CHAPTER 12: BASIC PAVEMENT STRUCTURES

12.1 Introduction of the Unit of Learning

This unit specifies the competencies required to design basic pavement structures. It involves conducting site visit, designing highway drainage and hydraulic structures, designing road geometrics, designing pavement structure, designing pedestrian and cyclist path and designing for road furniture.

12.2 Performance Standard

Conduct site visit, design highway, drainage and hydraulic structures, road geometrics, pavement structure, pedestrian and cyclist paths, and road furniture based on contract documents and standard procedures.

12.3 Learning Outcomes

12.3.1 List of Learning Outcomes

a) Conduct site visit
b) Design highway, drainage and hydraulic structures
c) Design road geometrics
d) Design pavement structure
e) Design pedestrian and cyclist paths
f) Design road furniture

12.3.2 Learning Outcome No 1: Conduct Site Visit

12.3.2.1 Learning Activities

Learning Outcome No 1: Conduct Site Visit	
Learning Activities	**Special Instructions**
1.1 Determine pavement location 1.2 Undertake preparation for site visit 1.3 Collect ***On site data***	• Direct instruction • Case studies • Field trips/site visits

12.3.2.2 Information Sheet No 12/LO1: Conduct Site Visit

Introduction to learning outcome

This learning outcome covers preliminary site visit, data collection methods, tools and equipment for data collection, collection of onsite data and determining pavement location.

Definition of key terms

Datum points: Are landmarks and heights from which all other heights and levels are measured.

Road reserve: An area of land set aside for potential construction of roads, for which construction is not permitted.

Settlement: Downward motion of the ground due to traffic loading.

Content/Procedures/Methods/Illustrations

1.1 Determine pavement location based on contract documents.

This is the process of identifying the most feasible location of a pavement i.e. a surfacing of a road, footpath, airstrip etc. A pavement transmits loads such as traffic loads, to the underlying soil. Pavements can either be flexible or rigid. In the case of flexible pavements, the surface is usually applied in two layers-the base course and wearing the course, with the base course and the extension of the road base layer, but providing a regulatory course on which the final layer is applied. In the case of rigid pavements, the structural function of both roadsides and the surface layers are built into the concrete slab approaching their workstations where they will provide the stipend and budget as well as those having expertise in the area.

The location of the site is described in the various specifications.
The site of the works shall be the area within the various road reserves, spoil areas, access roads and deviations, contractor's installations, storage areas, camp sites,

Engineer's offices, labouratories and accommodation, shown on the drawings or established specifically for the contract with the approval of the engineer.

Selecting the location of a proposed pavement is an important initial step in the design process.

Factors Affecting Choice of a Pavement location

The choice of location is usually based on:

- Usage: The traffic loading in terms of usage of a pavement determines its location.
- Topography; terrain of a place affects the cost as well as the ease of construction of a pavement which in turn affects its location.
- Soil characteristics; Different soil types have different characteristics; some soil types may exhibit favorable characteristics while other types such as expansive soils like clay may be unfavorable in terms of providing a stable foundation.
- Environmental factors such as noise and air pollution; Environmental pollution such as noise and air are an important factor when deciding the location of a pavement. Pavements are located away from residential areas as per standards due to their contribution.
- Economic factors; the cost of constructing a pavement is a core factor in deciding locations of pavements. The most economical designs of pavements are normally selected depending on location selected.

The process of positioning the pavement involves four processes as per contract documents as follows

i. Conducting an Office Study of Current Information on the pavement; this allows for a study on the available data and specifications required for the positioning of a pavement.
ii. Conducting a Recognition survey: This is conducted by carrying out a pre-visit to the selected locations.
iii. Conducting a Preliminary location survey: The survey of the possible locations identified for the pavement will help in determining their feasibility.
iv. Conducting a Final survey of the location identified: From the preliminary survey conducted a feasibility report is prepared and the location selected is surveyed in order to gather more data on the pavement location.

1.2 Undertake preparation for site visit as per contract document

Site Visits are a component of the contract documents. These include visiting the site where you are hoping to deploy your services for the purpose of obtaining in-depth information on the pavement. The procedure to be followed deals with a number of items that should be considered when preparing for visits to the actual and virtual site as per contractual documents.

Steps Undertaken in preparation for site visits

Step 1: desk study

This involves obtaining and reviewing documents relating to the pavement.

Useful sources of information for desk duty

- Geographical maps, including historical maps, can provide information on topography, drainage and the site 's former uses
- Geological maps may show the possible conditions on the ground and, for example, whether there is a possibility of subsidence or shear.
- Aerial photography records and Google maps provide valuable information to help recognize or validate past use of the site, unknown structures, and topographical and river course adjustments.
- Records of utilities can help to identify hidden utilities such as: power cables, irrigation, telephone cables.
- Past inquiries, estate record sketches

Step 2

- List all matters to be dealt with during the site visit in advance.
- Obtain all necessary equipment such as safety kits and any required procedures agreed upon.
- Note in advance all relevant issues, such as weather conditions, plant and equipment locations, measurements, etc.
- Revisit the matters to be dealt with during the site visit

Step 3

This stage includes a physical visit to the site, making observations and taking photographs of the conditions of the site.

The site conditions include general topography, access to rigs, geological features, land use conditions and water flow.

Step 4

Prepare a report from the site visit from the observations noted. Recommended items for a site visit:

- Field book
- Maps
- Sturdy boots
- Tape measure
- Reflective vest and hard hat
- Digital camera
- Introduction letter from your department in order to avoid conflicts.

Importance of undertaking preparation for site visits

- Assessing the ground conditions for the pavement to be designed
- To give prior knowledge and experience to the designing team
- To get a better understanding of the project.

1.3 Collect *On site data* (Datum points, Settlement, Natural features, Soil type, Water catchment areas, Accessibility of utility services, Land marks, Road reserve) according to standard procedures

This is the process of gathering data in order to enhance the implementation of the different types of pavements. On site data collection is an important step when designing different types of pavements. The data collected is helpful in the design process as the Engineer is able to understand site conditions and therefore design pavements according to specifications and standard procedures such as AASHTO Standards.

Factors that affect on-site data collection

Some of the factors that may affect the quality of data are but not limited to:

- Availability of tools and equipment; the availability of the right tools as per the standard specifications is an important factor.
- Weather; Adverse weather conditions may deter the data collection activity
- Cost; Data collection must not be an expensive activity.
- Bias- certain demographic factors such as the type of person collecting data may affect its quality. It must always be ensured that the person collecting data is an ethical profession in this field.

The methods used for data collection include and are not limited to; conducting surveys, sampling, observations and experiments.

Steps considered for on-site data collection

i. Identify the data element to be collected and determine the necessary tools needed for data collection.
ii. Determine the data collection procedure for the specific element as per the standard procedures.
iii. Conduct a site visit with the necessary tools and equipment and do the on-site data collection as per the specification used.

Conclusion

This learning outcome covered preliminary site visit, data collection methods, tools and equipment for data collection, collection of onsite data and determining pavement location.

Further Reading

Read more on the standard specifications for pavement design used in Kenya

12.3.2.3 Self-Assessment

Written Assessment

1. From the following choices choose the data collection methods
    a) Surveys
    b) Interviews
    c) Experiments
    d) Questionnaires
2. The following is a list of data collection tools, identify the tool that's not appropriate
    a) Camera
    b) Book
    c) Computer
    d) Calculator

3. Choose a step which is not part of determining pavement location based on contract documents.
    a) List all matters to be dealt with during the site visit in advance.
    b) Obtain all necessary equipment such as safety kits and any required procedures agreed upon.
    c) Determine the data collection procedure for the specific element as per the standard procedures.
    d) Determine the data collection procedure for the specific element as per the standard procedures
4. Select the correct answer from the following
    a) Road reserve- An area of land set aside for potential construction of roads, for which construction is not permitted
    b) Road reserve-An area of land set aside for potential construction of roads, for which construction is permitted
    c) Road reserve- An area of land set aside for construction, for which potential construction of roads is not permitted
    d) Road reserve- an area that has been set aside for construction of drainage features
5. On site data may include but are not limited to all the following. Select the best answer?
    a) Datum points, Settlement, Natural features, Soil type
    b) Datum points, road reserve, Natural features, Soil type
    c) Accessibility of utility services, roads, waterways
    d) Land marks, Road reserve, datum points, vehicles
6. Define Datum point
7. State four data collection methods
8. What is a preliminary site visit?
9. State the six tools and equipment used for data collection
10. Discuss how to conduct a preparation for a site visit as per contract documents

Practical Assessment

Using the knowledge that you have gained, conduct a site visit to a location where a pavement is being constructed and do data collection with the help of your lecturer.

Oral Assessment

State how you conducted the site visit according to the standard specifications.

12.3.2.4 Tools, Equipment, Supplies and Materials

- Computers
- Software
- Cameras

- Construction manuals
- Projectors
- Flip charts
- Calculators
- Rulers, pencils, erasers
- Charts with presentations of data
- Drawing sheets
- Internet
- Relevant videos

12.3.2.5 References

Garber, N. J., & Hoel, L. A. (2020). Traffic and highway engineering. Cengage.
Rogers, M. G., & Enright, B. (2016). Highway engineering. Chichester: Wiley-Blackwell.

12.3.3 Learning Outcome No 2: Design Highway, Drainage and Hydraulic Structures

12.3.3.1 Learning Activities

Learning Outcome No 2: Design Highway, Drainage and Hydraulic Structures	
Learning Activities	**Special Instructions**
2.1 Conduct a preliminary site visit 2.2 Estimate the surface run-off 2.3 Design highway drainage structures 2.4 Design bridges 2.5 Design drifts and causeways 2.6 Design retaining walls 2.7 Determine construction materials	• Case studies • Field trips/site visits • Discussions

12.3.3.2 Information Sheet No 12/Lo 2: Design Highway, Drainage and Hydraulic Structures

Introduction to learning outcome

This learning outcome covers hydrology and hydraulic engineering, establishment of longitudinal sections of a river, determination of water levels of a river and location of highway drainage sites.

Definition of key terms

Water catchment area: This is an area from which the natural environment receives water. In a catchment, rainfall and runoff water ends up flowing into the groundwater system or into a water body. In a catchment, human and natural systems such as animals, streams, fields, houses, plants, dams and humans can co-exist.

Surface run-off: Surface runoff is the flow of water that occurs above the ground. This flow happens when the soil is completely saturated and the rainfall intensity is greater than infiltration rate. Surface runoff frequently occurs in impermeable areas (such as roofs and paving) that do not allow water to soak into the soil.

Slope: Watershed slope is total elevation change divided by hydrologic length.

Content/Procedures/Methods/Illustrations

2.1 Conduct a preliminary site visit

Preliminary site investigation is the first step of a site investigation that includes gathering information on site-specific features that may need to be addressed during planning, design and construction, or problems that might require more thorough physical investigations.

Purpose of preliminary site investigation

- Offers an initial understanding of the features of a site or region.
- Provides early detection of site features and possible threats, so that they can be handled more effectively.
- Informs the details, scope and methodology of the investigations that follow.
- May help prevent excessive, expensive or intrusive inquiries.

A preliminary site investigation takes place in two steps: a desk study and a site visit.

Procedure for preliminary site investigation

Step 1: desk study

This step involves obtaining and reviewing documents relating to the site.

Useful sources of information for desk duty

- OS maps, including historical maps, can provide information on topography, drainage and the site 's former uses
- Geological maps may show the possible conditions on the ground and, for example, whether there is a possibility of subsidence or shear.
- Aerial photography records and Google maps provide valuable information to help recognize or validate past use of the site, unknown structures, and topographical and river course adjustments.
- Records of utilities can help to identify hidden utilities such as: power cables, irrigation, telephone cables.
- Past inquiries, estate record sketches

Step 2: Site visit

This stage includes a physical visit to the site, taking observations and pictures of the conditions of the site and the performance of other surrounding projects. The conditions of the site include general topography, access to the rigs, geological features, conditions of land use and water flow. Usually, preliminary site investigations will be supplemented by more thorough physical inspections to identify areas where more information is needed, or where unique questions are posed.

2.2 Estimate the surface run-off

Estimating and evaluating surface runoff is an important and relevant concern of hydrological and geographic research. Runoff is a significant factor in flood analysis, soil erosion and other hydrological hazards.

Methods of estimating surface runoff

- Rational Method
- Curve Number Method

Curve Number Method

This method is a commonly used, easy and efficient method to calculate the quantity of runoff in a given area. Annual runoff values can be determined from this method. The requirements for this approach are very small. The value of curve number depends on the land use, hydrological group of soils and hydrological condition of the region. The general equation to obtain volume of runoff using this method is:

$$Q = \frac{(P-I_a)^2}{(P - I_a) + S} \qquad (1)$$

Q = runoff (in)
P = rainfall (in)
S = potential maximum retention after runoff begins
I_a = initial abstratctions

$$I_a = 0.2\,S \qquad (2)$$

$$Q = \frac{(P - 0.2\,S)^2}{(P + 0.8\,S)} \qquad (3)$$

$$S = \frac{1000}{CN} - 10 \qquad (4)$$

Figure 126: quantity of runoff
Retrieved from https://engineering.purdue.edu

Values of the runoff curve numbers for typical land cover characteristics and a category of hydrological soils can be obtained from the United States Department of Agriculture.

Rational method

This method is the most common and easiest way of calculating surface runoff in the basin. The general equation for this method is given by

Q=ciA

Q = discharge (cumecs)

c = runoff coefficient

i = rainfall intensity, mm/hour

A = drainage basin area, acre

The runoff coefficient c is dependent on the drainage basin slope and soil type. The Rainfall intensity i, is obtained from rainfall duration /intensity curves for the particular geographical region.

2.3 Design highway drainage structures as per the design manuals and procedures

The objective of road drainage design is to remove the energy produced by flowing water. As their velocity increases, the destructive capacity of moving water also increases. Water must therefore have a velocity that minimizes wear along the drains.

Procedure for design of drainage structures

The commonly used equation for open channel flow design is the manning equation. This was developed in 1889 by the Irish mathematician Robert Manning. The Manning equation is based on uniform flow in open channels and it depends on roughness, slope and flow area. The general manning's equations is:

$V = \frac{k}{n}(\sqrt[3]{A/P})^2\sqrt{S}$

V = velocity (ft/s, m/s)

k = 1.0 for SI units and 1.49 for English units

n = Manning coefficient of roughness

S = slope (ft/ft, m/m)

Pw = wetted perimeter (ft, m)

A = cross sectional area of flow (ft^2, m)

Manning's roughness coefficients for various surfaces are tabulated and are given as a range.

Factors that affect n-values

- Silting / scouring
- Obstruction
- Surface roughness
- Shape of channel
- Vegetation

2.4 Design bridges as per the design manuals and procedures

A bridge is a structure that carries either a road or railway over an obstacle such as a river.

Figure 127: Example of a bridge, Nyali Bridge

Source: https://constructionreviewonline.com

Types of bridges

- Arch bridge
- Slab bridge
- Truss bridge
- Beam bridge
- Cable stayed/suspended bridge

Procedure for bridge design

Step1: Evaluating the Purpose of the bridge

In the process of design, the first significant step is understanding the purpose of the structure. Otherwise the design will end up being unbeneficial. The design team need to understand the bridge's purpose to ensure a design that is feasible, functional, and economical.

Step 2: Load Determination

The next step of design is the determination of the possible loads expected to act on the bridge. These loads are dependent on the function and location of the bridge. In design, engineers consider three categories of loads: dead loads, environmental loads and live loads:

- Dead loads include the self-weight and all other fixed components of the bridge, such as guardrails, road signals or road surfaces.
- Live loads- these include vehicles
- Environmental loads –these result from environmental factors such as wind and earthquakes.

Step 3: Load Combinations

To achieve the task of load combination, engineers use many methods. UBC and ASCE are the two most popular methods. The building code BS 5400 used in Kenya defines five different combinations of loads. With this approach, design planning uses the load combination which produces the most critical impact or highest load. In Kenya, the most common load combination includes dead load, live loads and wind load and in some cases earthquake loads depending on the location.

Step 4: Determination of Member Sizes

This step is conducted after the load combinations have been determined by the engineer. Depending on the loads the size of the members is determined. These members include beams (girders) and columns (piers. These members are designed separately suing different design techniques.

2.5 Design drifts and causeways as per the *design manuals* (Ministry of Works road design manuals, AASHTO Standards) and procedures

Drifts are essential structures, and can be the lowest type of construction of watercourse crossing. Drifts effectively provide a firm surface on which vehicles can pass a waterway on condition that the water level is low enough. Drifts are typically the most suitable option from an economical and technological point of view when big, normally dry rivers have to be crossed.

Procedure for drift design

i. On rivers with spans equal to or greater than 50 m and on rivers with spans of less than 50 m, the drift approach roads should be extended by 10 m on either side of the riverbank. The approach road should be built above the amount of flooding experienced to avoid damage at the end of the road when the floods are high.
ii. The foundations should have a minimum width of 500 mm, and a construction depth of 250 mm.

iii. Walls should have thickness of 300 mm. Depending on the volume of traffic and the typical load, the top slab, should have a thickness of 150-200 mm.
iv. The drift should be packed with hard-core material and compacted on sandy riverbeds to a maximum depth of 1 m, and 0.6 m on rocky riverbeds.
v. The foundations, walls, and slab should be bound together rigidly to provide maximum resistance to floodwaters being swept away by the drift. Depending on the form and amount of the expected traffic the width of the pavement slab will vary between 3 and 5 m.
vi. The drift height over the current riverbed should be a maximum of 1 m to ensure sufficient depth for upstream sand and water accumulation.

2.6 Design retaining walls as per the design manuals and procedures

A retaining wall is a structure designed and constructed for the purpose of withstanding lateral ground pressure and supporting soil materials. The lateral pressure comes from liquid pressure and the filling of soil

Types of retaining walls

- Gravity retaining wall
- Anchored retaining wall
- Cantilevered retaining wall
- Sheet piling retaining wall

Procedure for design of Retaining Walls

Calculate all loads applied. These include soil stresses, axial, wind, and surcharge loads.

i. Design the stem. Usually, this is a trial and error procedure. Design starts at the bottom of the stem where there's maximum moment and shear.
ii. Calculate overturning moments. These are calculated around the footing toe. An overturning factor of safety of at least 1.5 is considered standard
iii. Based on the assumed footing distance, measured around the front edge of the footing, compute resisting moments.
iv. Check sliding. A safety factor of 1.5 or more for the sliding is conventional. To achieve an accepted safety factor for sliding, an adjustment of footing depth is required.
v. Calculate the eccentricity of total vertical load based on an appropriate factor of safety against overturning.
vi. Calculate the toe and heel soil pressure. If the eccentricity, e, is > B/6, calculate another value of B
vii. Design moments and shear for footing. Pick reinforcement.

2.7 Determine construction materials

In road construction, a broad range of materials are used. These materials include soils), aggregates, bituminous materials and cement. The use of certain construction materials is dependent on their cost and availability.

Types of construction materials

1. **Soils**

Soil is the major material for many civil engineering construction projects such as the subgrade or even pavement for lower class. Soils serves as an embankment material for roads built on higher levels such as overpasses. Moreover, soil serves as foundation materials in many highway projects. For effective use of soils, they need to be are classified into a given system according to certain principles. A soil classification system groups different types of soil based on specific characteristics such as texture and gradation. The common systems used for general engineering classification of soils are:

- AASHTO Soil Classification System
- Unified soil classification system (USCS)

2. **Aggregates**

Mineral aggregates are the most significant materials used in construction of roads. Aggregates such as gravel are obtained naturally from disintegration of rocks. Other types of aggregates are manufactured. An example of this type of aggregate is blast furnace slag. To a highway engineer, the knowledge of the sources and types of aggregates, their evaluation and properties is of utmost importance. In general, aggregates are a widely sued construction material. Desirable properties of soil aggregates used the construction of road are:

- Strength
- Hardness
- Toughness
- Shape
- Texture

3. **Bituminous materials**

Bituminous materials or asphalts are a commonly used construction material in Kenya. This is because the materials are of relatively low cost and have excellent binding and waterproofing properties. Bituminous materials contain bitumen, which is a cementitious substance that can occur naturally or be manufactured. Bitumen is composed primarily of high molecular weight hydrocarbons. Bitumen is manufactured from crude petroleum through distillation

Different forms of bitumen

- Asphalt / bitumen cutback – these are also known as liquid asphalt and is obtained by dissolving bitumen in a distillate
- Bitumen Emulsion- A mixture in which asphalt cement is separated into globules in water containing an emulsifying agent.
- Straight run bitumen- This is bitumen manufactured from short residue this bitumen has a high viscosity.

4. Cement concrete

Cement concrete is a flexible commodity that has revolutionized civil engineering. A well-designed cement concrete provides a solid, stable and resilient pavement after setting and hardening after curing. A cement concrete pavement is able to resist repeated impacts from wheel loads, withstand adverse environmental conditions and its construction cost is relatively low.

Desirable properties of Cement Concrete

Workability

This is a property of fresh concrete and is defined as ease of placement. The workability of concrete is assessed using the slump test. A workable cement concrete mix allows the pavement to be easily placed and compacted. Dry mixes with a slump of 0-25 are used in road making.

Conclusion

This learning outcome covered the design of highways, drainage and hydraulic structures.

Further Reading

For further understanding of pavement construction refer to Ritter, L., Paquette, R., & Wright, P. (1987). Highway engineering. Chichester: Wiley

12.3.3.3 Self-Assessment

Written Assessment

1. How many soil classification systems are used in Kenya?
    a) 1
    b) 2
    c) 3
    d) I don't know
2. Which is not a desirable property of aggregates
    a) Strength
    b) Toughness
    c) Workability
    d) Texture
3. Which load is not considered in design of bridges in Kenya?
    a) Dead load
    b) Wind load
    c) Snow load
    d) Live load
4. Rational formulae for estimation of surface runoff is Q= ciA. where C is _____
    a) Runoff coefficient
    b) Roughness coefficient
    c) Curve number
    d) I don't know
5. Which among the following represents hydraulic radius in the manning's formula?
    a) Rh
    b) S
    c) V
    d) kn
6. List the three types of bitumen
7. What is the difference between a drift and a causeway?
8. List two methods used to estimate surface runoff
9. What is workability of concrete?
10. Discuss on the design procedure for bridges

Oral Assessment

Why do we conduct preliminary site investigations?

Practical Assessment

Using the knowledge gathered in class. Conduct a labouratory exercise to classify soils different types of soil

Oral Assessment

What is soil classification systems did you use and why?

12.3.3.4 Tools, Equipment, Supplies and Materials

- Construction manuals
- Projectors
- Flip charts
- Calculators
- Rulers, pencils, erasers
- Charts with presentations of data
- Drawing sheets
- Internet
- Relevant videos

12.3.3.5 References

Chow, V., Maidment, D., & Mays, L. (2013). Applied hydrology. New York: McGraw-Hill Professional.

Kutz, M. (2013). Handbook of transportation engineering. New York: McGraw-Hill.

12.3.4 Learning Outcome No 3: Design Road Geometrics

12.3.4.1 Learning Activities

Learning Outcome No 3: Design Road Geometrics	
Learning Activities	**Special Instructions**
3.1 Acquire ***resources*** 3.2 Obtain OGL (Original Ground Levels 3.3 Design horizontal alignments 3.4 Design vertical alignments 3.5 Design ***road intersections*** 3.6 Produce drawings 3.7 Prepare and present report	• Direct instruction • Discussions • Demonstration by trainer • Practice by the trainee

12.3.4.2 Information Sheet No 12/Lo 3: Design Road Geometrics

Introduction to learning outcome

This learning outcome covers the determination of the OGL, horizontal and vertical alignments, road intersections and preparation of working drawings and reports.

Definition of key terms

GIS: Stands for Geographic Information System, which is a computer system that by design captures, stores, analyses and displays data related to positions located on the surface of the Earth.

Horizontal curve: A horizontal curve is made between two tangent lengths of a roadway in order to provide a smooth transition. This is usually at the point where the road changes direction to the left or to the right.

Vertical Curve: These are curves that are used to connect stretches of roads going up or down a hill/slope. They can either be at the top of the hill, called summit curves/over verticals or at the bottom of a hill called sag vertical/ under verticals.

Content/Procedures/Methods/Illustrations

3.1 Acquire *resources* (Geometric tools, straight edge, ruler, compass, protractor, computers, AutoCAD Software, Civil 3D, Arch CAD, GIS) in accordance with geometric design requirements.

Geometric design of a highway refers to the determination of the dimensions and layout of the features of the highway. It is concerned with positioning these elements according to existing standards. The existing standards take into account the following factors:

a. Design speed
b. The type of vehicle
c. The slope/ road grade
d. The stopping distance
e. The view obstructions

The features include horizontal alignments, vertical alignments and intersections.

After the design parameters have been determined, the subsequent design will require resources. Stationery such as rulers, compasses and geometric tools can be bought easily from a nearby bookshop. Software such as Auto CAD, Civil 3D, Arch CAD, GIS can be acquired from the internet by directly purchasing it from the software provider. Subsequently, the software should then be installed on a computer so that it can be used.

3.2 Obtain OGL (Original Ground Level) according to standard road construction procedures.

Original Ground Level refers to the vertical height of an area with relation to the mean sea level. This is established after the site for the road has been cleared and machinery used to compact the ground.

Using survey equipment, the site for the road is levelled and the information recorded on a field book.

3.3 Design horizontal alignments based on standard road construction procedures.

Horizontal alignments are done so as to provide safe, continuous operation of vehicles at the designed speed for considerable lengths of highway. Considerations taken into account for horizontal alignment are the following:

a. Design speed
b. Topography
c. Safety
d. Profile grade
e. Geological features
f. Drainage
g. Existing highway
h. Likelihood of future developments

i. Cost of construction
j. Environmental issues
k. Right of way

These considerations have to be balanced to produce an alignment appropriate to the highway in terms of its location and classification.

Types and Properties of Horizontal Alignments

a. **Simple curves:** A simple curve is an arc that joins two tangents.
b. **Spiral curves:** A spiral curve is used to provide a gradual curvature change from a road that is straight to one that's circular.
c. **Reverse curves:** It is made up when two consecutive circular curves join at a point of tangency with their centers on opposite sides of the main tangent.
d. **Compound curves**

This is made up of two or more consecutive circular curves that are in the same direction which have varying radii.

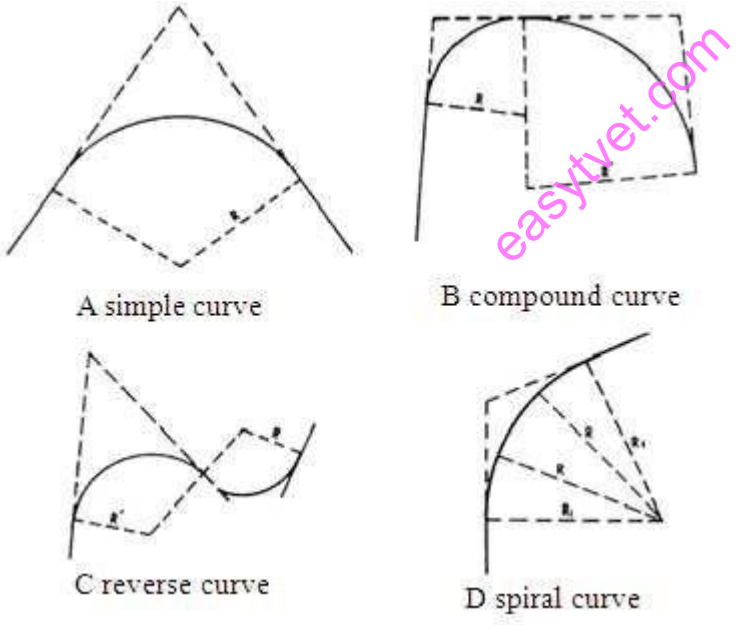

Figure 128: Types of Horizontal Curves
Source: Engineering Aid 1-Advanced Structural Engineering Guide Book, Chapter 11, Figure 11-3

The four main variables of simple curves include;

1. Radius,
2. Design speed,
3. Side friction factor and
4. Super elevation.

The parameters used in designing horizontal curves depend on the relationship between the curvature and design speed. This relationship co-relates also with super-elevation and side friction. Side friction factor is the lateral acceleration acting on a vehicle. It is calculated according to the following formula:

$$f = \frac{v^2}{127R} - 0.01e$$

Where,

f is the side friction factor

e is the rate of super elevation

v is the vehicle design velocity

R is the radius of the curve

Super elevation is having the highway tilted. It helps a vehicle overcome centripetal forces while going round a curve. It is usually set at 6%. In calculating the minimum radius, the following equation is used:

$$R_{min} = v^2/127(0.01e_{max} + f_{max})$$

Where,

v is the design velocity

e is the super elevation

f is the side friction factor

R is the radius of the curve

3.4 Design vertical alignments based on standard procedures

Vertical alignment curves should be able to provide:

a. Safety
b. Adequate sight distance
c. Comfortable driving
d. Good drainage
e. Pleasing appearance

Vertical curves are parabolic in nature. The minimum length to the crest is usually determined by the headlight stopping distance, where the lighting isn't sufficient. Where it is adequate, the passenger comfort factor is used to determine the length of the sag vertical. The minimum length of vertical curves should be 300 feet or according to design speed; it should be 3 times that value.

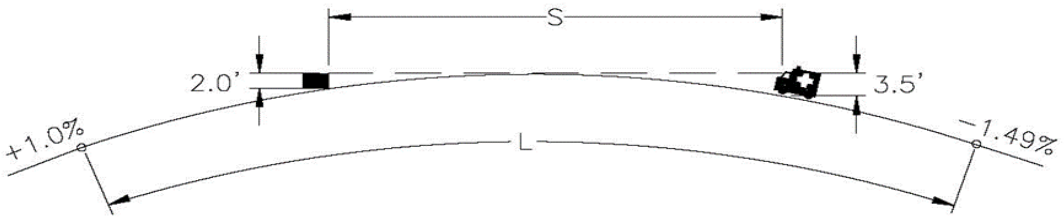

Figure 129: An Example of Crest Vertical Curve
Source: www.researchgate.net

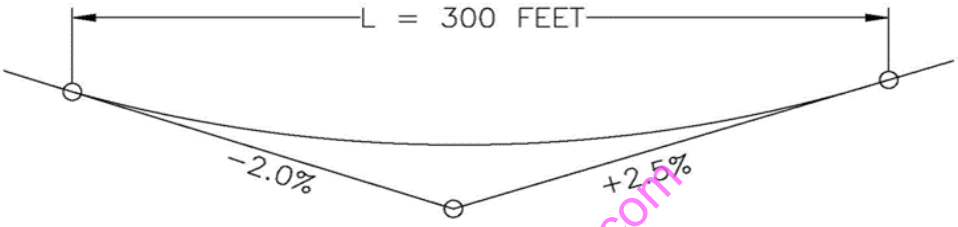

Figure 130: An Example of Sag Vertical Curve
Source: www.researchgate.net

Steps followed in determining the curve parameters.

1. **Deciding sight distance to be used:** When designing curves in a hilly place, the stopping sight distance is used. The intermediate sight distance is also useful while doing curve design.

2. **Determining the value of K:** After the design speed and road type are established, the value of K can be obtained from the following table:

MINIMUM VERTICAL CURVE 'K' VALUES.

Table 33: Minimum Vertical Curve 'K' Values

Design speed (km/hr)	Single lane roads (3.7m carriageway)	Two lane single carriageway roads (6.2 and 7.3m carriageway)			Dual carriageway roads (2 x 7.3)
	ISD	SSD	ISD	OSD	1SD
30	4	2	4	18	-
40	9	4	9	35	-
50	18	9	18	70	18
65	35	18	35	140	35
80		35	70	270	70
100		70	140	540	140

Source: adapted from Table 7.47, RMSS, Vol V11A

3. **Calculating A:** A is the change in grade in percentage form. It's necessary as it determines if the change in grade necessitates a vertical curve. The values can be obtained from the following table:

VERTICAL CURVE APPEARANCE CRITERIA.

Table 34: Vertical Curve Appearance Criteria.

Design speed (km/hr)	Max. Change in grade permitted without using a vertical curve (%)	Minimum length of vertical curve for good appearance. (m)
30	1.5	15
40	1.2	20
50	1.0	30
65	0.8	40
80	0.6	50
100	0.5	60

Source: adapted from Table 7.42&7.43, RMSS, Vol. V11A

4. **Calculating the length of the curve:** $L = K \times A$

5. **Carrying out cross checks:** Check L and compare it with the minimum length of the curve and adjust it if necessary. If the sight distance is longer than the vertical curve, use $L = 2S - 960/A$ to recalculate curve length where S is the sight distance.

6. **Checking for feasibility and doing any necessary amends:** Avoid using curves with a radius between ISD and SSD. This might tempt them to overtake.

3.5 Design road intersections (Y-junctions, T-junctions, underpass, overpass, roundabout, cross-junction, interchange) as per standard road construction procedures

An intersection is an area shared by two or more roads that enables drivers to change route directions. There are 3 categories of intersections;

- Grade separated intersections without ramps
- Grade separated intersections with ramps/ Interchanges
- At grade intersections

Intersections are of various forms including Y intersections, T intersections, scissor, cross, staggered etc. Intersections can also be circular, to produce a circular traffic pattern and reduce the crossing conflict points. These are called traffic circles. Roundabouts are a type of Traffic Circle but have the following definitive characteristics:

a. They yield control at each approach.
b. They allow speeds of below 30 miles /hour due to their geometric characteristics of the central island.
c. They separate conflicting traffic using raised islands or pavement markings.
d. Parking within the circulating highway is not allowed.

Generally, while doing design of an intersection, the four main elements that have to be taken into consideration are:

1. Human factors
2. Traffic considerations
3. Physical elements
4. Economic factors

3.6 Produce drawings as per design data

Based on the data gathered in designing of a highway from the design calculations drawings of the highway can be generated either on paper or by using software such as Auto CAD. The drawings will include cross sections, profile drawings and the plan drawing. The plan drawing will include alignments, the cross-section levels etc. When using software, one can easily be able to generate reports from the plan. It also facilitates generating a more presentable plan in 3D.

3.7 Prepare and present report as per contract document

Based on the requirements of the contract, the road design report should include the following sections:

1. The roadway design drawings
2. The specifications
   This includes the design and construction details and requirements.
3. The quality management plan
4. Construction quality management plan

Conclusion

This learning outcome covered the determination of the OGL, horizontal and vertical alignments, road intersections and preparation of working drawings and reports.

Further Reading

Read more on the geometric design of roads so as to be able to carry out the necessary calculations. Do some further reading and write notes on levelling.

12.3.4.3 Self-Assessment

Knowledge Based Evidence

Written Assessment

1. Which of the following is not a type of vertical alignment?
   a) Simple curve
   b) Complex curve
   c) Spiral curve
   d) Compound curve
2. Which one is not a category of intersections?
   a) At grade intersections
   b) Interchanges
   c) Bridge
   d) Intersections without ramps

3. Which one is not a main element while designing an intersection?
    a) Human factors
    b) Traffic considerations
    c) Specifications
    d) Economic factors
4. Define geometric design of highway.
5. What are factors affecting geometric design?
6. List five considerations taken while doing vertical alignment.
7. List three types of intersections.
8. Write an essay detailing the process of highway design and the steps taken until drawings are obtained.

Case Study Assessment

Based on roads in your vicinity, obtain the plans used and study them. Using the skills you have learnt point out any improvements that can be made especially on the curve design. Note down the improvements you came up with.

Oral Assessment

1. Mention four types of horizontal curves.
2. Mention some road intersection features.

12.3.4.4 Tools, Equipment, Supplies and Materials

- Computers
- Software
- Cameras
- Construction manuals
- Projectors
- Flip charts
- Calculators
- Rulers, pencils, erasers
- Charts with presentations of data
- Drawing sheets
- Internet
- Relevant videos

12.3.4.5 References

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12.3.5 Learning Outcome No 4: Design Pavement Structure

12.3.5.1 Learning Activities

Learning Outcome No 4: Design Pavement Structure	
Learning Activities	**Special Instructions**
4.1 Acquire resources 4.2 Estimate traffic load 4.3 Determine ***road/pavement type*** 4.4 Design ***pavement structures*** 4.5 Produce pavement structural drawings 4.6 Develop materials schedules 4.7 Prepare and present a detailed report and specifications	• Case studies • Discussions • Project • Demonstration by trainer • Practice by the trainee

12.3.5.2 Information Sheet No 12/ Lo 4: Design Pavement Structure

Introduction to learning outcome

This learning outcome covers preparation of pavement structural drawings, development of material schedules and preparation and presentation of a detailed report and material specifications.

Definition of key terms

Subgrade: The in-situ materials or improved ground with imported materials that form the platform for a pavement structure.

Sub-base: In transportation engineering, a subbase is a load-distributing layer immediately below and usually of inferior materials to the road base.

Rigid Pavement: This is a pavement whose main structural layer is a concrete slab. They are termed rigid due to their high flexural strength or high modulus of elasticity.

Content/Procedures/Methods/Illustrations

4.1 Acquire resources in accordance with pavement structure requirements.

The design of pavement structures requires the determination of the thickness of layers and composition of materials. The resources and tools required in pavement design can be found through;

- Online USGS store for topographical maps
- Download Road Design Manuals online from the KeNHA web page.
- Visiting the library for literature on pavement structures
- Accessing design software from trusted online suppliers.

4.2 Estimate traffic load as per traffic survey information.

Traffic loading in transportation engineering is the cumulative load characterized by traffic volume, magnitudes, wheel repetition, and truck weight data. The procedure for determining traffic loading is:

- Determining the axle load
- Calculating the Equivalent Factor and the number of single axle loads (SAL)
- Calculating the total SAL as Cumulative standard axle (CSA)

4.3 Determine *road/pavement type* (rigid and flexible pavement) as per client/developer/financier requirements and nature of the ground.

Pavement types are categorized into two major types; rigid and flexible pavements.

The procedure for selection of a pavement structure involves:

- Assessing the initial cost of construction
- Evaluating life cycle costs in the pavement maintenance and subsequent rehabilitations
- Determining the traffic loading
- Identifying the topography and land use

4.4 Design *pavement structures* (sub-grade, sub-base, base, surface) based on traffic engineering analysis outputs and material testing results

The typical components of a pavement that functions to support and distribute traffic load are what makes a pavement system. The procedure for design is as follows:

- Collecting and analyzing traffic data into CSA
- Collecting and analyzing material testing results on subgrade for CBR, OMC and MDD.
- Determining the pavement thickness based on traffic and material testing results.

Figure 131: pavement thickness
Source: https://www.nbmcw.com/tech-articles/roads-and-pavements

4.5 Produce pavement structural drawings as per design outputs

Pavement structural drawings are documents that depict the detailed cross-section of a proposed road. The software that are commonly used are AutoCAD and Civil 3D.
The process of producing structural drawing should include:

- Drawing of cross-sections after every 100m or in areas of a sudden change in gradient.
- The area of fill and cut to be shown at all times

4.6 Develop materials schedules according to design results

Materials scheduling is the process of organizing and controlling the sequence of delivery of materials on site. Material scheduling requires considerable knowledge of technical specifications for each component in structural design. The procedure to develop material schedule is:

- Identifying and working out quantities of materials needed from the structural drawing
- Identifying where materials will be procured
- Identifying the unit cost of the materials
- Determining the lead times of the materials

4.7 Prepare and present a detailed report and specifications as per the contract document

A detailed project report and specifications is a planning and design output document that provides particulars for a specific project. The preparation and presentation of a detailed report and specifications, with regards to pavement design, will involve the following;

- Identifying the projects particulars such as the project description, the scope, existing conditions, and the field investigations.
- Collecting information on the final route location
- Collecting the specification for soils and materials
- Collecting and organizing design details of the pavement, culverts and other features
- Compiling and presenting all the projects details and parameters.

Conclusion

This learning outcome covered preparation of pavement structural drawings, development of material schedules and preparation and presentation of a detailed report and material specifications.

Further Reading:

1. Conduct further research on pavement structure from the Road Design Manual Part III -Materials and Pavement Design for New Roads. Chapter 9: The Standard Pavement Structure
2. Read more on preparation of detailed report from the article: Tips for Writing an Engineering Project Report https://www.projectengineer.net/tips-for-writing-an-engineering-project-report/

12.3.5.3 Self-Assessment

Written Assessment

1. Rigid Pavements are analyzed by
    a) Infinite layer theory
    b) Elastic plate theory
    c) Rigid plate theory
    d) Interlocking of aggregates
2. The most superior pavement layer is that which distributes loads as
    a) Uniformly varying load
    b) Uniformly distributed
    c) Point load
    d) Triangular load
3. Which among the following is not a contract document?
    a) Bill of Quantities
    b) Financial Statements
    c) Specifications
    d) Construction Scheduling

4. Load transfer in flexible pavements is by
    a) Consolidation of sub-grade
    b) Grain to grain contact
    c) Bending action of layers
    d) Shear deformation
5. Which of the following is not typical layer of flexible pavements
    a) Tack coat
    b) Road base
    c) Sub-base
    d) Sub-grade
6. Briefly describe the functions of each layer in flexible pavements.
7. What are the advantages of rigid pavements?
8. Briefly describe how material scheduling is conducted.
9. Briefly describe four factors controlling the design of pavements.
10. List and explain the various pavement design methods
11. Discuss the input data required to design a pavement

Oral Assessment

1. What is the importance of preparing Bill of Quantities and Specifications for pavement structures to contractors?
2. In which instances it would a rigid pavement be selected instead of a flexible pavement?

Project Assessment

You are first required to briefly highlight the procedure of CBR test. Thereafter, design a flexible pavement using MoPW Design Method using the following data; trial pits dug at intervals of 500mm produced CBR results ranging 10-20% for the subgrade and 25-40% for the subbase. The traffic data for the pavement is estimated to be 1500/day with predicted growth rate of 5% p.a. According to axle loading survey, Ef=2.25SA/CV. Design the pavement for design life of 15years.

12.3.5.4 Tools, Equipment, Supplies and Materials

- Computers
- Software
- Cameras
- Construction manuals
- Projectors
- Flip charts
- Calculators
- Rulers, pencils, erasers

- Charts with presentations of data
- Drawing sheets
- Internet
- Relevant videos

12.3.5.5 References

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12.3.6 Learning Outcome No 5: Design Pedestrian and Cyclist Paths

12.3.6.1 Learning Activities

Learning Outcome No 5: Design Pedestrian and Cyclist Paths	
 **Learning Activities**	**Special Instructions**
5.1 Identify and gather required resources 5.2 Estimate pedestrian and cyclist traffic 5.3 Determine a pedestrian and cyclist path location 5.4 Design pedestrian and cyclist paths 5.5 Produce drawings 5.6 Specifications	• Direct instruction • Case studies • Field trips/site visits • Discussions • Practice by the trainee

12.3.6.2 Information Sheet No 12/ Lo 5: Design Pedestrian and Cyclist Paths

Introduction to learning outcome

This learning outcome covers the determination, designing and locating of pedestrian and cyclist path.

Definition of key terms

Pedestrian crossing: This is a specially designated area on a road where pedestrians have the right way.

Information signs: These are traffic signs that function to guide motorists in navigation and offer information on important facilities along the way.

Warning signs: Traffic signs that caution road users of potential dangers along the road.

Content/Procedures/Methods/Illustrations

5.1 Identify and gather required resources as per design requirements

Resources required in the design of pedestrians and cyclists' paths are materials that will help in determining the thickness and dimensions of the paths. Resources for design include GIS tools, computer tools, and expertise, maps, and travel surveys.

The procedure of identifying and gathering resources include;

- Identifying information on demographical data, legislations for special needs groups, and land use
- Getting the areas plan and the available road reserve.
- Utilize the information to determine the dimensions of the paths

5.2 Estimate pedestrian and cyclist traffic in accordance with traffic survey information

Pedestrian and cyclist traffic are the aggregation of road users not using vehicular means of transport. According to Nordback, Sellinger, and Phillips (2017), the procedure to estimate this type of traffic involves;

- Evaluating land use and road network connectivity
- Enhancing models to conduct non-motorized trip generations in a smaller zone

5.3 Determine the pedestrian and cyclist path location according to road profile

Pedestrian and cyclist paths are routes that provide a safe passage from non-motorized road users. According to Segadilha and Sanchez (2014), selection of the location of a pedestrian and cyclist paths according to the road profile is subject to:

- Visibility
- Gradient and cross fall

5.4 Design pedestrian and cyclist paths as per design manuals and procedures

Pedestrian and cyclist paths should be designed to ensure minimal conflicts and with special consideration to people with impairments. The design of these paths demands;

- Providing paths dimensions and geometry that accommodate all users
- Surface materials to be selected on the basis of safety and convenience.
- Providing and designing street furniture's accordingly

5.5 Produce drawings according to design output

The design drawings for the pedestrian and cyclist path illustrates the cross-section layout of the paths. Design drawings are produced using software such as AutoCAD which will provide information on:

- Dimensions of the paths, including their thickness.
- Dimensions of the street furniture such as Kerb

5.6 Prepare and present the report and material specifications according to contract document

Reports according to contract documents give information on, but not limited to the project milestones, stages, labour, and equipment. The procedure to make a report will include;

- Collecting and organizing information on project activities, labour, and materials
- Structure the information into relevant segments
- Present the report with accurate charts and spreadsheets.

Conclusion

This learning outcome covered the determination, designing and locating of pedestrian and cyclist path.

Further Reading

Read more on providing footpaths and recommended dimensions

12.3.6.3 Self-Assessment

Written Assessment

1. Which among the following is NOT a zone of a footpath?
    a) Through route
    b) Frontage zone
    c) Carriage way
    d) Street furniture zone
2. All the following are traffic signs except
    a) Warning signs
    b) Explanatory signs
    c) Information signs
    d) Regulatory Signs
3. The following are design features of a pedestrian and a cyclist path except?
    a) Gradient
    b) Visibility
    c) Width
    d) Length

4. All the following are street furniture except
    a) Bollards
    b) Traffic signs
    c) Culverts
    d) Rubbish bins
5. A report provides information on
    a) Manpower
    b) Materials
    c) Project milestone
    d) All the above
6. What is the difference between a zebra crossing and a pedestrian crossing?
7. Given the information acquired, which measures will be most effective in reducing cyclist-motorist collision?
8. Give two instances where it is unsuitable for providing a pedestrian footpath along the way.
9. Highlight three surfacing materials used in pedestrian and cyclist paths.

Oral Assessment

1. Vehicles parking on pedestrian and cyclist path has been a common practice in the recent past. Which measure should be put in place to prevent cars from closing and obstructing side paths?
2. In your specific locality, which surfacing material is most common along pedestrian paths? Mention at least two advantages and disadvantages of the said materials.

Project Assessment

You are required to conduct a traffic survey for cyclists and pedestrians in your locality. Use the data collected to design a combined pedestrian and cyclist path. Your design output should be structural drawings, from AutoCAD or any other software, illustrating the cross-section, and width of the path. Please note to design for safety and aesthetics.

12.3.6.4 Tools, Equipment, Supplies and Materials

- Computers
- Software
- Cameras
- Construction manuals
- Projectors
- Flip charts
- Calculators
- Rulers, pencils, erasers
- Charts with presentations of data

- Drawing sheets
- Internet
- Relevant videos

12.3.6.5 References

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12.3.7 Learning Outcome No 6: Design Road Furniture

12.3.7.1 Learning Activities

Learning Outcome No 6: Design Road Furniture	
Learning Activities	**Special Instructions**
6.1 Gather required resources 6.2 Determine ***type of road furniture*** 6.3 Determine location of road furniture 6.4 Design road furniture 6.5 Produce drawings 6.6 Prepare and present the report and material specifications	• Direct instruction • Field trips/site visits • Discussions • Demonstration by trainer

12.3.7.2 Information Sheet No 12/ LO6: Design Road Furniture

Introduction to learning outcome

This learning outcome covers the determination and design of road furniture.

Definition of key terms

Guard rails: This is a boundary that is used to deter access to off-limits area, it allows light and visibility in a much greater way than a fence

Traffic lights: This is a signalling instrument found at road intersections, pedestrian crossings and wherever needed to control traffic flow

Street lights: This is a standard raised source of light at the boundary of a road or path

Content/Procedures/Methods/Illustrations

6.1 Gather required resources according to design needs

Design needs are those requirements that are required to be met to ensure the functionality and reliability of a structure. The resources that are required to be gathered include;

i. The Kenya National Highway regulations
ii. Experts in the road and Highway construction management sector

They can be gathered by approaching their workstations where they will provide the stipend and budget as well as those having expertise in the area

6.2 Determine *type of road furniture* (Road markings, information signs, warning signs, street lights, traffic lights, guard rails) based on road type and relevant manuals

Road Furniture are devices that provide road users with the necessary information on warnings, rules or directions in order to ensure safe use of the roads

- They serve many functions related to the usage of the streets in many ways whether directly or indirectly Their importance includes;
- Lead to a better usage of the streets as an urban space been used by people
- These setups the streets are not only passages of movement, but also living spaces that contains and improves people's lives and human activities
- With the lack of street furniture designs, these setups are considered as barriers and obstacles in the streets that may affect negatively, the functions being performed in the streets.

Road markings: This is any kind of physical representation of official information on a road surface end is usually placed with road marking machines

Information signs: This is a very readably printed or distinguishable placard to convey the purpose of an object or give the directive on the use of something

Warning signs: These are a type r regulatory signs that are used to show a potential hazard, obstacle or condition requiring caution

Street lights: These are standard raised source of light at the boundary of a road or path

Traffic lights: This is a signalling instrument found at road intersections, pedestrian crossings and wherever needed to control the flow of traffic

Guard rails: This is a boundary that is used to deter access to off-limits area, it allows light and visibility in a much greater way than a fence

6.3 Determine location of road furniture as per geometric road design

Road furniture are devices that provide road users with the necessary information on warnings, rules or directions in order to ensure safe use of the roads.

To determine the location of the road furniture the following steps must be undertaken:

a. Site visit
b. Collect the onsite data collected according to standard procedures
c. Identify the road intersections as designed as per standard road procedures
d. OGL (Original Ground Levels) are obtained according to standard road construction procedures
e. Horizontal alignments are designed based on standard road construction procedures
f. Vertical alignments are designed based on standard procedures
g. Sketch the data determined and a report is compiled of all the completed tasks

6.4 Design road furniture according to standard road construction procedures

Road Furniture are devices that provide road users with the necessary information on warnings, rules or directions in order to ensure safe use of the roads

The design of Road furniture includes

Route planning: Establish specific goals and prescriptions for road network development along with the more general location needs.

Design Criteria which includes the following among others;

- Resource management objectives; why is it needed
- Environmental and physical factors' topography and vegetation characteristics of the area
- Environmental and Social-political constraints e.g. high rainfall intensities and land ownership boundaries
- Traffic requirements; average daily traffic (ADT)
- Vehicle characteristics; distinguishing between "design vehicle" and "Critical vehicle"
- Road uses distinguishing from Administrative users, Agricultural users among others six Safety -Safety requirements such as stopping distance, sight distance or allowable deign speed
- Economics -Economic evaluations should be done

The design elements which include the Number of Lanes and Lane width, Road width and Turnouts, turn arounds, curve widening, Clearance, Speed and Sight distance, Horizontal and vertical alignment as well as travel time

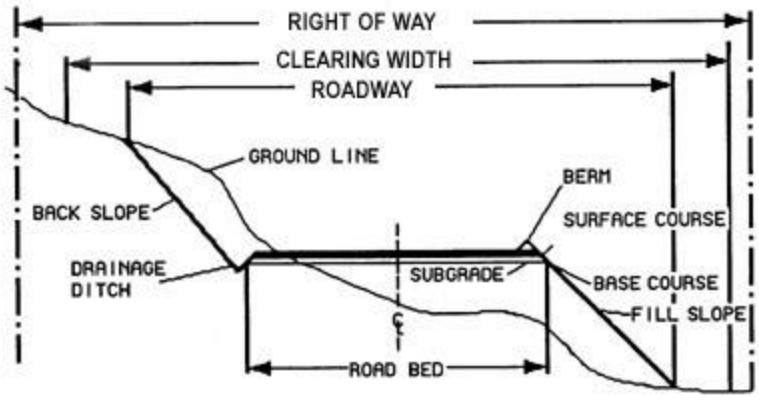

Figure 132: Design elements

Source: www.FAO.org

6.5 Produce drawings based on design requirements

The design and construction of Road furniture goes through a rigorous process which includes cooperation of many entities to deliver a quality road.

Basic Requirements for Producing Drawings

- Computer installed with Civil 3D software
- Survey data

Steps of Producing Drawings based on design requirements.

- OGL data of the road is taken with the help of the survey team using a Total Station
- The data is then loaded into a computer with the necessary processing power.
- The road is then designed as per the standard requirements in the Ministry of Roads and Transportation using different software, preferable Civil 3D
- A report is then generated from the design with all the cut and fill data as well as the elevations of the pavement.

Conclusion

This learning outcome covered the definition of various road furniture, the standards and design of road furniture.

Further Reading

Read on Standard Specification for Road works and standard specification
Project Management for Construction than develop a flow chart on the mandatory steps that must be conducted when designing a road furniture device.
Read manuals on the Safety Measures in developing countries and identify the specific to road users and Pedestrians
Read reports on Road and Highway constructions and determine the similarities in them

12.3.7.3 Self-Assessment

Written Assessment

1. Which of the following is not a road furniture?
    a) Standard lights
    b) Safety barriers
    c) Bridge
    d) Traffic lights
2. Which of the following is not an objective of Warning Signs?
    a) Convey the purpose of an object or give the directive on the use of something
    b) Indicate potential hazard
    c) Indicate obstacle or
    d) Indicate condition requiring caution
3. Which of the following is a factor to be considered as a standard in road furniture design?
    a) Original ground level
    b) Horizontal alignment
    c) Vertical alignment
    d) Economics
4. Which of the following is not a performance criterion when constructing a road furniture?
    a) Conduct site visit
    b) Design highway drainage structures
    c) Design road geometrics
    d) Quality system requirements
6. Which of the following is a requirement needed in a report prepared before construction of a road furniture?
    a) Referenced documents
    b) Social-political factors
    c) Road markings
    d) Agricultural users
7. Which of the following is not a skill required to be competent in road furniture construction?
    a) Drawings
    b) Innovation
    c) Leadership
    d) Marketing

8. Which of the following is the correct definition of a traffic light?
    a) These are standard raised source of light at the boundary of a road or path
    b) This is a signaling instrument found at road intersections, pedestrian crossings and wherever needed to control traffic flow
    c) This is a boundary that is used to deter access to off-limits area, it allows light and visibility in a much greater way than a fence
    d) These are a type regulatory signs that are used to show a potential hazard, obstacle or condition requiring caution
9. Briefly describe the various categories of Traffic Users (4 marks)
10. Explain five Environmental factors that influence the road furniture standards
11. What is geometric road design
12. Distinguish between "design vehicle" and "Critical vehicle", vehicle characteristics
13. Explain the resource management objectives that could lead to the construction of road furniture
14. List and explain the on-site data that should be collected during construction site visit
15. Explain the various pavement structures

Oral Assessment

1. What are the two types of Pavement types (2 marks)
2. Name 5 road furniture (5 marks)

Case Study Assessment

In the new constructed super highway there was a government directive to place Road furniture at every exit to assist the road users. According to the Standards of Road and Highway, identify 5 established exits identify the road furniture expected, specify the distances appropriate to place them and explain the social-political factors that influence the road furniture at a specific area

12.3.7.4 Tools, Equipment, Supplies and Materials

- Computers
- Software
- Cameras
- Construction manuals
- Projectors
- Flip charts
- Calculators
- Rulers, pencils, erasers
- Charts with presentations of data
- Drawing sheets
- Internet

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