Building Structural Design

Introduction
Three Aims in Structural Design

• First the structure must be safe, for society demands security in the structures it inhabits.

• Second, the structure must fulfill its intended purpose during its intended life span.

• Third, the structure must be economical with regard to first cost and to maintenance costs.
Overview of Structural Design

- Idealization of the structure into load bearing frames and elements for analysis and design
- Estimation of loads
- Analysis to determine the maximum moments, thrusts and shears for design
- Design of sections and reinforcement arrangements for slabs, beams, columns and walls using the results from the analysis
- Production of detail arrangements and bar schedules
Design Procedure

• What does the client actually want the building to accomplish?

• What conditions exist or will exist after construction that are beyond the designer’s control?
Functions of Building

• The function of a building is to provide a desired spatial (relating to space) environment within it continuously, for a given human activity.

• The building therefore provides a safe and comfortable internal environment against the existing external and unwanted internal conditions for the given human activity.
Building Safety

• Building must be safe against forces of nature viz., gravity, wind, rain and snowfall and earthquake etc besides forces imparted due to human actions.

• Function is to withstand loads SAFELY.
Environment

• Comfortable against natural external environment, namely temperature, relative humidity, moisture ingress, condensation, etc.

• Comfortable against man made external and internal agency causing discomfort example: noise, air pollution
Structures

- Function of a *bridge* is to allow safe and smooth passage of traffic over it.
Structures

- Function of a **dam** is to allow safe storage and distribution of water.
Types of Design

Two types of design:

• **Functional Design**
  based on overall dimensions

• **Structural Design**
  size detailing
Types of Loads

• Some types of loads, for example that are due to self-weight, are deterministic (steady) and will not change with time.

• Some are deterministic but may change with time, eg: loads due to furniture, occupant and machinery, etc (quasi steady)

• Some are uncertain, transitory in nature, eg: seismic load and wind load.
Design Loads

• Precise computation of actual load that a structure is likely to encounter in service is difficult.

• Reliance on experience and scientific knowledge.

• Loads decided on the basis of experience and currently accepted scientific knowledge are put down in code of practice.
Types of Load

• **Dead Loads**
  density of materials and size of member

• **Imposed Loads**
  characteristic load depends on occupancy type and functional usage

• **Wind Loads**
  depends on design wind speed
Types of Load

Special Loads

• Temperature effects, shrinkage, moisture, fire, etc.

• Hydrostatic and soil pressure, fatigue, load during construction, impact, collision.
Examples of Loads

- Dead Load

- Live Load
Structural Elements & Frames

A building structure generally consists of the following elements:

• Bases and Foundations
• Slabs
• Beams
• Columns
• Walls
Bases and Foundations

• are pads or strips supported directly on the ground that spread the loads from columns and walls so that they can be supported by the ground without excessive settlement. Alternatively the bases may be supported on piles.
Slabs and Beams

- are horizontal plate elements carrying lateral loads

- acts as lateral restraint against notional load or wind load beside carrying vertical load
Columns

- are vertical members carrying primarily axial loads but subjected to axial load and moment
Walls

• are vertical plate elements resisting vertical, lateral or in-plane loads.

• acts as lateral restraint against notional load or wind load beside carrying vertical load
Load Carrying Mechanism of a Typical RC Building

- Slab
- Beam / Column (for flat slab design)
- Column or Wall
- Foundation
Structural Elements & Frames
Structural Materials

• The performance of materials can be increased by combining different materials to achieve better properties.

• The interaction between material and structure may arise on different length scales and offers possible applications in quite diverse fields.
Materials Used in Construction

- Rock materials (blocks of rocks and fragments of rocks)
- Binder materials (lime, plaster, cement, etc)
- Concrete materials
- Ceramic materials (bricks, tiles, stoneware, etc)
- Other materials (steel, aluminium, copper, wood, plastic, glass, etc)
Material Information Resources

- American Society for Testing and Materials (ASTM)
- American National Standards Institute (ANSI)
- British Standards Institution (BSI)
- Singapore Standards (SS)
International Classification for Standards

- International Classification for Standards (ICS) field used in the Singapore Standards Catalogue:

- 91 Construction Materials & Building

- 93 Civil Engineering
Construction Materials & Building

• Construction Industry in General (Examples)

SS 517: 2005
Information exchange and documentation at handing / taking-over of buildings upon completion

SS 527: 2006
Building project documentation control system
Singapore Standardization Programme

• SPRING Singapore works closely with industry to develop national standards.

• SPRING promotes and encourages companies to use and adopt Singapore Standards (SS).

• SS are aligned with international standards to help Singapore’s manufactured goods and exports gain entry into overseas markets.
Singapore Standards

- There are 697 Singapore Standards and 17 Technical References, of which, 158 standards have been aligned to international standards.

As of 31 December 2008
Standards Committee

• Standards Committees are appointed by the Standards Council to develop Singapore Standards.

• There are currently eight Standards Committees.

• There is a Standards Committee covering Building & Construction
Establishment of Singapore Standards

- Request for Singapore Standards
- Standards Committee approves the request
- TC prepares standards
- Public comments
- Standards Committee approves standards
- Gazetting
- Printing of Standards
Standardization Process

• Standards Council delegates to Standards Committees the authority to approve standards on its behalf.
Copyright of Singapore Standards

• SPRING Singapore holds the copyright of Singapore Standards and no part of any standard may be reproduced or transmitted by any means without permission in writing from SPRING Singapore.
Generic Type of Structure

• Buildings are different.

• There are expected ways of building certain types of buildings:
  1. Ways they look – Architects concern
  2. Ways they function – Engineers concern

• Buildings have become more complex over time and the number of types has increased.
Regulations Involved

• Qualified Person (QP) who is a Professional Engineer (PE) in civil & structural or geotechnical, to prepare and submit structural plans for approval, apply for a permit to commence works and to supervise the works.

• Qualified Person (QP) who is a registered architect, to prepare and submit the building plans.

- Building Control Act & Building Control Regulations
Basic Tenets of Structural Analysis

A structure has to basically satisfy the following:

• Equilibrium

• Kinematics

• Stress-Strain compatibility
Kinematics

• Kinematics is a branch of mechanics concerned with the motion of objects without reference to the forces which cause the motion.
• Kinematics is a study aimed at explaining the motion of objects.
Sustainable Construction

• Sustainable Construction most comprehensively addresses the ecological, social and economic issues of a building in the context of its community.

• Principles of Sustainable Construction apply across the entire life cycle of construction, from planning to disposal

• Decision making during each phase of the design and construction process.
Zero Energy Building (ZEB)

- The ZEB @ BCA Academy is a zero energy building because the building produces enough energy to run itself.
- Converted from a three-storey former workshop, the ZEB houses offices, classrooms and a resource centre.
- The building shows how an existing building can be retrofitted with green technologies to achieve energy efficiency and sustainability.
ZEB @ BCA Academy