CHAPTER 14: ENGINEERING STRUCTURES DESIGN

14.1 Introduction of the Unit of Learning

This unit specifies the competencies required to design engineering structures. This involves load estimation, designing structural elements, assessing of cost effectiveness of designs, analysing site test data and modifying structural designs.

14.2 Performance Standard

Calculate load estimates, design structural elements, assess cost effectiveness of the design, and modify structural designs client's needs, design standards and structural use, and code procedures.

14.3 Learning Outcomes

14.3.1 List of Learning Outcomes

a) Calculate load estimates
b) Design structural elements
c) Assess cost effectiveness of the design
d) Modify structural designs

14.3.2 Learning Outcome No 1: Calculate Load Estimates

14.3.2.1 Learning Activities

Learning Outcome No 1: Calculate Load Estimates	
Learning Activities	**Special Instructions**
1.1 Determine intended use of a structure 1.2 Create the layout of the structure from the architectural drawings 1.3 Determine the codes of practice/manuals required to obtain the required loading 1.4 Carry out load analysis/estimation	• Demonstration by trainer • Practical work by trainee • Demonstration videos • Projects • Group discussions

14.3.2.2 Information Sheet No14/LO1: Calculate Load Estimates

Introduction to learning outcome

This learning outcome deals with the determination of the intended use of a structure as per clients need, creation of layouts from architectural drawings, load analysis and estimation and gaining knowledge of codes of practice and manuals.

Definition of key terms

Codes of practice – refers to a set of rules in the form of a written document which explains and guides how people in a certain profession should behave or act in their professional practice.

Layout – refers to a drawing or a plan that shows how a structure will be build.

Intended use – refers to the purpose for which a structure is built for.

Content/Procedures/Methods/Illustrations

1.1 Determine intended use of a structure as per client needs

The intended use of a structure can be determined based on the purpose for which the larger part (space of the building) of the total floor area of the building is used. The intended use of a structure can be but not limited to the following

- Residential – used for peoples dwelling
- Commercial – used for business purposes
- Industrial – used for various purposes such as processing etc.
- Educational – used for learning purposes
- Agricultural – used for agricultural purposes such as storage facilities

In order to carry the intended use of a structure, BS6399-1:1996 gives various categories of occupancies and usage of structures. This categorizes helps know the types and magnitude of loads experienced by each occupancy. These include;

- Domestic and residential areas
- Office and work areas
- Shopping areas
- Areas that are susceptible to accumulation of goods
- Areas where people congregate
- Traffic and vehicle areas

1.2 Create the layout of the structure from the architectural drawings as per design standards and structural use

Creation of a building layout helps mark out positions of columns, walls, boundaries or any other structural element of a building. An understanding of the type of dimensions present in the drawing is necessary in order to create a layout. The layout gives other engineers the type of structural elements presents in the building. The general rules or procedures of preparing a structural layout are as follows;

a) Adhere to the architect's original plan – architectural drawings supersede structural layouts. Make your arrangement to coincide with the architect's work.
b) Choose a stable arrangement – the layout should represent the structural behavior of the structure. Ensue stability and equilibrium.
c) Build ability – the arrangement you select should be buildable. The consideration of the technical capacity of the contactors is necessary.
d) Balance between economic and structural aspects – consider a choice that is more economical for instance the use of more concrete or steel.
e) Produce the layout on a CAD software.

Once the layout is created, the setting out of the structure can be carried out to establish the building physically on the ground. An example of a layout from an architectural drawing is shown below.

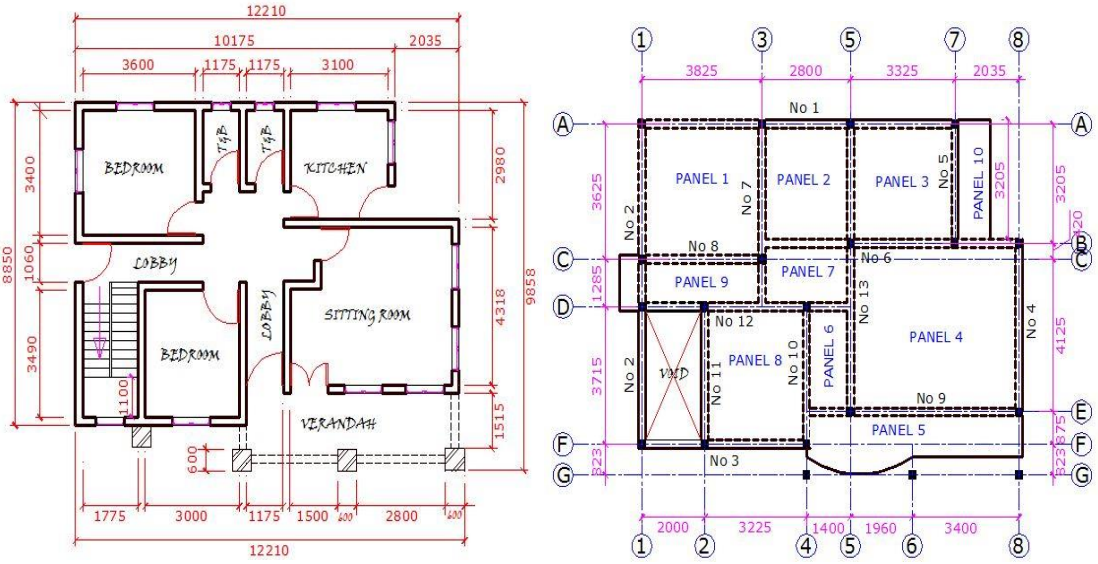

Figure 148: Floor plan and corresponding structural layout
Source: Structville.com

1.3 Determine the Codes of practice/manuals required to obtain the required loading are based on structural use.

A code of practice to be used can be determined on various aspects;

- Type of construction material – e.g. the code for steel is different from that of timber
- Type of structure – e.g. the code for buildings is different from the code of practice for roads
- Type of loads experienced – e.g. the code for wind loads is different from the code of practice for
- Region – the environmental factors also influence the choice of the code of practice. Additionally, various regions have different codes of practice.

Some of the commonly used codes of practice are;

- BS6399 –Part 1:1996 – for loads on various structures depending on the occupancy
- BS8110 – Part 1:1997 –for the design and construction of reinforced concrete structures
- BS5950 –Part 1:2000 – for the design of rolled and welded steel sections in building construction.
- Eurocodes- these are currently being developed to replace the BS codes.

1.4 Carry out load analysis/estimation as per code procedures

Load estimation is based on the structural elements such as beams, columns, slabs and other elements which are not necessarily structural such as partitions, furniture and finishes. Load estimation also starts with a knowledge of the various types of loads that the structure may experience. The following are categories of loads which can be experienced by a structure.

- Dead loads – these are the permanent elements in the structure. They include the roof, floor, walls,
- Imposed or live loads – these are the temporary elements or components in the structure. They include; furniture, people etc.
- Wind loads
- Earthquake loads
- Snow loads

Dead loads are obtained by multiplying the unit weight of the material used with the volume of the element. Imposed load values are read from BS6399-1:1996 and they depend on the type of occupancy or usage of the structure. Loads analysis can be carried out as follows;

a) Determine the type of structural elements present in the structure – these include beams, columns, slabs etc.
b) Calculate the dead loads (G_k)
c) Calculate the imposed loads (Q_k)
d) Multiply the loads with the safety factors to get the design loads
e) Determine the ultimate design load (W) from the combinations of dead and imposed loads. $W= 1.4G_k +1.6Q_k$
f) Calculate shear, moment and deflection.

Example of Column load calculation

Unit weight of concrete = 24kN/m3
Volume of column = Length (l) x Width (w) x Height (h) x No. of columns
Weight of columns = unit weight x volume

Example of load calculation of a slab

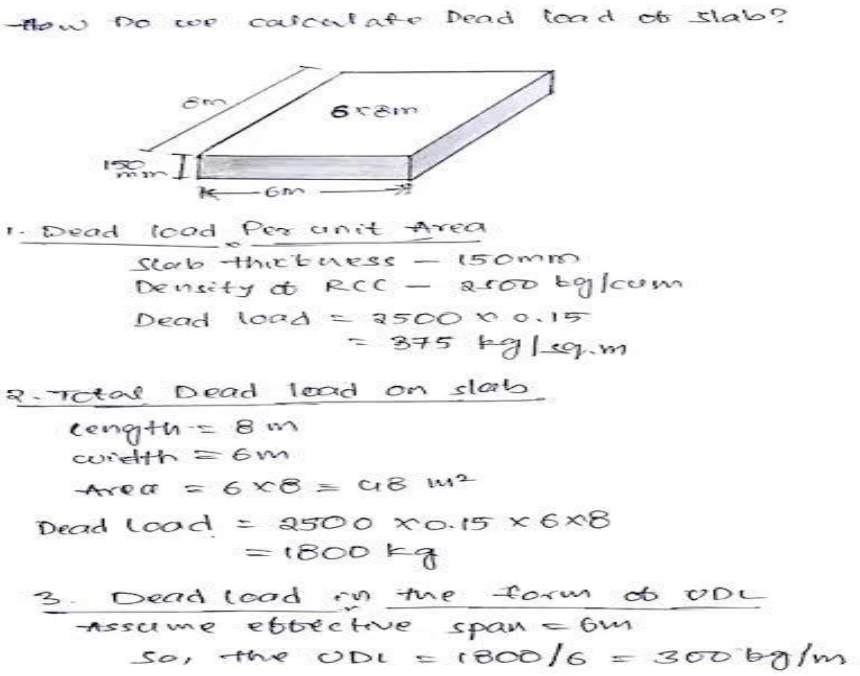

Figure 149: Example of load calculation of a slab
Source: Quora.com

Conclusion

This learning outcome covered codes of practice, creation of different layouts from architectural drawings and load analysis and calculations as per the codes of practice.

Further Reading

Read more on the following;

1. Design loads acting on structural elements
2. Types of structural loads - buildings and other structures(Wind loads, earthquake loads and snow loads)
3. Methods of structural load analysis

14.3.2.3 Self-Assessment

Written Assessment

1. The following are various types of structural layouts except one;
    a) Foundation layout
    b) Beam layout
    c) Floor plan
    d) Column layout
2. Dead load usually comprises of the following, which one?
    a) Temporarily attached loads
    b) Permanently attached loads
    c) Permanent and temporary attached loads
    d) Wind and snow loads
3. Structural loads are of various categories, select the odd one out.
    a) Dead load
    b) Rain load
    c) Live load
    d) Wind load
4. Explain the following different types of loads; dead loads, Imposed loads
5. Evaluate at least four structural elements in a building.
6. Apart from dead and imposed loads, define other types of loads which may be experienced in a building.
7. A code of practice guides the way work should be done. Why were codes of practice developed?
8. According to BS6399-1; 1996 building loads are determined with the type of usage for the building. List the various categories of occupancy listed.

Essay question

Describe the procedure of producing a building structural layout using illustrations.

Oral Assessment

Explain the various existing codes of practice and the applicability in load estimation
What would happen to the loads in a structure in the case the usage of the structure is changed from the original intended use.

Practical Assessment

Visit a nearby construction project site and identify the following structural elements, columns, beams, foundation, and slab. Sketch the layout on a piece of paper and carry out structural load analysis of the various elements.

14.3.2.4 Tools, Equipment, Supplies and Materials

Tools and equipment

- Computers
- Printers
- Measurement tools
- Survey instruments

Materials

- CAD software
- Stationery
- Workstations
- Civil Engineering labouratories
- Legal documents (Engineers Act)
- Civil Engineers Code of Practice

14.3.2.5 References

Allen, A. (2002). Reinforced Concrete Design to BS8110 simply explained. CRC Press.

Chudley, R., & Greeno, R. (2013). Building Construction handbook. Routledge

Hibbeler, R.C., & Kiang, T. (2015). Structural Analysis. Upper Saddle River: Pearson Prentice Hall

14.3.3 Learning Outcome No 2: Design Structural Elements

14.3.3.1 Learning Activities

Learning Outcome No 2: Design Structural Elements	
Learning Activities	**Special Instructions**
2.1 Select design methods 2.2 Determine design software 2.3 Design structural elements	• Demonstration by trainer • Practical work by trainee • Demonstration videos • Projects • Group discussions

14.3.3.2 Information Sheet No14/LO2: Design Structural Elements

Introduction to learning outcome

This learning outcome deals with design methods which are cost effective and design softwares such as AutoCAD Structural Design Software, Prokon, and Revit. The design of various structural elements is also dealt with in this outcome.

Definition of key terms

Design methods- procedures of designing which provide different kinds of activities that someone designing is able to apply during the process of design.

Design software- computer based operating information and programs that aid in the drawing or plan developed to demonstrate the working of a building.

Structural elements- load bearing components of a structure.

Content/Procedures/Methods/Illustrations

2.1 Select design methods based on cost effectiveness and client needs as per code standards

Cost effective design methods are those structural design procedures that require very low cost or no cost at all, while client needs are the specifications of the clients that must be met by the design method while code standards are set specifications preset by structural design organization for uniformity in the field. The coast effective design methods include;

a) Utilization of cost and value engineering

Most of the time projects are not given excess money but money just enough, therefore, all expenses have to fall below budget. Utilizing cost is the management of all these costs. Value engineering is the controlling of the expenses involved so that every one of them falls within the budget

b) Economy analysis for alternative designs

For many industries if not all take this into serious account. Things like operation, maintenance, replacements and investments are looked into prior to the building's design. With time the cost of these things change hence future projections are very important. Understand how the buildings future investments will be rated.

c) Considering priceless gains such as aesthetics, sustainability etc.

Not everything can be bought or charged at a price. Some building features such as formality are not an exception. The main reason of a life cycle assessment is to determine costs and benefits of design other options for better decision-making. Something like cost is easily measurable compared to gain since it has a price on it. Gains have no price attached to them. In some cases, priceless cases are able to come ahead of quantity available cost comparisons.

d) Full analysis and design software;

- Effective and fast design method.
- Each of the members is designed and modeled in one workflow
- Materials, members, forces and section properties can all be accessed automatically from the software model.
- Standards can be preset for reference.

2.2 Determine design software as per organizational standards.

Software as per organization standards are software that meet the specification of procedures or methods of structural design. The organization standards include;

- Accuracy
- Appearance
- Scalability
- Flexibility

The design software that meet these standards include;

1. **AutoCAD structural software-**

A product of Autodesk. Its major application is creation of different dimensional designs, drafting of layouts, modeling workflows etc. It enables you to; evaluate and digest the project performance, responds quickly to changes and maintains data and processes consistently. Some of its advantages include;

- Appearance - drawings are clear, simple to use when reduced (minimized) and predictable.
- Scalability- AutoCAD drawing sheet is enormous thus eliminating scaling error possibilities and also allows the drawing to be printed at any scale.
- Flexibility - work can be shared and distributed electronically

2. **Autodesk Revit structural software**

A product of Autodesk used for modelling and enables design of structures, buildings and components in 3D also allows access to building information from building model data base. Some of its advantages are that it allows modifications on different structures hence flexibility and scalable.

3. **Prokon**
    - Software that allows structural design of elements.
    - Easier and faster input and comprehensive integration.
    - Easier access to detailed analysis output.

4. **SAP2000-** Civil engineering software good for design and analysis of any type of structural system. Looks forward to bring together distinct modules in a company

5. **RISA**-Develops creative structural design and analysis tools to solve most of recent engineering problem.

Some of its advantages include;

- It is fast
- It is productive
- It is accurate
- Has a user-friendly interface that interacts with other products such as RISA foundation.
- It comes embedded with the most recent design codes for steel design, cold-formed steel, concrete design, aluminium, masonry and timber
- Provides needed tools in case of multi material structure

6. STAAD Pro- does structural analysis design and modelling, also provides a user-friendly interface easy to navigate.
    - Easy to use interface

7. Naviswork

A product of Autodesk. This is a comprehensive project review solution. Navisworks is used by design, engineering and construction management professionals. Its use is to obtain detailed insight into the project and enhance productivity and quality.
Some of its advantages include;

- Allows the users to open, combine, review and share detailed design models in various file formats.
- Easy to Import all file formats and merge all the files to create a model

2.3 Design structural elements as per design standards

The procedure of design

i. Determination of loads acting on the structure

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ii. Determination of loads acting on individual elements

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iii. Determination of bending moments, shear forces and deflections

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i. Beam sizing

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ii. Column sizing

Structural elements are load bearing parts of a structure and include;

- Columns
- Wall
- Trusses
- Frames
- Slabs
- beams
- cables

In concrete, steel, timber and masonry.

Factors to understand during structural elements analysis

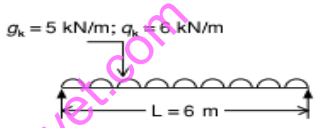
a) Free body diagrams – these are to understand the load path and checking your assessment. Free body diagrams are load and moment diagrams drawn which show the applied loads and moments at an equilibrium with corresponding reaction loads and moments and shear forces.
b) Buckling –this is majorly in columns
c) 3D rigid body analysis - Sometimes this method is used in determination of loads on joints, a classical hand calculation in structural analysis.

Example: design of a beam singly and doubly reinforced rectangular

A simply supported beam for an office building has a span of 6 m. Calculate the values of the design bending moments, $M_{E,d}$, assuming

(a) the beam supports uniformly distributed permanent and variable actions of 5 kNm^{-1} and 6 kNm^{-1} respectively
(b) in addition to the actions described in (a) the beam also supports an independent variable concentrated load of 20 kN at mid-span.

LOAD CASE A



Since the beam is subjected to only one variable action use equation 8.6 to determine E_d where

$$E_d = \sum_{j\geq 1} \gamma_{G,j} G_{k,j} \text{ "+" } \gamma_{Q,1} Q_{k,1}$$

$$\Rightarrow F_{E,d} = 1.35 \times (5 \times 6) + 1.5 \times (6 \times 6) = 94.5 \text{ kN}$$

Hence, $M_{E,d} = \frac{F_{E,d} L}{8} = \frac{94.5 \times 6}{8} = 70.9$ kNm

An alternative estimate of $M_{E,d}$ can be obtained using equations 8.8 and 8.9, respectively

$$E_d = \sum_{j\geq 1} \gamma_{G,j} G_{k,j} \text{ "+" } \gamma_{Q,1} \psi_{0,1} Q_{k,1} \text{ "+" } \sum_{i>1} \gamma_{Q,i} \psi_{0,i} Q_{k,i}$$

$$\Rightarrow F_{E,d} = 1.35 \times (5 \times 6) + 1.5 \times 0.7 \times (6 \times 6) + 0 = 78.3 \text{ kN}$$

$$E_d = \sum_{j\geq 1} \xi_j \gamma_{G,j} G_{k,j} \text{ "+" } \gamma_{Q,1} Q_{k,1} \text{ "+" } \sum_{i>1} \gamma_{Q,i} \psi_{0,i} Q_{k,i}$$

$$\Rightarrow F_{E,d} = 0.925 \times 1.35 \times (5 \times 6) + 1.5 \times (6 \times 6) + 0 = 91.5 \text{ kN (critical)}$$

Hence $F_{E,d}$ is 91.5 kN and $M_{E,d} = \frac{F_{E,d} L}{8} = \frac{91.5 \times 6}{8} = 68.6$ kNm.

Figure 150: Design of a beam singly and doubly reinforced rectangular
Source: Design of structural Elements by Chanakya Arya

Conclusion

This learning outcome covered design methods, design softwares and structural elements.

14.3.3.2 Further Reading

Read on:

1. Design of Structural Elements
2. Stress analysis https://www.stressebook.com/classical-hand-calculations-in-structural-analysis/
3. Whole Building Design Guide https://www.wbdg.org/design-objectives/cost-effective

14.3.3.3 Self-Assessment

Written Assessment

1. Of the following which one is not a structural design element?
    a) Train
    b) Truss
    c) Arch
    d) Cables
2. From below which structural design software has the highest rating
    a) AutoCAD
    b) Prokon
    c) Revit
    d) Miniso
3. Select a design method which is not cost effective
    a) Free Software
    b) Spreadsheets
    c) Hand calculation
    d) Charged software
4. Define the term structural design
5. Explain scalability of a design software
6. Give two advantages of Prokon design software

Essay questions

AutoCAD adheres to organization standards, elabourate.

Oral Assessment

Why would you choose Revit if you are given a structural design project?

Case Study Assessment

Kenyatta University intends to expand the school of engineering building another workshop. The civil engineering in charge has selected you as his assistant and has given you a sketch of the building and told you to present it to the board during the launch of construction to all board members. Select the most appropriate software to use to present the design and give reasons why and also design the elements of construction for the steel frame.

Oral Assessment

Why would you need to analyse different design methods before choosing the one to use?

Practical Assessment

Using AutoCAD design a three-floor building with a 300 people carrying capacity

14.3.3.4 Tools, Equipment, Supplies and Materials

Tools and equipment

- Computers
- Printers
- Measurement tools
- Survey instruments

Materials

- CAD software
- Stationery
- Workstations
- Civil Engineering labouratories
- Legal documents (Engineers Act)
- Civil Engineers Code of Practice

14.3.3.5 References

Arya, C. (2009). Design of structural elements: concrete, steelwork, masonry and timber designs to British standards and Eurocodes. CRC Press.

Lurie, K. A., & Cherkaev, A. V. (2018). “Effective Characteristics of Composite Materials and the Optimal Design of Structural Elements. In Topics in the mathematical modelling of composite materials (pp. 175-271). Birkhäuser, Cham.

Mazars, J., Kotronis, P., Ragueneau, F., & Casaux, G. (2006). Using multifiber beams to account for shear and torsion: Applications to concrete structural elements. Computer Methods in Applied Mechanics and Engineering, 195(52), 7264-7281.

14.3.4 Learning Outcome No 3: Assess Cost Effectiveness of the Design

14.3.4.1 Learning Activities

Learning Outcome No 3: Assess Cost Effectiveness of the Design	
 **Learning Activities**	**Special Instructions**
3.1Determine alternative cost saving design methods and materials 3.2 Review preliminary designs to determine elements that can be reduced or replaced	• Demonstration by trainer • Practical work by trainee • Demonstration videos • Projects • Group discussions

14.3.4.2 Information Sheet No14/LO3: Assess Cost Effectiveness of the Design

Introduction to learning outcome

This learning outcome deals with cost saving design methods and optimization of the design cost by either replacement or reduction of some elements.

Definition of key terms

Cost effective design: this is a plan that is affordable and efficient.

Content/Procedures/Methods/Illustrations

3.1 Determine alternative cost saving design methods and materials based on site conditions

Cost effective design methods are those structural design procedures that require very low cost or no cost at all likewise to the materials in this case we look at those based on site condition which are mostly harsh weather conditions like rainy or sunny. They include;

a) The process of design;

The advice you seek from consultancy firms play an important role in the reduced cost of your building. Websites provide affordable designs for buildings. It will enable you to obtain a proper design within what you can afford within limited time.

b) Application of technology;

The latest technologies like the use of renewable energy which are maximumly affordable and keep buildings cost effective. They don't make your building dismal but purpose is more important and you don't have to go bankrupt.

c) Location selection

Where you choose to build your building will determine the cost you incur in designing the building. A higher percentage of this is true among commercial buildings. For example, the right selection of a commercial property location influences the final outcome positively as this makes it easy to estimate the traffic load in order to correctly arrange the layout of the property. Therefore it is possible to start the process of designing a cost-effective building design before the actual blueprints have been initialized.

d) Orientation of the building

Orientation of building is in terms of the position of sunlight at various times of the day. Buildings are designed around the movement of the sun over an area. Most of the activities are planned in sections where the intensity of the sun is not high.The same way, sections that have limited interactions are designed to be in areas where the sun is intensified. This orientation helps create buffer zones between the sections thus keeping spaces with more activity cooler in a passive way.

e) Plan Layout

When properly done can really sell out. A proper layout helps obtain affordable building specifications. For example; if the west side of your structure will be subject to high sunlight throughout the day, it will be unthoughtful of you to put the kitchen on this side otherwise you will need engineered cooling methods, that will rather be expressive. Therefore, placing on the eastern part will be more logical

f) Wall Cladding

The physical appearance of a building is enhanced with the walls of the structure. How long the structure will last will be determined by the durability of the materials that make up the walls. In this manner a low temperature is maintained in the room by insulating walls. Proper wall cladding will enable a big difference in maintaining the running cost of your establishment to the minimum. For cost-effective building design, wall cladding play a very important method.

g) Roof Materials

Just like the wall, the roof details are very vital when it comes to creating a cost-effective building design. How long the structure will last will be determined by the durability of the materials that make up the roofing materials as well.

h) Interior design and interior furniture

Interior design can entail small details that can make the design quite expensive. Some simple interior design rules can help make a cost-effective building design.

i) Sourcing Materials

Understanding where to get the best, low cost materials will sky rocket you career in building and construction. Beware of high-end places that give poor quality materials at very high prices. Carry out research concerning all the places where you can get materials before decide on one final choice

j) MEP & HVAC

The selection of MEP (Mechanical, Electrical and Plumbing) and HVAC (Heating, Ventilation and Air Conditioning) is crucial in determination of the overall cost of the design process. However, high quality systems can make a building costs much lower as compared to low quality systems. The following should be considered in the selection of such systems.

- System should have an efficiency of more than 90%
- Ensure no energy is wasted by choosing the right size
- Adaptability of the system to future extensions, choose a system that is adaptable

3.2 Review preliminary designs to determine elements that can be reduced or replaced as per design standards

This is referred to as design optimization technique which simply means using available resources to obtain maximum benefit. Factors to be considered while doing optimization include;

- Model of structure
- Dimensionality of structure
- Choice of design variable.

Problems encountered also include;

- Sizing optimization-boundary and connectivity
- Shape optimization - area
- Topology optimization.

The main components of optimization include;

- Design parameters- specify the geometry and topology of the structure and also the physical parameter of the structural elements like area etc.
- Constraints which includes stress, buckling, deflection etc
- Object functions which merit the structure; if the fiction is something like weight of the structure then it is to be minimized, if its energy or thermal requirement then it is to be maximized if both then it will need balance. This equation is solved mathematically.

Conclusion

This learning outcome covered cost saving design methods.

Further Reading

 Read on:

1. Cost saving design methods
2. Structure and design https://comelite-arch.com/blog/cost-effective-building-design-solutions/

14.3.4.3 Self-Assessment

Written Assessment

1. From below, choose the odd on out
    a) Topology optimization
    b) Constraints
    c) Design parameters
    d) Object function
2. The following are factors which influence design optimization except one, which one?
    a) Design variable choice
    b) Structure type
    c) Dimensionality of structure
    d) Shape
3. The following are design constraints except which one
    a) Deflection
    b) Weight
    c) Buckling
    d) Stress
4. Evaluate alternative cost saving design methods and materials based on site conditions.
5. Summarize the problems encountered during design optimization.
6. Summarize the factors that contribute to design optimization.

Essay questions

Design optimization is a complicated process. Elabourated.

Oral Assessment
Why do you think design optimization is important in structural design?

Case Study Assessment
A proposed structural design was found to be very expensive compared to the normal average design of such a building during engineers review meeting. If you are awarded with the duty to optimize the design. Outline the factors you will consider and the modules you will maximize or minimize during the process.

Oral Assessment
Of the fundamental modules of design optimization, explain what design parameters represent

Practical Assessment
Your class is to visit a nearby construction sites and recognize the cost saving design methods and materials based on site conditions present in the site.

14.3.4.4 Tools, Equipment, Supplies and Materials
Tools and equipment

- Computers
- Printers
- Measurement tools
- Survey instruments

Materials

- CAD software
- Stationery
- Workstations
- Civil Engineering labouratories
- Legal documents (Engineers Act)
- Civil Engineers Code of Practice

14.3.4.5 References

Thanedar, P. B., & Vanderplaats, G. N. (2005). Survey of discrete variable optimization for structural design. Journal of Structural Engineering, 121(2), 301-306.

Koski, J. (2000). Multicriterion optimization in structural design. TAMPERE UNIV OF TECHNOLOGY (FINLAND).

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14.3.5 Learning Outcome No 4: Modify Structural Designs

14.3.5.1 Learning Activities

Learning Outcome No 4: Modify Structural Designs	
 **Learning Activities**	**Special Instructions**
4.1 Modify preliminary designs to suite site conditions 4.2 Retest preliminary hypotheses for practicality to site conditions 4.3 Establish new hypotheses to support new designs and reflect site conditions	• Demonstration by trainer • Practical work by trainee • Demonstration videos • Projects • Group discussions

14.3.5.2 Information Sheet No14/LO4: Modify Structural Designs

Introduction to learning outcome

This learning outcome deals with modification of preliminary designs to suite site conditions, retesting of hypotheses for practicability to site conditions with the establishments of new hypotheses to support new designs.

Definition of key terms

Preliminary design: Gerson Sunyé - University of Nantes Definition of Preliminary Design is the first step of software design. During this phase, a high-level design concept that meets the requirement specification is created. The concept is expressed as a set of components with clear interfaces. The preliminary design fills up the void between conception of the design and the detailed design.

Content/Procedures/Methods/Illustrations

4.1 Modify preliminary designs to suite site conditions as per code of practice standards.

The Preliminary design stage is the most low-cost and applicable stage to make design changes such as modifying design variables. These changes therefore should conform to the code of practice standards and suite the site conditions provided. Modification of these preliminary designs may be influenced by either internal or external factors of the project at hand.

Some of the internal factors influencing such changes include:

Factors from the client:

- Client's wish to modify or change the design.
- Additional work.
- Omission of work.
- Financial difficulties from the client.
- Errors due to incorrect information.

Factors from the design consultant:

- Insufficient information in the drawings.
- Alterations made as per the consultant's request.
- Presence of conflicts that may arise due to the contract.
- Illogical period of project completion.
- Significant variations in the structural and architectural plans.

Factors from the managing consultant:

- Miscommunications between members I the project.
- Lack of accurate resolutions.
- Lack rapid formulation and execution of resolutions.
- Improper checking of planning documentation.

Factors from the contractor:

- Illogical construction schedule from the contractor.
- Correction of construction and structural mistakes.
- Alterations made as per the contractor's request.
- Inadequate project management by the contractor.
- Quality improvement change by the contractor.

Some of the external factors influencing such changes include:

Factors due to the environment:

- Unexpected conditions in the ground.
- Lack of enough data about the geological composition of the site.
- Natural occurrences disasters.
- Unpredicted weather changes.

Economic and political factors:

- Lack of enough tools and materials.
- Changes in material pricing due to fluctuation.
- Changes in the original use of the project.
- A change in policy.

Factors due to third party:

- Alterations made as per the end user request.
- Grievance from the vicinity.
- Alterations made as per the regulation bodies request.
- Alterations made as per the new investor's request.

4.2 Retest preliminary hypotheses for practicality to site conditions as per design standards.

Retesting of the preliminary hypotheses is quite critical in the design process for many various reasons and therefore the hypothesis should be practical to the site conditions and as per the design standards.

Some of the importance of testing include:

- It enables one to determine whether the hypotheses being tested are true.
- It enables to determine whether the proposed solution will achieve the goals targeted.
- It enables the enhancement of the design process.
- To determine whether the hypothesis will guarantee an improvement for further progress.

During the process of retesting of hypotheses, some of the steps involved will include:

- Stating of the hypotheses including both null hypothesis and alternative hypothesis.
- Formulation of the analysis plan that will include both the test method and the significance levels.
- Analyzing of the sample data.
- Interpreting of the results to draw conclusion.

4.3 Establish new hypotheses to support new designs and reflect site conditions as per the required conditions.

In order to establish a new hypothesis one can follow the steps below:

- Coming up with a question that is specific and is within the constraints of the project.
- Conduct preliminary research that will lead to a conceptual framework.
- Formulate and refine the hypothesis according the relevant variables of the project and the predicted outcome.
- Phrase the hypothesis in three ways.
- Write a null hypothesis

Conclusion

This learning outcome covered the modification of preliminary designs to suite site conditions and the application of hypothesis to test the practicability of the site conditions.

Further Reading

Refer to Admin, How to Write a Hypnosis, https://www.scribbr.com/research-process/hypotheses/, last accessed 24th June 2020. For further reading on how to write a hypothesis.

14.3.5.3 Self-Assessment

Written Assessment

1. In which stage of a project is the modification of structural designs relevant.
    a) Project conception
    b) Construction stage
    c) Detailed design stage
    d) Preliminary design stage
2. Explain the preliminary design stage in the most low-cost and relevant stage in the modification of structural designs.
3. Modification of preliminary designs to suite site conditions should conform to?
    a) An educated guess
    b) Code of practice standards
    c) Profits of the project
    d) Personal interest only
4. Explain the term hypothesis?
5. Explain the term preliminary design?
6. Explain the different components found in a preliminary design.
7. Summarize on the importance of retesting of a preliminary hypothesis.
8. Summarize on the steps taken to test a hypothesis.

Oral Assessment

Outline the need to modify structural designs.

Practical Assessment

Given the project of the construction of a single storage room, with initial site conditions and preliminary design of your choice. Modify the preliminary design given that the site conditions change due to a 50% reduction in the available land for the construction of the project.

14.3.5.4 Tools, Equipment, Supplies and Materials

Tools and equipment

- Computers
- Printers
- Measurement tools
- Survey instruments

Materials

- CAD software
- Stationery
- Workstations
- Civil Engineering labouratories
- Legal documents (Engineers Act)
- Civil Engineers Code of Practice

14.3.5.5 References

Admin, How to Write a Hypnosis, https://www.scribbr.com/research-process/hypotheses/last accessed 24th June 2020.

Bang, Anne & Krogh, Peter & Ludvigsen, Martin & Markussen, Thomas. (2012). The Role of Hypothesis in Constructive Design Research.

Admin, How to Test Hypotheses, https://stattrek.com/hypothesis-test/how-to-test-hypothesis.aspx, last accessed 24th June 2020.