CHAPTER 4: STRUCTURAL DESIGN AND ANALYSIS

4.1 Introduction

This Unit describes the competencies required to Perform Structural Design and Analysis. It involves analysing structural designs, designing structural elements, preparing structural drawings interpreting structural drawings and applying structural drawings

4.2 Performance Standard

Analyse structural elements, design structural elements, prepare structural drawings, interpret structural drawings and apply structural drawings according to building codes, structure, drawing and support requirements, and structural design requirements.

4.3 Learning Outcomes

4.3.1 List of Learning Outcomes

a) Analyse structural elements
b) Design structural elements
c) Prepare structural drawings
d) Interpret structural drawings
e) Apply and use structural drawings

4.3.2 Learning Outcome No 1: Analyze Structural Elements

4.3.2.1 Learning Activities

Learning Outcome No 1: Analyse Structural Elements	
Learning Activities	**Special Instructions**
1.1 Determine methods used in analyses of structural members 1.2 Work loadings 1.3 Sketch structural members 1.4 Determine maximum moments in each section 1.5 Draw shear force and bending moments diagram	• Demonstration by trainer • Practical work by trainee • Demonstration videos • Projects • Group discussions

4.3.2.2 Information Sheet No4/L01: Analyse Structural Elements

Introduction to learning outcome

This learning outcome covers Analyses of structural elements, Preparation of sketches, Determination of maximum moments and Structural designs.

Definition

Building codes: These are laid down standards for any building structure.

Bending moments: These are structural reactions when a structure is subjected to moment or applied load.

Shear force: This is the reaction imposed by a structure when loads are imposed.

Content/Procedures/Methods/Illustrations

1.1 Determine Methods used in analyses of structural members according to building codes

Several methods are used in the analysis of structural members. A structural system is made up of different members and each member is analysed differently. The methods of analysis used in beams include:

a. Energy methods

Two methods are commonly used i.e.

- Methods of virtual work
- Castigliano's theorem

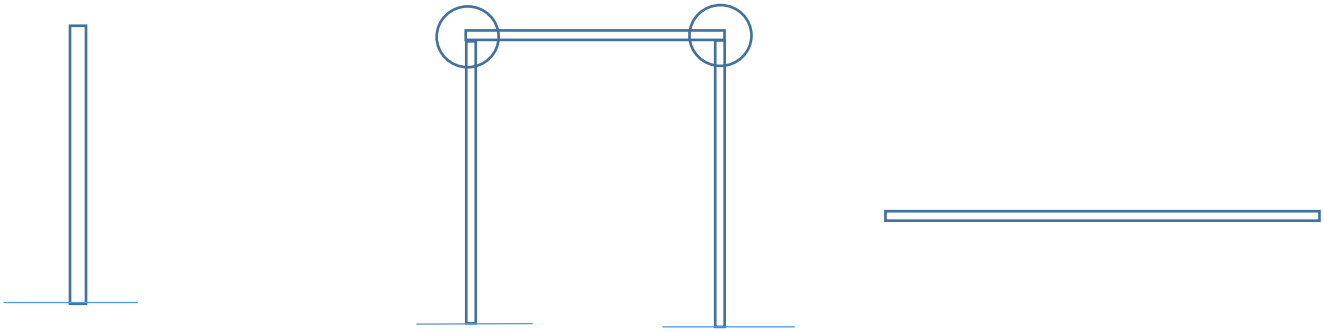
b. Displacement methods of analysis
    - Slope deflection methods
    - Moment distribution methods
c. Approximate methods of analysis.
    - This method is used in the analysis of statically indeterminate structures.
d. Double integration method
    - In this method, sign convention and boundary conditions are well defined. It is mostly used in determining deflections.
e. Elastic beam theory
    - The method relates to slope, displacement as well as the internal moments of a beam. Its development is fully dependent on this.
f. Moment area methods
    - This method is mainly used when checking for deflection. It involves determining slope and deflection of an elastic curve.
g. Conjugate- beam method
    - This method relies mainly on statics for determining deflection in beams.
h. Stiffness method of analysis

1.2 Work loadings on according to the structure

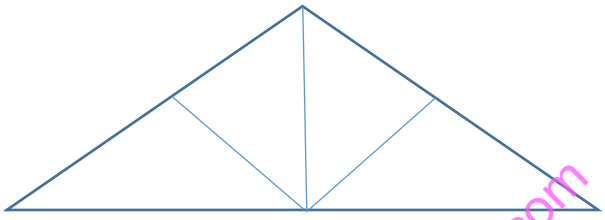
These are loadings that are subjected to a structure. Different structures are subjected to different loadings depending on the location, height as well as purpose of use.

a. Dead loads
    - These are loads that are permanent in a structure. They include the self-weight of the structure, finishes, masonry etc.
    - During analysis, these loads are taken into considerations to ascertain the safety of the structure.
b. Live loads
    - These are loads that are temporary. They include people, furniture, etc.
    - There are other types of live loads such as impact loads (loads imposed by moving cars), highway bridge loads (caused by traffic), wind loads and snow loads.

1.3 Sketch structural members as per the drawings and support requirements



i. Column ii. Frame iii. Beam



iv. Truss

Figure 73: Sketch structural members

1.4 Determine maximum moments in each section in accordance with appropriate methods

Maximum moments in different sections of a structural member is determined using mathematical equations.

It is also necessary to note that maximum moment occurs at zero- shear force.

The line of influence method of determining maximum moment is often used for statically determinate structures.

The method assumes that summation of shear force area under the influence line is the moment at any given section in the structure.

That is, Mmax= Summation of area under shear

- ✓ For statically indeterminate structures, the force method is used in which,

$Mmax = \frac{PL}{8}$ ----- fixed support beams

$Mmax = \frac{PL}{8}$ ------ Simply supported beams

1.5 Draw shear force and bending moments diagram according to structural design requirements

Drawing shear force and bending diagrams is very essential since it creates an image of how a structure will fail.

Before doing so, one is required to follow certain procedures as discussed below:

Shear force diagram

a. Determine Shear, V at distance x. Distance x is always the distance from one load application to another.
b. Plot a graph of V against x

Bending moment diagram

a. Determine moment, M by find the area under shear in the SFD.
b. Plot a graph of moment M, against distance x.

The diagram attached below is an example of how to draw a bending moment diagram (BMD) as well as the shear force diagram (SFD)

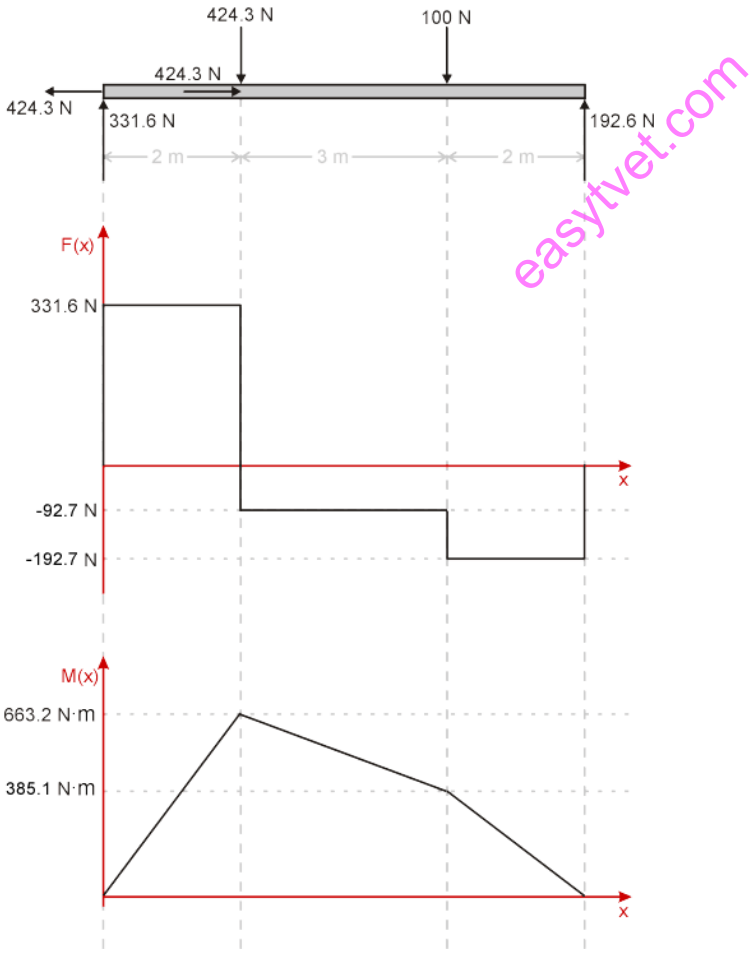


Figure 74: bending moment

Source: Structural mechanics, 2008

Conclusion

This learning outcome covered Analyses of structural elements, Preparation of sketches, Determination of maximum moments and Structural designs.

Further Reading

4.3.2.3 Self-Assessment

Written Assessment

1 Which one of the following is a type of load?
   a) Furniture load
   b) Rail truck load
   c) Live load
   d) Steel load

2 Which of the following is a method is used to analyze statically indeterminate structure?
   a) Influence line analysis method
   b) Superposition
   c) Energy methods
   d) Finite element method.

3 The following methods are used in the analysis of trussed which one is not?
   a) Method of joints
   b) Method of sections
   c) Virial work methods
   d) Influence line methods

4 Which of the following is not a displacement method of analysis?
   a) Castigliano's theory
   b) Slope deflection equations
   c) Moment distribution method

5 Which of the following is not a structural member?
   a) Beams
   b) Walls
   c) Columns
   d) Frames

6 Define what is a structure

7 Explain the importance of structural analysis
8 Differentiate between Structural design and structural analysis
9 What is the difference between influence line and shear force and bending moment diagram?
10 Differentiate
    1. Column
    2. Beam
    3. Frame
    4. Truss
11 Discuss Displacement methods in details
12 For each of the methods outlined, discuss their shortcomings.

Oral Assessment

1. What is analysis?
2. Why do we need to analyze structures?

Project Assessment

1. Analyze a one-story building.

4.3.2.4 Tools, Equipment, Supplies and Materials

- Computers
- Office equipment
- Calculators
- Scale rule
- Computer software
- Design codes (British Standards)
- Stationery
- Standard design manuals
- Dust coat
- First aid kit

4.3.2.5 References

Bhavikatti, S. (2010). Structural analysis. New Delhi: Vikas Publishing House.
Hibbeler, R. (2012). Structural analysis. Upper Saddle River: Prentice Hall.
Kaveh, A. (2004). Structural mechanics. Baldock, England: Research Studies Press.
Stanford, J. (2012). Structural Analysis Made Easy.

4.3.3 Learning Outcome No 2: Design structural elements

4.3.3.1 Learning Activities

Learning Outcome No 2: Design structural elements	
 **Learning Activities**	**Special Instructions**
2.1 Gather Design recourses 2.2 Identify types of structural elements 2.3 Identify different methods of designs 2.4 Identify different types of standard design codes 2.5 Determine maximum moments used in design 2.6 Identify and gather design tools and equipment 2.7 Design structural elements	• Demonstration by trainer • Practical work by trainee • Demonstration videos • Projects • Group discussions

4.3.3.2 Information Sheet No4/L02 Design structural elements

Introduction to learning outcome

This learning outcome covers Structural designs, Methods of designs, Design codes, Design tools and equipment, Structural elements designs and Schedules for different elements.

Definition of key terms

Structural elements: Structural elements have to do with the part of the building that is concerned with preserving the physical integrity (ensuring the structure satisfies the ultimate limit state and the serviceability limit state requirements) and continues to exist in the world as a physical object.

Structural designs: This refers to the process of undertaking a structural analysis and selecting materials, member types, configuration and size to safely carry and transfer the intended loads both in a serviceability and ultimate limit state.

Content/Procedures/Methods/Illustrations

2.1 Gather *Design recourses* according to standard design requirements

In design, it is said that there is no one way of solving a design problem. Focusing on just one solution instead of considering other alternatives is almost certain that you are overlooking other attractive solutions. Generating design options is a phase in project planning known as conceptual design and it includes producing ideas and taking into account the advantage and limitations of implementing those ideas.

This is done to manage costs, minimize the likelihood of errors, evaluate success and assess risks of undertaking the intended project. Some of the design recourses undertaken in project include:

i) Changing the materials.
ii) Changing the member types.
iii) Changing the member configuration and arrangement.
iv) Changing the member sizes.

2.2 Identify types of structural elements as per building codes

Structural elements have to do with the part of the building that is concerned with preserving the physical integrity (ensuring the structure satisfies the ultimate limit state and the serviceability limit state requirements) and continues to exist in the world as a physical object. The following are some of the structural elements:

i) **Foundations:** The foundation is part of an engineered system that transmits to the underlying soil or rock the loads supported by the foundation itself and its self-weight in such a way that the soil is not overstressed or excessive settlement occurs.
ii) **Columns:** These are vertical members that majorly resist axial compressive loads.
iii) **Beams:** These are horizontal members that primarily carry vertical loads and resist failure in bending.
iv) **Walls:** A wall is a structure that demarcates the different spaces in a building as well as the external boundary. Some walls are load bearing and carry the structural loads of the building.
v) **Ties:** This is a slender structural element that carries the loads in tension.
vi) **Struts:** This a structural member that carries the loads in compression only.
vii) **Trusses:** This a structure that is composed of a series of struts and is used to carry loads in compression.
viii) **Frames:** This type of structure is composed of beams and columns that are either pin or fixed connected.
ix) **Slabs:** This are horizontal structures built to provide a flat surface in buildings.

2.3 Identify different methods of designs as per the design manuals

The following are the design methods according to BS 5950:

i) Simple design method: The connections between members are assumed not to develop moments adversely affecting either the members or structure as a whole. So, the structure is assumed to be pinly-jointed for analysis.
ii) Semi-rigid design method: Are capable of transmitting some moments. Here the joints are capable of transmitting partial moment.

iii) Rigid design method: Connections are assumed to be capable of transmitting 100% moment required by analysis assuming full continuity.

iv) Experimental verification: The code states that where design of a structure or elements by calculation in accordance with any of the above methods is not practical, the strength will be confirmed by loading tests.

2.4 Identify different types of standard design codes according to construction materials

The following are some of the design codes currently in use in Kenya:

i) Design of reinforced concrete structures- BS 8110

ii) Design of steel framed buildings- BS 5950

iii) Design of timber structures- BS 5628

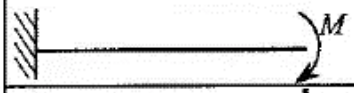
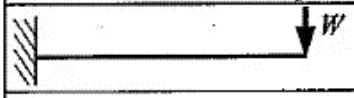
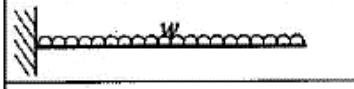
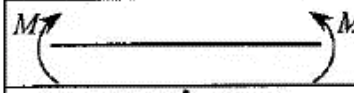
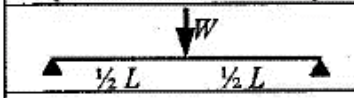
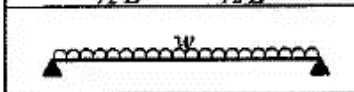
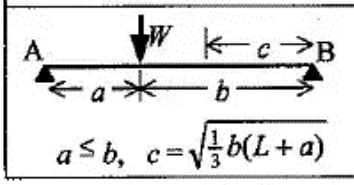
iv) Design code on the occupancy load requirements of a building- BS 6399 Part 1.

2.5 Determine maximum moments used in design according to standard specification manuals

The maximum bending moment occurs in beam where the shear force is zero. Below is a table showing how to calculate bending moment for various types of beams:

Table 4: How to calculate bending moment for various types of beams

BEAM BENDING

L = overall length W = point load, M = moment w = load per unit length	End Slope	Max Deflection	Max bending moment
	$\frac{ML}{EI}$	$\frac{ML^2}{2EI}$	M
	$\frac{WL^2}{2EI}$	$\frac{WL^3}{3EI}$	WL
	$\frac{wL^3}{6EI}$	$\frac{wL^4}{8EI}$	$\frac{wL^2}{2}$
	$\frac{ML}{2EI}$	$\frac{ML^2}{8EI}$	M
	$\frac{WL^2}{16EI}$	$\frac{WL^3}{48EI}$	$\frac{WL}{4}$
	$\frac{wL^3}{24EI}$	$\frac{5wL^4}{384EI}$	$\frac{wL^2}{8}$
 $a \le b,\ c = \sqrt{\frac{1}{3}b(L+a)}$	$\theta_B = \frac{Wac^2}{2LEI}$ $\theta_A = \frac{L+b}{L+a}\theta_B$	$\frac{Wac^3}{3LEI}$ (at position c)	$\frac{Wab}{L}$ (under load)

Source: www.learneasy.info

2.6 Identify and gather design tools and equipment according to standard design manuals

Check the tools, equipment, supplies and materials section.

2.7 Design structural elements as per the design codes

The following is the procedure followed in the design of a beam according to BS 5950:

i) Determine the loading condition of the beam.
ii) Calculate the design load of the beam.
iii) Perform structural analysis to determine the design moment and the design shear.
iv) Perform a strength classification and section classification.
v) Choose a section based on its moment capacity equation.
vi) Perform a moment capacity check.
vii) Perform a shear capacity check.
viii) Evaluate whether it's a low or high shear load.
ix) Perform a deflection limits check.
x) Perform a web bearing check.

Conclusion

This learning outcome covered structural designs, methods of designs, design codes, design tools and equipment, structural elements designs and schedules for different elements.

Further Reading

1. British standards Institute. (2002). Design of reinforced concrete structures-BS 8810. BSI.
2. British standards Institute. (2002). Design of steel structures-BS 5950. BSI.
3. British standards Institute. (2002). Design of timber structures-BS 5628. BSI.

4.3.2.3 Self-Assessment

Written Assessment

1. Which of the following is not a type of foundation?
    a) Mat
    b) Isolated footing
    c) Retaining wall
    d) Combined footing
2. Which of the following is not a check done during the design of reinforced concrete beam?
    a) Shear capacity check.
    b) Moment capacity check.
    c) Web buckling check.
    d) Deflection check
3. Which of the following is not a phase during design of structures?
    a) Technical design
    b) Developed design
    c) Conceptual design
    d) Handover
4. Which of the following is not a structural element?
    a) Ties
    b) None
    c) Trusses
    d) Joists
5. Design a reinforced concrete beam of your choosing according to the design code BS 8110.

6. Describe the various type of foundations and when should be used.
7. Describe the design principles that should guide an engineer during the design process.
8. Describe the main design theories.
9. Write an essay describing the how an engineer with poor communication skills can lead to poor quality construction.

Project Assessment

1. Using a BIM software application of your choice obtain architectural drawings from the internet and develop a corresponding structural model.

Oral Assessment

1. Describe how you as a student pursuing a diploma of civil engineering can develop shop drawings for fabrication of steel members when requested by the professional engineer.
2. What skills have you gained as a result of performing the project assessment described above.

4.3.2.4 Tools, Equipment, Supplies and Materials

- Computers
- Office equipment
- Calculators
- Computer software
- Design codes (British standards)
- Stationery
- Standard design manuals

4.3.3.5 References

Abdy Kermani (2008) Structural timber design. Blackwell science, London.

N. Subramanian (2010). Steel structures design and practice. Oxford university press, New Delhi.

W.H Mosley, R. Hulse, J.H Bungey (2012). Reinforced Concrete Design. Red Globe Press, New York.

4.3.4 Learning Outcome No 3: Prepare Structural Drawings

4.3.4.1 Learning Activities

Learning Outcome No 3: Prepare structural drawings	
Learning Activities	**Special Instructions**
3.1 Identify and gather drawing resources 3.2 Determine methods of drawing for structural members 3.3 Prepare standard working structural drawings for various elements 3.4 Prepare materials schedules	• Demonstration by trainer • Practical work by trainee • Demonstration videos • Projects • Group discussions

4.3.4.2 Information Sheet No4/ L03 Prepare structural drawings

Introduction to learning outcome

This learning outcome covers Drawing tools and equipment, Methods of drawing, Standard structural drawings and Preparation of material schedules.

Definition of key terms

Drawing resources: This refers to the various resources required in order to produce the complete set of structural drawings.

Structural members: Structural members have to do with the part of the building that is concerned with preserving the physical integrity.

Content/Procedures/Methods/Illustrations

3.1 Identify and gather drawing resources according to structural elements designed

- Computers
- Office equipment
- Calculators
- Computer software
- Design codes (British standards)
- Stationery
- Standard design manuals

3.2 Determine methods of drawing for structural members as per the designs

Structural drawings confine themselves to the load-carrying members of a structure.

The following outlines the methods for drawing structural members:

i) Structural plan. These drawings show the floor, foundation and roof plan of a building and provide information like location and size of different elements present in the plans.

ii) Elevations. These shows the exterior walls of a building or structure and the structural properties of elements present in the walls and cannot be seen in plan drawings.

iii) Sections. These are referenced in the plan drawings and provide more information about elements that may not be seen in plan drawings.

iv) Detail drawings. These provides particular information on how to connect or construct the structural elements.

3.3 Prepare standard working structural drawings for various elements as per designs

Structural drawings have to be produced as the design process evolves since the drawings are required in construction of the structure. Production of structural drawings takes place as follows:

i) The schematic architectural drawings are obtained from the architect. (Conceptual design phase)

ii) The engineer determines the loadings applied to the structure based on the drawings and performs design to size the members according to the forces applied to the building. (Developed design phase)

iii) As the design process evolves the engineer produces more detailed drawings, bar bending schedules, notes, specifications, details and at the end of this stage we have construction ready documents. (Technical design phase)

iv) The drawings are included in a tender pack to be tendered together with drawings from other disciplines during the bidding and tendering process.

3.4 Prepare materials schedules as per design codes

A material schedule is a detailed list of construction materials required to complete construction of the intended project.

i) Decide what is required. This requires that you thoroughly interrogate the drawings and specifications to determine the required materials.

ii) Decide whether to prefabricate the materials or construct on-site. This involves deciding whether to purchase materials for construction on-site or purchase prefabricated components.

Conclusion

This learning outcome covered drawing tools and equipment, methods of drawing, standard structural drawings and preparation of material schedules.

Further Reading

1. N.Krishna Raju (1992) Structural design and drawing: Reinforced concrete and steel. Universities Press.
2. Leonard Koel. (1999) Construction print reading. Delmar Cengage Learning.

4.3.4.4 Self-Assessment

Written Assessment

1. Which of the following is not a method of drawing structural members?
    a) Specifications
    b) Structural plans
    c) Elevations
    d) Details
2. Which of the following is not among the drawing resources required to produce structural plans?
    a) Computers
    b) Computer software
    c) Standard design manuals
    d) Office equipment
3. Which of the following is not a phase during design of structures?
    a) Technical design
    b) Developed design
    c) Conceptual design
    d) Handover
4. State the various computer software required in the production of structural drawings.
5. Explain the procedure of developing shop drawings.
6. Describe what is detailing of structural drawings.
7. Write an essay describing Building Information Modelling (BIM) and its impact on the production of structural drawings.

Project Assessment

Obtain a set of structural drawings for a project from the internet and interpret them to draw up a material schedule.

Oral Assessment

1. Explain the skills required to competently interpret structural drawings.
2. Explain the steps followed in interpreting structural drawings.

4.3.4.4 Tools, Equipment, Supplies and Materials

- Computers
- Office equipment
- Calculators
- Computer software
- Design codes (British standards)
- Stationery
- Standard design manuals

4.3.4.5 References

R.K Dhawan (2012). A textbook of engineering drawing. S.Chand 3rd rev.

Leonard Koel. (2000) Construction print reading. Delmar Cengage Learning.

4.3.5 Learning Outcome No 4: Interpret structural drawings

4.3.5.1 Learning Activities

Learning Outcome No 3: Interpret structural drawings	
Learning Activities	**Special Instructions**
4.1 Identify project 4.2 Identify and obtain structural drawings 4.3 Obtain and prepare steel schedules and materials schedules	• Demonstration by trainer • Practical work by trainee • Demonstration videos • Projects • Group discussions

4.3.5.2 Information Sheet No4/ L04 Interpret structural drawings

Introduction to learning outcome

This learning outcome covers Identification of project, Structural drawings, Steel and material schedules preparation and Standard construction procedures

Definition of key terms

Steel schedules: This is a list that explains the location, mark, type, size, length and number of each steel bar in a reinforcement drawing of a structure.

Structural drawings: These are plans illustrating in detail how a structure or building should be constructed. Engineers come up with structural drawings from performing checks using the loads that the structure is to carry, co-currently with standard codes.

Content/Procedures/Methods/Illustrations

4.1 Identify project according to the contract document

Project Identification is one of the major stages of a project cycle

Steps taken in identifying a project:

- Preliminary stakeholder analysis
- Analyzing the problem
- Setting of Objectives
- Analyzing alternatives
- Analyzing accountability
- Logical framework thinking
- Analyzing assumptions and associated risks
- Definition of Progress indicator

4.2 Identify and obtain structural drawings as per design manuals

Structural drawings

These are plans illustrating in detail how a structure or building should be constructed. Engineers come up with structural drawings from performing checks using the loads that the structure is to carry, co-currently with standard codes.

Structural drawings should basically include the following information;

- Setting out dimensions
- Notes describing the specifications
- Sections, plans and elevations
- Compass direction – North point

Reinforcement Drawing

These are drawings describing the location, number, size, type of reinforcement and illustrate the direction in which the reinforcement is to be laid.

Standard Details

This is a description of certain standard details that keep recurring in several structural drawings and are kept for use whenever necessary.

Standard details include;

- Notes
- Expansion joints details
- Concrete box culverts
- Pile caps and column bases

Record Drawings

This is a drawing that has been revised to cater for unforeseen challenges. A revision letter is normally included in the revised drawing to indicate that it is a revision.

4.3 Obtain and prepare steel schedules and materials schedules according to construction procedures

Factors to be considered when preparing a Steel Schedule

- Location of reinforcement
- Mark of reinforcement
- Type of reinforcement
- Size of reinforcement – diameter of steel
- Length of reinforcement

Factors to be considered when preparing a Materials Schedule

- Type of material
- Amount of material

Conclusion

This learning outcome covered identification of project, structural drawings, steel and material schedules preparation and standard construction procedures.

Further Reading

Read further on the Project cycle

4.3.5.3 Self-Assessment

Written Assessment

1. Structural drawings should basically include the following information. Which one is not among them?
    a) Setting out dimensions
    b) Notes describing the specifications
    c) Sections, plans and elevations
    d) Amount of material
2. While developing a steel schedule the site engineer left out one crucial detail necessary. Which one of the following is it?
    a) Color of reinforcement
    b) Location of reinforcement
    c) Dimensions of structure
    d) Height of the structure
3. Define the term Structural drawings
4. State three types of construction drawings
5. Discuss in detail the steps taken in project identification

Oral Assessment

Why is it necessary to master the art of interpreting structural drawings?

Practical Assessment

Get construction drawings of a given structure and point out the different structural element present and come up with a steel schedule for the reinforcement

4.3.5.4 Tools, Equipment, Supplies and Materials

- Computers
- Office equipment
- Calculators
- Scale rule
- Computer software
- Design codes (British standards)
- Stationery
- Standard design manuals
- Dust coat
- First aid kit

4.3.2.5 References

McCormac. (2007). Structural Steel Design. Prentice Hall, 4th edition. ISBN:013221816X
Segui (2006). Steel Design. Cengage-Engineering, 4th edition. ISBN: 0495244716

4.3.6 Learning Outcome No 5: Apply and use Structural Drawings

4.3.6.1 Learning Activities

Learning Outcome No 5: Apply and use Structural Drawings	
Learning Activities	**Special Instructions**
5.1 Identify and obtain construction resources 5.2 Gather statutory documents 5.3 Determine setting out activities 5.4 Establish foundation 5.5 Prepare structural members 5.6 Develop and adhere to working drawing, steel schedules and materials schedules	• Demonstration by trainer • Practical work by trainee • Demonstration videos • Projects • Group discussions

4.3.6.2 Information Sheet No5/ L05 Apply and use structural drawings

Introduction to learning outcome

This learning outcome covers Interpretation of drawings, Statutory requirements, Foundation engineering, Preparation of structural elements and Development of working drawing, steel schedules and materials schedules

Definition of key terms

Statutory documents: This refers to documents with instructions or requirements which are applicable by virtue of law enacted by the government.

Steel schedules: This is a list that explains the location, mark, type, size, length and number of each steel bar in a Reinforcement Drawing of a Structure.

Content/Procedures/Methods/Illustrations

5.1 Identify and obtain construction resources as per the tender documents

Construction resources – this is basically the materials and personnel necessary for the construction process from start to finish.

Construction resources include;

a) **Time –** Time as a resource in construction is very sensitive since most construction projects are working under a certain time frame requested by the client. The fact that some construction works such as concrete works which require *curing time* makes the resource of time quite valuable.

b) **Materials –** Construction materials are a great resource since they sum up the ingredients necessary to have a finished structural work. These include but are not limited to building blocks, cement, sand, water, ballast etc.
c) **Labour –** this includes human personnel, from the manual worker to the construction experts such as engineers.
d) **Plant and Machinery –** These are necessary in order to have some finished products such as concrete which requires a *concrete mixer*.
e) **Health and safety equipment –** This is whereby we have guard rails at the edge of high-rise buildings under construction, the use of bright coloured tape surrounding shafts, presence of fire extinguishers on site and health and safety training for all personnel.
f) **Technology –** technology such as a crane which is necessary for lifting heavy construction materials such as steel, scaffolding, shuttering, buckets of concrete etc.
g) **Works Requirement –** This comprises of the working drawings and specifications required for the construction project.
h) **Construction site –** This is the very place where the proposed structure is to be constructed.

5.2 Gather statutory documents as per the project requirements

Statutory documents

This refers to documents with instructions or requirements which are applicable by virtue of law enacted by the government. Almost every proposed development project has statutory obligations that do not arise out of the contract, but are imposed by law. These obligations are applicable to the design, construction and operation of buildings and will depend on the specific nature of the proposed development.

Statutory documents are required for the following areas when drafting construction contracts:

Labour

- The Employment Act 2007
- The Labour Institutions Act
- The Labour Relations Act

Tax

- The Income Tax Act

All workers in any construction project must be subject to the payment of income tax

Health and Safety

- Occupational Safety and Health Act 2007 (OSHA**)**
- Work Injury Benefit Act, 2007

Environment and Pollution

- Environmental Management and Coordination Act

Noise

- Legal Notice No.61 (NEMA)

Traffic

- The Road Traffic Act

Building

- Building Regulations

Planning

- The Urban Planning Act

Public Procurement

- The Social Value Act

Products and Services

- The Supply of Goods and Services Act

5.3 Determine setting out activities according to the approved drawings and standard construction processes

Setting Out – the act of establishing the location points of site boundaries, columns, foundations, center-lines of walls and any other necessary structural part.

Types of Setting Out

- **3-4-5 method**
  Used especially in setting out right angles from certain points on the base line.
- **Rope method**
  The rope method is used in setting out a perpendicular line in reference to the base line, beginning from a point which is not on the base line.
- **Single and Double Prismatic Square**
  This is used in setting out both right angles and perpendicular lines.

The methods of setting out listed above are used in conjunction with the total station, prisms, etc.

Steps undertaken in Setting out a building

- Clearing the site
- Obtain the working drawing of the proposed building
- Ensure that the materials for construction are ready
- A parallel line is then established
- The 3-4-5 setting out method is then used for setting out
- Profiles are then established
- The points of excavation on the profiled are nailed
- The points of the column on the profile are then nailed.

5.4 Establish foundation as per the working drawings and standard construction procedures

Factors to be considered when establishing the foundation

- Excavation depth and volume
- Soil bearing capacity
- Base area of foundation
- Proximity to property lines

5.5 Prepare structural members in accordance with the working drawings

Structural Members

These are simple structural elements that when viewed or put together, make up the structural body in a drawing

Structural members include;

- **Columns** – these are vertical elements that carry loads from slabs and beams.
- **Beams** – these are horizontal elements that carry loads from slabs and sometimes walls
- **Slab** – these is a horizontal element that covers a described portion in the x-plane and carries both fixed and static loads depending on the use of the structure
- **Stairs** – are structural elements that are in the z-plane. They can be diagonal or vertical in the y-plane and are horizontal in the x-plane.
- **Walls** – These are vertical elements constructed using masonry and can carry loads.
- **Foundations** – this is a substructure element that transfers the loads of the superstructure to ground

5.6 Develop and adhere to working drawing, steel schedules and materials schedules according to standard construction processes

Factors to be considered in developing Working Drawing

- Internal forces – Moment and Shear (ULS – Ultimate limit state)
- Safety Checks on deflection, cracking, corrosion and fire resistance
- Loads – dead loads and imposed loads
- Partial Safety factors – On dead loads a partial safety of 40% ($1.4G_k$) and a partial safety factor of 60% on imposed loads ($1.6Q_k$)
- Moment distribution

Factors to be considered when developing a Steel Schedule

- Location of reinforcement
- Mark of reinforcement
- Type of reinforcement
- Size of reinforcement – diameter of steel
- Length of reinforcement

Factors to be considered when developing a Materials Schedule

- Type of material
- Amount of material

Conclusion

This learning outcome covered interpretation of drawings, statutory requirements, foundation engineering, preparation of structural elements and development of working drawing, steel schedules and materials schedules.

Further Reading

Read further on statutory documents necessary for construction works in Kenya.

4.3.6.3 Self-Assessment

Written Assessment

1. Sophia is a student undertaking a diploma course in civil engineering. While arranging a bookshelf at her home, she came across structural drawings to their proposed new home in Ruai. Which of the following was not a structural member in the drawings?
    a) Columns
    b) Beams
    c) Slab
    d) Steel reinforcement
2. Victor a recently graduate civil engineer was asked to come up with a steel schedule back at work. Which of the following is not a factor he should consider while developing the steel schedule?
    a) Location of reinforcement
    b) Size of reinforcement
    c) Color of reinforcement
    d) Length of reinforcement
3. In an interview for a civil engineering job, an interviewee was asked to state the steps undertaken when setting out a building. Which of the following should have been his first step?
    a) Establishing the profile
    b) Using the 3-4-5 method to set out
    c) Clearing the site
    d) Establishing a parallel line
4. State construction resources necessary for the construction process
5. State 5 factors to be considered when developing a working drawing
6. Using examples, define statutory documents
7. Discuss the significance of partial safety factors on loads and materials

Performance Based Evidence

Oral Assessment

What are the factors considered when selecting concrete cover?

Practical Assessment

Given a 4 by 5 two-way spanning solid slab, with the aid of a structural drawing, develop a steel schedule for the slab.

4.3.6.4 Tools, Equipment, Supplies and Materials

- Computers
- Office equipment
- Calculators
- Scale rule
- Computer software
- Design codes (British standards)
- Stationery
- Standard design manuals
- Dust coat
- First aid kit

4.3.6.5 References

McCormac. (2007). Structural Steel Design. Prentice Hall, 4th edition. ISBN:013221816X
Segui (2006). Steel Design. Cengage-Engineering, 4th edition. ISBN: 0495244716