depth of carbonation	2.22	(33)	Durability survey	Concrete alkalinity	Moderate/ minor	Chemical	Approximate indication of extent of carbonation
Resonant frequency	2.1	BS 1881-209[a] (supersedes BS 1881-5)	Quality control	Dynamic elastic modulus	None	Electronic	Specially cast specimen required
Strain measurements	2.24	BS 1881-206[a] (supersedes BS 4408-2)	Monitoring movements in structures	Changes in strain	Minor	Optical/ mechanical/ electronic	Attachment and reading requires skill, can only indicate changes in strain

[a] In preparation.

Causes of Nonperformance and Failures

The followings are nonperformance, degradation or failure of concrete structural members or components.

Alkali-Carbonate Reaction & Alkali-Silica Reaction
Bleeding Channels
Carbonation
Cement-Aggregate Reaction
Chemical Degradation (Sulfate, acid, alkali-aggregate reactions)
Chloride Attacks
Contaminated Aggregate
Contaminated Mixing Water
Corrosion
Cracking
Delamination
Deterioration
Discoloration

Causes of Nonperformance and Failures

The followings are nonperformance, degradation or failure of concrete structural members or components.

Disintegration
Distortion
Efflorescence
Erosion
Freeze & Thaw Damage (not in Malaysia)
Honeycomb
Leeching
Popouts and Spalling
Scaling
Stratification
Structural Performance
Sulfate Attack
Unsound Cement or Concrete

Steel Structures

Engineering properties of Structural Materials

The determination of the properties and physical condition of structural steel may be required to provide an indication of its condition. Observed problems in the structure may indicate areas requiring investigation. Commonly measured properties and physical conditions are defined and discussed in this Section.

Ductility and Elongation
Durability
Fatigue properties
Fracture properties
Chemical Composition and Toughness
Coating Mass
Hardness
Weldability

Critical Characteristics

The followings are critical characteristics associated with design for ultimate limit state (ULS) rather than just serviceable limit state (SLS).

Compressive Strength
Tensile Strength
Yield Strength
Breaking Strength

Structural Steel Codes and Standards

British Standard BS5950: Structural use of Steelwork in Building
British Standard BS EN 10025: Hot-rolled Products of Structural Steels
British Standard BS EN 10027: Designation of Systems for Steel
British Standard BS EN 10029: Hot-rolled Steel plates 3mm Thick and above
British Standard BS EN 10034: Structural Steel I and H sections
British Standard BS EN 10058: Hot-rolled Flat Steel Bars…
British Standard BS EN 10059: Hot-rolled Square Steel Bars…
British Standard BS EN 10060: Hot-rolled Round Steel Bars..
…. Many others

*British Standard BS5400: Steel, Concrete and Composite Bridge (Withdrawn, replaced by Eurocode)

Testing of Materials and Structures

Destructive Test

- Tensile Test, Shear Test, Fatigue Test and Flexure Test

Non-Destructive Test

- Eddy Current Method
- Radiographic Method
- Ultrasonic Method
- Dye Penetrant Method
- Magnetic Particle Method

Causes of Nonperformance and Failures

The followings are nonperformance, degradation or failure of concrete structural members or components.

Deformation
Direct chemical attack
Discontinuity
Delamination
Electrolytic or electrochemical corrosion
Fatigue cracking and fracture cracking
Extreme heat
Laminar tearing
Nonbinding condition and tightness
Overall or local buckling
Overstressing
Porosity
Slag deposit

Timber Structures

Engineering properties of Structural Materials

Classification
Density
Fiber Saturation Point
Grade
Growth Characteristics
Moisture Content (main factor affecting the strength)

Critical Characteristics

Bending/flexural strength
Compression parallel to grain
Compression perpendicular to grain
Fatigue strength
Modulus of elasticity
Shear strength
Tensile strength parallel to grain
Tensile strength perpendicular to grain

Structural Timber Codes and Standards

British Standard BS5268: Structural use of Timber
British Standard BS EN 1001: Durability of Wood and Wood-based Products

Malaysia Standard MS544: Code of Practice for Structural Use of Timber
Malaysia Standard MS758: Glue Laminated Timber – Performance Requirements and Minimum Production Requirements
Malaysia Standard MS837: Solid Timber – Determination of Moisture Content
Malaysia Standard MS1714: Specification for Visual Strength Grading of Tropical Hardwood Timber

Testing of Materials and Structures

Destructive Test

- Tensile Test, Shear Test, Fatigue Test and Flexure Test

Non-Destructive Test

- Ultrasonic Method
- Moisture Content
- Microdrilling
- Pilodyn (Wood Hardener Tester)
- Sylvatest
- Radiography

Causes of Nonperformance and Failures

Deterioration due to adhesive
Chemical Exposure
Chemical Treatment
Creep
Decay
Deflection
Insect and Animal Attack
Moisture
Temperature and Weathering


END. THANK YOU.