**STRUCTURE ANALYSIS 1 & 2**

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**1. Introduction**

All objects have structure. Every structure is made of members connected together to make it whole so that it can perform the function for which it was designed. Both natural and man-made structures vary in size, form and function. The most popular man-made civil engineering structures are residential and commercial buildings, bridges, dams, ships, tunnels and canals. The job of [structural engineers](https://gharpedia.com/hire-structural-engineer/) is to design and assess any structure to make sure that it is stable and functionally efficient.

There are two very important terminologies in structure analysis. These are structural analysis and structural design. Structural analysis deals with the calculation of all loads mounted on the members and analyzed to know if the materials of construction will carry the loads. Structural design on the other hand specifies the dimensions of the structural members based on the calculated loads from the structural analysis. Structural engineers are responsible for both the [structural analysis](https://gharpedia.com/structural-analysis/) and [structural design](https://gharpedia.com/structural-design-why-it-is-required/).

The numerous engineering structures we see around can be classified into two categories. These are geometrically unchangeable structures and geometrically changeable structures.For the geometrically unchangeable structures, any distortion of the structure could result in the deformation of its members. This means that this type of structure has rigid members and therefore cannot change its form. In the case of the geometrically changeable structures, distortion of the structure takes place but no deformation of its members.

This assignment will outline the different types of civil engineering structures, procedures and steps used in the analysis of the different civil engineering structures, different type of loads that could be applied to members of structures, major approaches to the analysis of forces on structures and the various approaches to the analysis of structures.

**2. Types of Civil Engineering Structures**

In civil engineering, a structure is referred to a number of components known as elements connected together to provide for the transmission of forces. The forces are due to loads imposed on the structure and the elements are designed to transmit these forces to the foundations of the structure.

There are several engineering structures that are constructed following some standard analysis procedures. Among them are:

**i. Load bearing structure**: Here, the wall carries the weight of the structure because it supports the roof and floor that are directly connected to the wall. The wall which is built on a foundation transfers the load to the soil. The loads on the trusses which hold the roof must be determined so that the foundation and the wall will be constructed appropriately to avoid collapse. The advantages of load bearing structures are that they are highly durable and solid. They have high fire resistance and the masonry units are available in various colors and textures. This gives freedom of creativity and do not require advanced preparations to construct. Load bearing structures are also aesthetically appealing. The tools and equipment needed for construction are simple to use and cheap to get. The disadvantages are that these types of structures perform poorly during earthquake action. Construction is expensive because more labor is required. The construction of masonry is slow because it requires a large number of masonry units and this makes it expensive and structurally unreliable. As a result of many units of masonry, the structure has more weight and the thermal insulation properties are very poor.

**ii. Framed structure:** In this type of structure, the load is transferred to the soil through the members of the structure such as the slabs, beams, columns and footings. Here, the slabs and beams are referred to as flexural members. The slabs are connected to the beams and the beams in turn transfer the load to the columns fixed to the footings that are resting on the soil.

The framed structures are of different types. The following are some of them:

#### ****a. Light-frame structure:** In light-frame structure, the**materials commonly used for construction are wood, rectangular steel tube or channel. In this case, pieces of wood are fastened together by nails or screw-steel pieces which are in turn attached to nuts and bolts. Plywood or composite sheathing is used for exterior finishes for walls and ceilings. Examples of this type of structure are brick, stone surfaces and plaster finishes.

**b. Timber structure:** They are usually made of wood materials because they have good compressive, tensile and flexural strength. The various members of this structure are joysticks, studs, rafters and purlins. The two major types of timber frame structures are balloon frame and platform frame. The more efficient of the two is the platform frame structure. The reason for the efficiency of the platform frame structure is that it can be used to erect many high-rise structures for residential accommodation unlike the balloon leveling structure. There are however, several advantages and disadvantages of timber frame structures. Among the several advantages is that the supporting members like columns and footings are always in compression and therefore the walls do not carry the load. The weight is in turn transferred to the beams on which they are supported. [Reinforced concrete](https://constructionor.com/reinforced-cement-concrete/) or steel can be used for construction and the speed of construction is faster than for load-bearing construction. In addition, [precast concrete](https://constructionor.com/precast-concrete/) members and [ready-mixed concrete](https://constructionor.com/ready-mixed-concrete/) can be used and therefore the speed of construction is greatly increased. **The disadvantage of a timber frame structure is that it uses long** spans which are liable to lateral deflections.

**iii. Composite structure:** A composite structure is made up of a load-bearing structure and a framed structure. The exterior wall of a composite structure could be load-bearing while the column and beam could be internally supported. The floor, ceiling and roof-top of a composite structure are supported by the walls and columns. Composite structures are very suitable for industrial sheds and warehouses where large spans are used in construction. A composite structure has both advantages and disadvantages. The advantages are that the composite structures are highly resistant to heat and electricity. They are lighter in weight than traditional materials and so composite structures are easy to carry and install. They are flexible which makes them easy for engineers to design according to their requirements. The disadvantages of composite structures are that the materials are expensive and require highly skilled labor for construction.

**iv. High-rise buildings:** High-rise or multi-storeyed building is one that can be easily affected by lateral forces induced by wind or earthquake and sometimes by both. To avoid damage by any external force, proper design, selection of construction materials and analysis of forces should be carried out.

**v. Dams:** A dam is a reservoir constructed for the purpose of retaining a large volume of water. It is constructed using impervious materials across a river to impound water upstream for several purposes. In order for the dam to hold the quantity of water required without failure, proper design, use of appropriate materials and accurate analysis of hydraulic pressure forces should be done.

**vi. Bridges:** A bridge is a structure constructed for vehicular and human traffic across a river or valley. Bridges are structures which carry people and vehicles across natural or man-made obstacles. Proper design, selection of construction materials and analysis of the type of forces to be experienced by the bridges should be carried out.

**vii. Retaining wall:** A retaining wall is a structure constructed in a vertical position to wedge soil, rock or other materials from falling. A retaining wall also provides lateral support for soil so that it will not collapse into a more natural shape or where it is not needed. To perform optimally, accurate design, selection of construction materials and analysis of the different types of forces to be encountered by the structure should be made.

**viii. Chimney:** Chimney is a structure constructed for the purpose of evacuating poisonous gases or smoke from manufacturing and production facilities to higher elevation so that the gases do not contaminate the surrounding atmosphere. This structure is tall and slender in shape. It is constructed using different materials of high heat resistance. The materials commonly used for construction are concrete, steel or masonry. Proper design and selection of construction materials that could resist heat are very important for high performance of any chimney.

 There are several other civil engineering structures that require proper design, selection of construction materials and accurate analysis of forces. These include industrial structures and electronics industry. Hydraulic structures include canal head regulator, siphon and barrage while marine structures include docks, harbors and jetty

## 3. Types of Loads

There are different types of loads that could be imposed on a structure. The most common are dead, live, building, bridge, wind, earthquake, soil pressure and hydrostatic pressure loads.

 Dead loads are those that have constant magnitudes and fixed positions and they act permanently on the structure. These types of loads consist of the weights of the structure itself and of all other material equipment permanently attached to the structure. Examples of dead loads for a building structure are frames, framing and bracing systems, roofs ceiling, walls, stairways, heating and air conditioning systems, plumbing, and electrical systems. The weight of the structure is not usually known in advance of design but usually assumed. After the structure is analyzed and the sizes of the members are determined, then the actual weight is computed by using the member sizes and the unit weights of materials used.

Live loads have different magnitudes and their positions vary from time to time. Live loads are generated by the use of the structure. Examples of such loads are human traffic, snow and wind. The position of a live load could change with time and therefore each member of the structure must be designed taking into consideration the maximum load that could be imposed on it.

An earthquake is referred to a sudden undulation of a portion of the surface of the earth. During earthquake event, the ground surface moves in both horizontal and vertical directions. The magnitude of the ground motion generated by earthquake in the vertical direction is usually small and therefore does not have much effect on most civil engineering structures. The magnitude of reaction of ground motion caused by earthquake in the horizontal direction is what causes structural damage. Therefore, horizontal reaction forces of structures constructed in places where earthquake is most likely to occur must be considered in the design of any structure. During earthquake, the foundation of the structure moves with the ground and the portion of the structure above the ground resists the motion because of the inertia of its mass; causing the structure to vibrate in the horizontal direction. These vibrations generate horizontal shear forces in the structure. In order to predict the stresses that may develop in a structure in the event of an earthquake accurately, a dynamic analysis that considers the mass and stiffness characteristics of the structure should be carried out.

Hydrostatic loads are loads imposed on structures that retain water. Examples of hydrostatic structures are dams and tanks. The volume of water in a dam and the depth of storage have great effect on the pressure to be imposed on the structure. To avoid collapse of the dam, proper design and careful selection of construction materials are essential. Soil pressure loads are loads imposed on the structures that are imbedded in the soil or are in contact with the soil. Examples of structures imbedded in the soil are foundations of buildings and reinforcements in dam construction.

Wind loads are generated by wind flowing at very high speed around a structure. The magnitude of wind loads that may impact a structure depends on the location of the structure. The wind forces will be less on the structure if there are obstructions near or around it such as tall trees, mountains and high-rise buildings. The geometry and vibration characteristics of the structure itself will determine the impact of forces on it. To design structures that could resist wind loads, the geographical location of the structure, seasonal wind speed and direction should be considered.

Snow loads are loads imposed on a structure by snow. In many parts of the world, huge deposits of snow are seen on roof-tops of buildings, bridges and roads. These deposits have the capacity to deform some portions of structure such as roofing materials like zinc. In such places, snow loads should be analyzed in designing structures. The design snow load for a structure should be based on the ground snow load for its geographical location.

**4. Major Groups of Structural Analysis**

**Analysis of civil engineering structures can be carried out by using static, dynamic, stability and vibration analysis. Static analysis**is concerned with the evaluation of stresses and buckling of members under constant loads. Constant loads are described as loads applied very slowly such that speed does not have any effect and the magnitude of the load remains constant with time.

Static analysis determines the displacements, stresses, strains and forces in members of structures or components caused by loads that do not initiate significant inertia and damping effects. In steady loading, response conditions are usually assumed. This means that the loads and the reactions of the structures are assumed to vary slowly with respect to time. The types of loading that can be analyzed in a static case are usually applied externally. Examples are steady-state inertial forces such as gravity, rotational velocity, imposed nonzero displacements and temperatures. Here, vibration occurs when dynamic forces are generated by compressors, pumps, rotating shafts, machine or parts of a machine. The disadvantage of vibration is that it leads to piping failures, poor equipment reliability and safety. **Vibration analysis** predicts the dynamic effects of loads on structures and machinery itself. Dynamic loads give rise to imbalance, misalignment, pulsation forces and moments.

**Dynamic analysis** is concerned with the evaluation of vibration levels and stresses induced by loads on members of a structure. To avoid unwanted vibrations of structural members, the first step will be to limit those vibrations. The resistance given by a structure to undesirable movement like sliding, collapsing and over turning is called stability. Stability depends upon the conditions of supports and arrangements of members in the structure. Stability analysis is carried out to ensure that structures operate safely and perform optimally as expected without causing injuries to users.

**5. Methods of Analysis of Structures**

The basic objective of structural analysis is to determine the response of the structure to the application of loads. To do this effectively, the loads, materials, geometry and the form of the structure must be put into consideration. The response of the structure can be measured in different ways. One of the different ways is the resulting deflections of the structure which can be measured or calculated at discrete points. However, unless the structure is a mechanism, the deflections are simply the aggregate effect of internal deformations of the elements which cause strain and stress within the element. The conditions of stress, strain and deflection are however all inter-related. The response or behavior of the structure must meet certain minimum requirements for the structure to be considered satisfactory. Deflections must be confined to reasonable limits otherwise the structure may not be able to perform its intended function. The stresses must be similarly limited to values which will not cause failure within the elements or connections.

Structural analysis is a comprehensive determination of the nature and magnitude of the loads to be imposed on the structure in order to ensure that all deformations that will be generated as a result of load application on the structure will be much lower than the permissible limits. It is the responsibility of [structural engineers](https://gharpedia.com/hire-structural-engineer/) to design and assess the structures to ensure that they are efficient and stable. The results of the analysis are used to verify the strength of the structure for high performance and efficient use.

The process of finding out the reactions at the supports, bending moment, rotations, stresses, strains, shear force and deflection that a particular member of a structure would undergo as a result of the application of different [types of loads](https://gharpedia.com/classification-of-loads-on-structure/) is referred to as response.

Structural analysis is also concerned with the calculation of loads coming on the structure and analyzing them to see if that members could carry them. This procedure is used to find out the effect of the external forces on the members of the built structure. Structural engineers use the results of structural analysis to convince clients that a structure can withstand various types of forces that it would encounter during its life span.

Each time a member of any structure is loaded, it will experience direct compression, tension, bending or torsion. If the load imposed on the member is not accurately determined, the member will deform. The process of finding out the magnitude of the sheer force, bending moment, deflection, rotation, shear stress and strain is what is known as structural analysis.

 There are two broad classifications of analysis methods. These are stiffness methods and flexibility methods. Under the broad classification of stiffness methods, we have moment distribution, slope deflection and matrix methods. Under flexibility methods, we have energy, matrix flexibility and column analogy methods. For stiffness methods, the degree of difficulty of analyzing a particular structure increases with the increase in the number of degrees of freedom. The method relies on equilibrium equations. For flexibility methods, the more the degree of static indeterminacy, the more complex the problem becomes for analysis.

**i. Force method: This is also referred to as** flexibility or consistent deformation method. The method is used to calculate the internal forces and reactions in statically indeterminate structures. Force method of analysis depends on transforming a given structure into a statically determinate primary system and calculating the magnitude of statically redundant forces required to restore the geometric boundary conditions of the original structure.

**ii. Displacement method:** This method involves writing the unknown displacements in terms of the loads using the load-displacement relationship. This is followed by solving the equilibrium equation for these displacements. After calculating the displacements, the unknown loads are determined from the compatibility equations. In displacement method, three methods which are closely related to each other are:

a. **Slope deflection method: This** can be used to analyze statically determinate and indeterminate beams and frames. Here, it is assumed that all deformations are due to bending only and influences of axial and shear stresses are neglected. The second assumption is that all the joints of the structure are rigid; meaning that the angles between the members at the joints do not change when loads are applied on the members of the structure

**b. Moment distribution method: In this case,** the method begins by assuming each joint of a structure to be fixed. This is followed by unlocking and locking each joint in succession and then the internal moments at joints are distributed and balanced until the joints have rotated to their final position.

**c. Direct stiffness method:** This is a matrix analysis method which implies that equilibrium equations are formulated into a single matrix relationship. The free joint displacement equations can be automatically selected from the full system matrix and then solved.

**iii. Approximate methods: This method is** useful in determining the forces and moments in the different members of the structure. This method is conducted by making realistic assumptions about the behavior of the structure. For analysis of members subjected to vertical loads, points of inflection are used whereas portal method or cantilever method is used for frames subjected to horizontal loads.

**a. Portal method: Here, i**t is used to analyze members subjected to horizontal loads only. The assumptions made are that the points of inflection are located at the mid-height of each column of a structure. The points of inflection occur at mid-span of beams and total horizontal shear force is distributed among the columns of the structure such that the exterior columns carry half the force carried by the inner columns of the structure.

**b. Cantilever method:** This method is applicable to high rise structures and the basic **assumptions of the method are that there is a**n inflection point at the midpoint of each girder and an inflection point occurs at mid-height of each column of the structure.

**c. Points of inflection method:** This method is used to analyze structures subjected to vertical loads only. Here, the structure is reduced to a statically determinate form by introducing an adequate number of points of inflection. The loads on the structure are usually uniformly distributed.

## ****6. Steps for Analysis of Structure****

Structural analysis has to be performed before structural design. The analysis procedure involves several steps. The main step is known as structural idealization. In order to determine the loads in the various members of a structure with reasonable degree of simplicity and accuracy, it is necessary to represent the structure in a simple manner that is suitable for analysis. Structural components have width and thickness. However, concentrated loads do not act at a single point but are distributed over small areas. If these characteristics are taken into consideration in detail, analysis of the structure will be very difficult if not impossible to perform. To simply the process of analysis, a concept called structural idealization is introduced. Structural idealization is the process of replacing an actual structure with a simple system conducive to analysis. In most cases, lines that are located along the centerlines of the components represent the structural components.

The next step in the analysis of a structure is to consider how the loads are applied on the members of the structure. Loads can be applied in the vertical and lateral positions on a structure. The loads can also be concentrated or uniformly distributed. After the application of the loads, the next thing to do is to calculate the reactions generated on each of the loaded member to see if their sizes can carry the imposed loads. Following the calculation of the reactions of the structural members to the applied loads, the next step is to calculate the internal forces of the members. Accurate determination of the internal forces will give a good idea on how long the structure will sustain the applied loads over a period of time. After that, calculation of the internal stresses of the members follow and the evaluation of the efficiency and safety of the entire structure is made.

**7. Summary**

The assignment is on structure analysis. The different definitions of structural analysis were given. The different types of civil engineering structures which includes load bearing structures, composite structures, dams, bridges, retaining walls, chimney and high-rise buildings were described. Different types of loads which include dead, live, earthquake, hydrostatic, wind and snows loads which could be imposed on civil engineering structures have been presented and discussed. The major groups of structural analysis which comprises of static, dynamic, stability and vibration analysis have been enumerated. Methods of analysis of structures which includes force, displacement and approximate were given and discussed. The steps structural engineers take in the analysis of forces on structures have been enumerated and discussed in details.

**8. Specific Details in the Articles**

The articles enumerated the different types of civil engineering structures that requires proper design, selection of construction materials and comprehensive analysis of forces to be imposed by the loads. The articles also described the different types of structures and their methods of construction. The different types of loads to be imposed on each type of structure were discussed. The major groups of structural analysis were given in the articles. The various steps for the analysis of the forces imposed on the different types of structures were discussed in details.

**9. Lessons learnt from the Articles and how I can apply them to my Studies at AIU**

I have learnt that there are many types of civil engineering structures. Each has its own materials of construction and force analysis procedure based on the type of loading. I have also understood that there are different major groups of analysis of the structures.

Proper design, selection of appropriate construction materials and accurate mathematical analysis of the forces to be imposed on the members of the structure will ensure a stable, strong and reliable structure that could withstand both human and environmental factors. This knowledge will help me advice structural design engineers, material scientists and policy makers responsible for civil engineering construction projects and contractors. This course will also count towards my getting a bachelors degree in civil engineering at AIU.

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an inflection point occurs at mid-height of each column of the structure.

c. Points of inflection method: This method is used to analyze structures subjected to vertical

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