UNIT - V

GEOTECHNICAL ENGINEERING

Geotechnical Engineering is the branch of Civil Engineering concerned with the engineering behavior of earth materials. It includes investigating existing subsurface conditions and materials; determining their physical/mechanical and chemical properties; assessing risks posed by site conditions; designing earthworks and structure foundations; and monitoring site conditions. It includes:

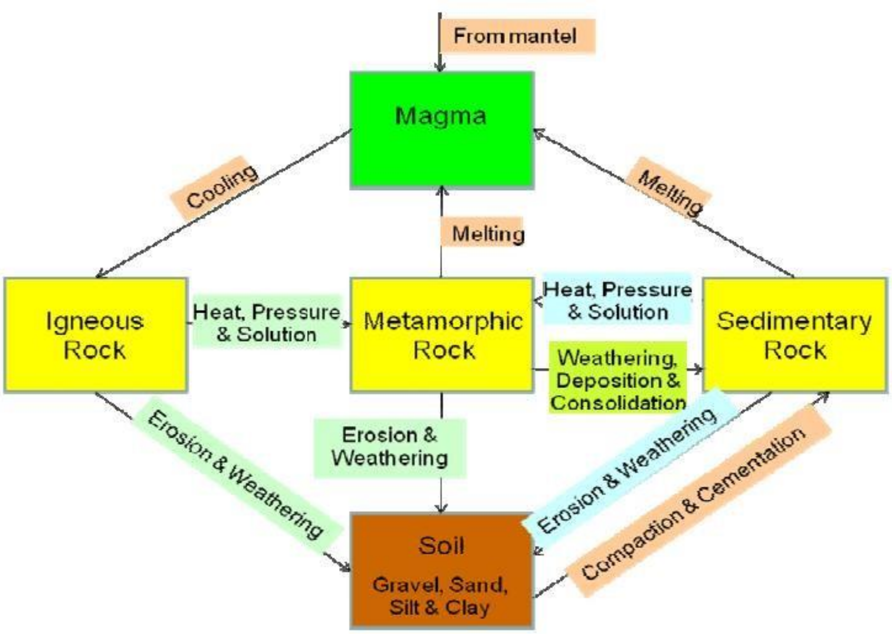
Soil Mechanics (Soil Properties and Behavior).
Rock Mechanics (Rock Stability and Tunneling).
Foundation Engineering (Shallow & Deep Foundations).
Soil Dynamics (Dynamic Properties of Soils, Earthquake Engineering).
Earthworks Engineering (Embankments, Slops Stability, Dams).
Earth Retaining Structures.
Pavement Engineering (Flexible & Rigid Pavements).
Ground Improvement (Soil Reinforcement, Geosynthetics).
Costal and Ocean Engineering.

For engineering purposes, soil is defined as the mixture of mineral grains and decayed organic matter (solid particles) with liquid and gas in the empty spaces between the solid particles.

Soil is used as a construction material in various civil engineering projects, and it supports structural foundations. Thus, civil engineers must study the properties of soil, such as its origin, grain-size distribution, and ability to drain water, compressibility, shear strength, and load- bearing capacity.

Soil mechanics is the branch of science that deals with the study of the physical properties of soil and the behavior of soil masses subjected to various types of forces. Soils engineering is the application of the principles of soil mechanics to practical problems.

Origin and Formation of Soil



Soil is formed by the process of 'Weathering' of rocks, that is, disintegration and decomposition of rocks and minerals at or near the earth's surface through the actions of natural or mechanical and chemical agents into smaller and smaller grains.

Weathering is the process of breaking down rocks by mechanical and chemical processes into smaller pieces. Mechanical weathering may be caused by the expansion and contraction of rocks from the continuous gain and loss of heat, which results in ultimate disintegration. Frequently, water seeps into the pores and existing cracks in rocks. As the temperature drops, the water freezes and expands. The pressure exerted by ice because of volume expansion is strong enough to break down even large rocks. Other physical agents that help disintegrate rocks are glacier ice,wind, the running water of streams and rivers, and ocean waves. It is important to realize that in mechanical weathering, large rocks are broken down into smaller pieces without any change in the chemical composition.

In chemical weathering, the original rock minerals are transformed into new minerals by chemical reaction. Water and carbon dioxide from the atmosphere form carbonic acid, which reacts with the existing rock minerals to form new minerals and soluble salts. Soluble salts present in the groundwater and organic acids formed from decayed organic matter also cause chemical weathering. The minerals formed at higher temperatures in Bowen's reaction series are less resistant to weathering than those formed at lower temperatures.

Residual Soils

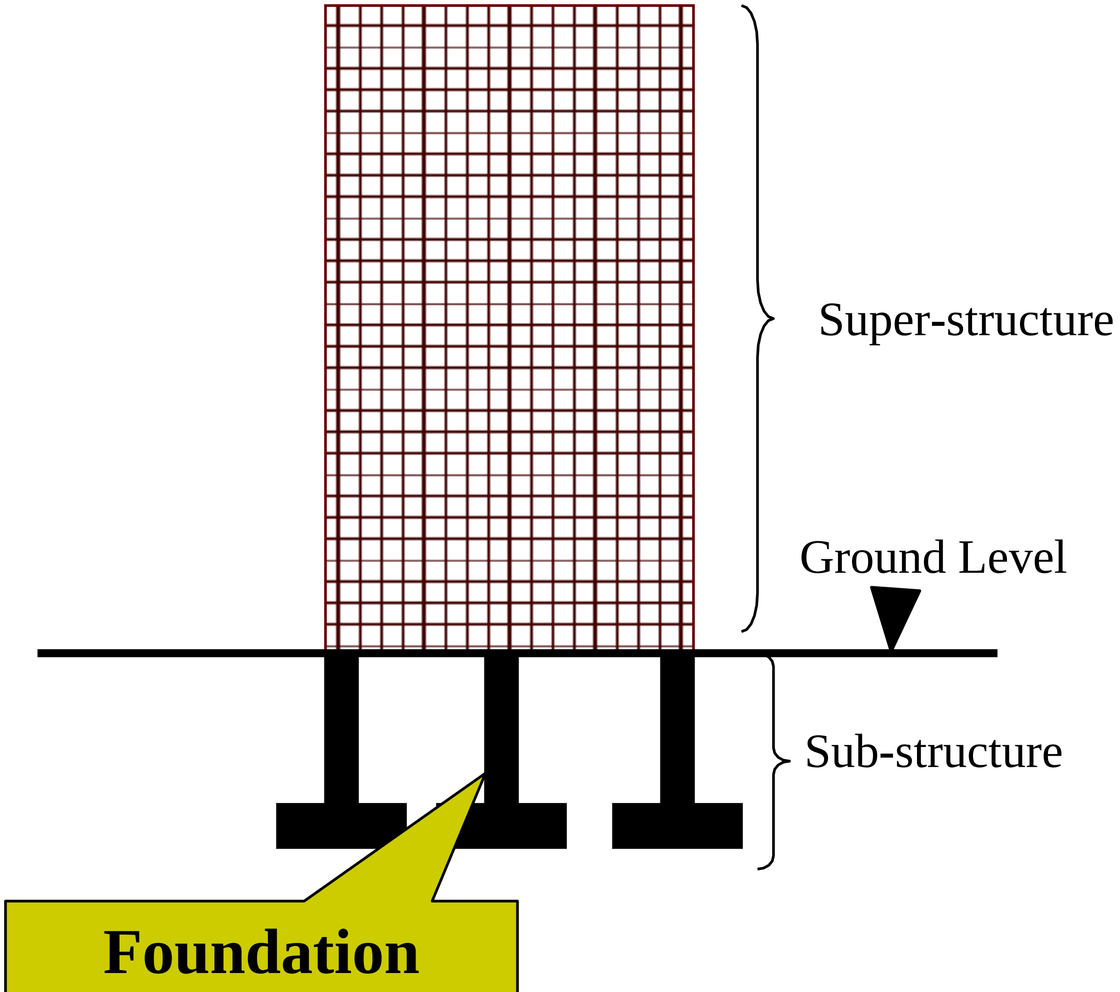
The soils formed by the weathered products and remain at their place of origin are called residual soils. An important characteristic of residual soil is the gradation of particle size. Fine grained soil is found at the surface, and the grain size increases with depth. At greater depths, angular rock fragments may also be found.

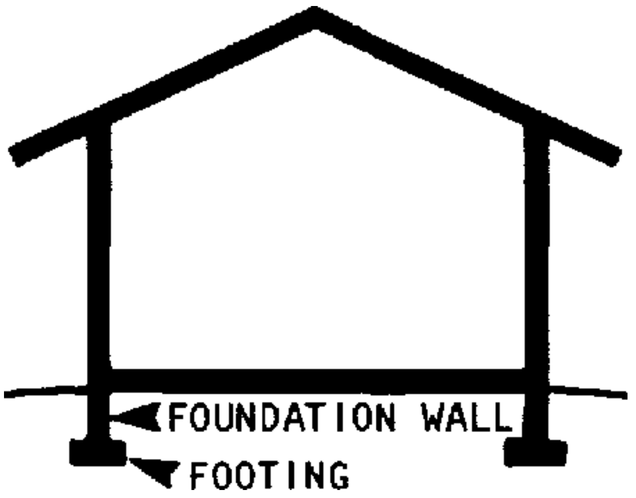
Transported Soils

Soils which are formed by weathering of rocks and that have been moved from their place of origin are called residual soils. The transported soils may be classified into several groups, depending on their mode of transportation and deposition:

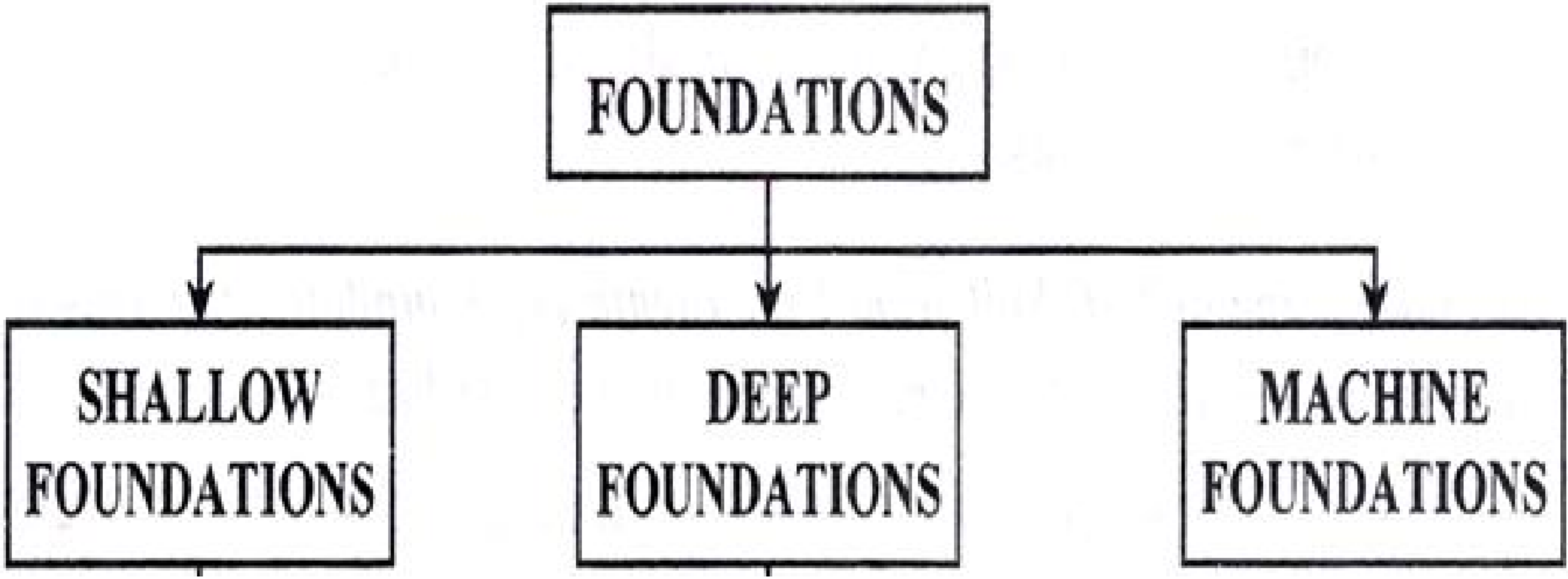
1. Glacial soils—formed by transportation and deposition of glaciers
2. Alluvial soils—transported by running water and deposited along streams
3. Lacustrine soils—formed by deposition in quiet lakes
4. Marine soils—formed by deposition in the seas
5. Aeolian soils—transported and deposited by wind
6. Colluvial soils—formed by movement of soil from its original place by gravity, such as during landslides.

Building Components





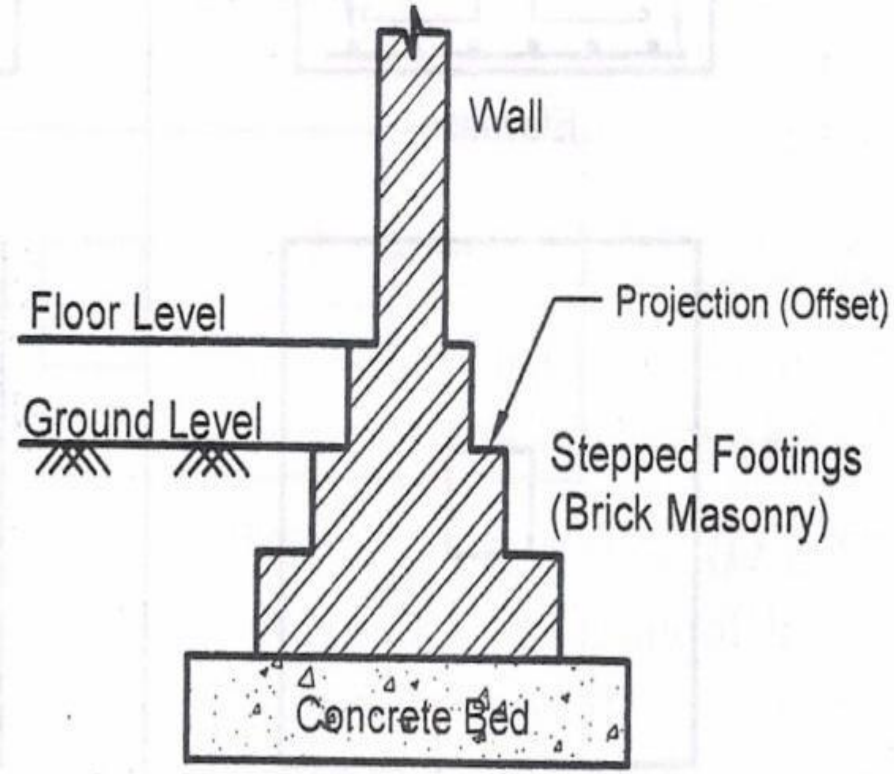
Types of foundation



SHALLOW FOUNDATIONS

(Open Foundations)

A Shallow Foundation is a type of foundation in which depth is equal to or less than its width.



(ii) Elevation

SHALLOW FOUNDATIONS

(Open Foundations)

It is built by open excavation of the soil. Hence, it is also known as Open Foundation.

The base of the structure is enlarged or spread to provide good and individual support to the load.

This type of foundation is provided for structures of moderate height, built on sufficiently firm dry ground.

This foundation is practicable up to a depth of 3 m to 4 m.

It is generally convenient above the water-table.

SHALLOW FOUNDATIONS

DEEP FOUNDATIONS

(Open Foundations)

A foundation is said to be a Deep Foundation, when its depth is more than the width of the foundation.

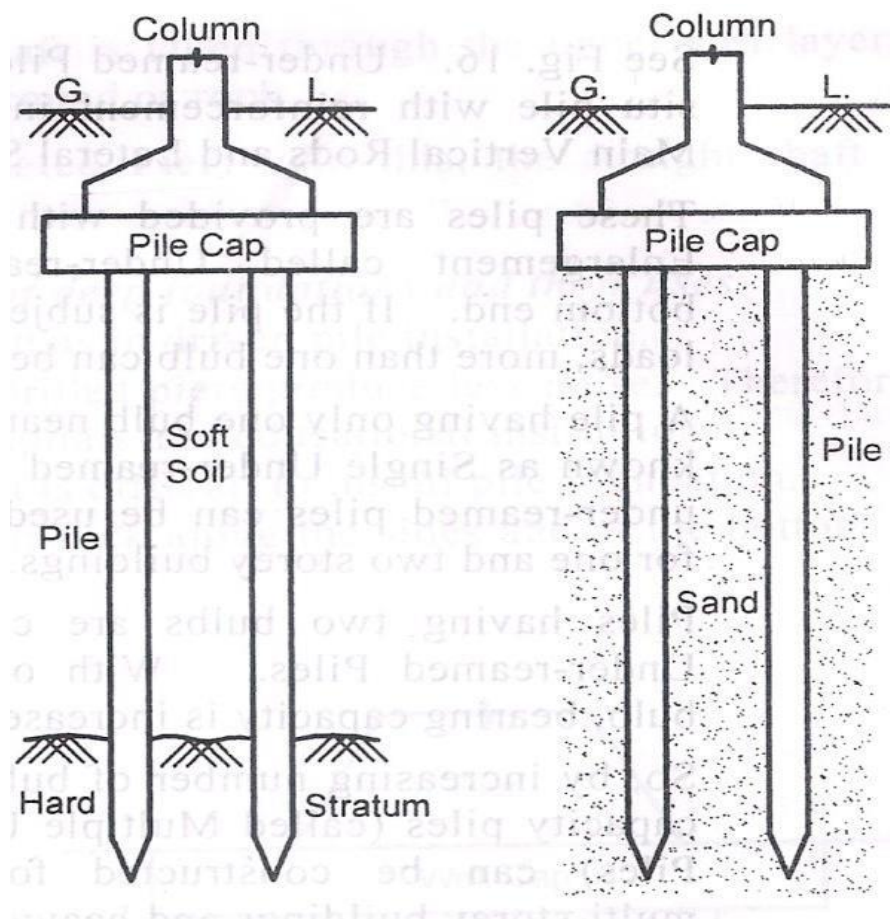


FIG. 14
END-BEARING PILES

FIG. 15
FRICTION PILES

DEEP FOUNDATIONS

Deep foundations transmit the load of a structure through weak soils to strong soil beds or rock beds available at great depth.

When the soil available at a reasonable depth of less than, say, 3 to 6 meters is not having the desired bearing capacity, deep foundation is used.

SHALLOW FOUNDATIONS

(Open Foundations)

Types of shallow foundations

(i) Spread footings

(ii) Combined footings

(iii) Strap footings

(iv) Raft or Mat Foundations

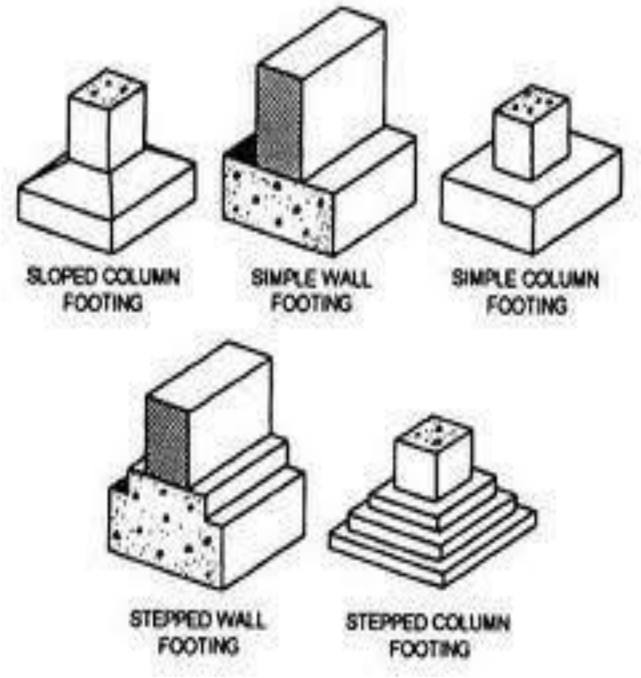
SHALLOW FOUNDATIONS

(Open Foundations)

(i) **Spread footings**

Spread footings are those which spread the Super-imposed load of wall or column over a larger area.

It supports one wall or one column.



Spread footings:

a) Strip footing

b) Isolated or Pad footing

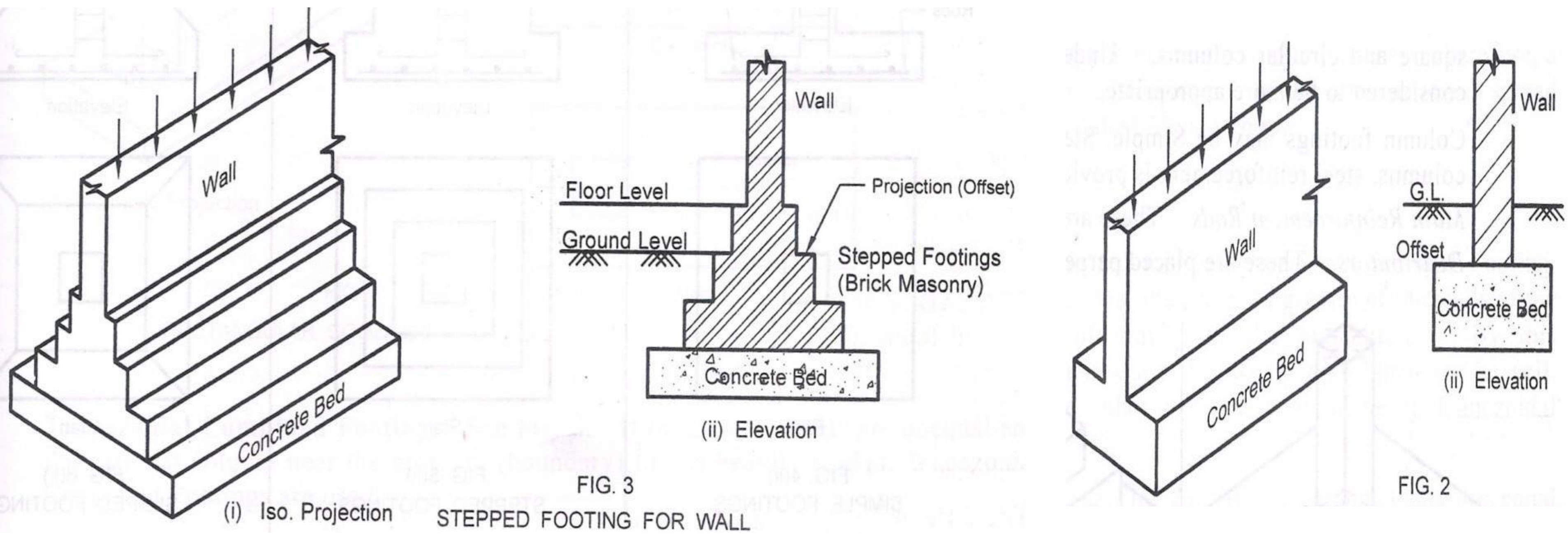
SHALLOW FOUNDATIONS

(Open Foundations)

Spread footings:

a) **Strip footing**: provides a continuous longitudinal bearing.

Spread footing for a continuous wall is called Strip footing.



SHALLOW FOUNDATIONS

(Open Foundations)

Spread footings:

b) **Isolated or Pad footing**:

Spread footing for a single column is called Isolated or Pad footing

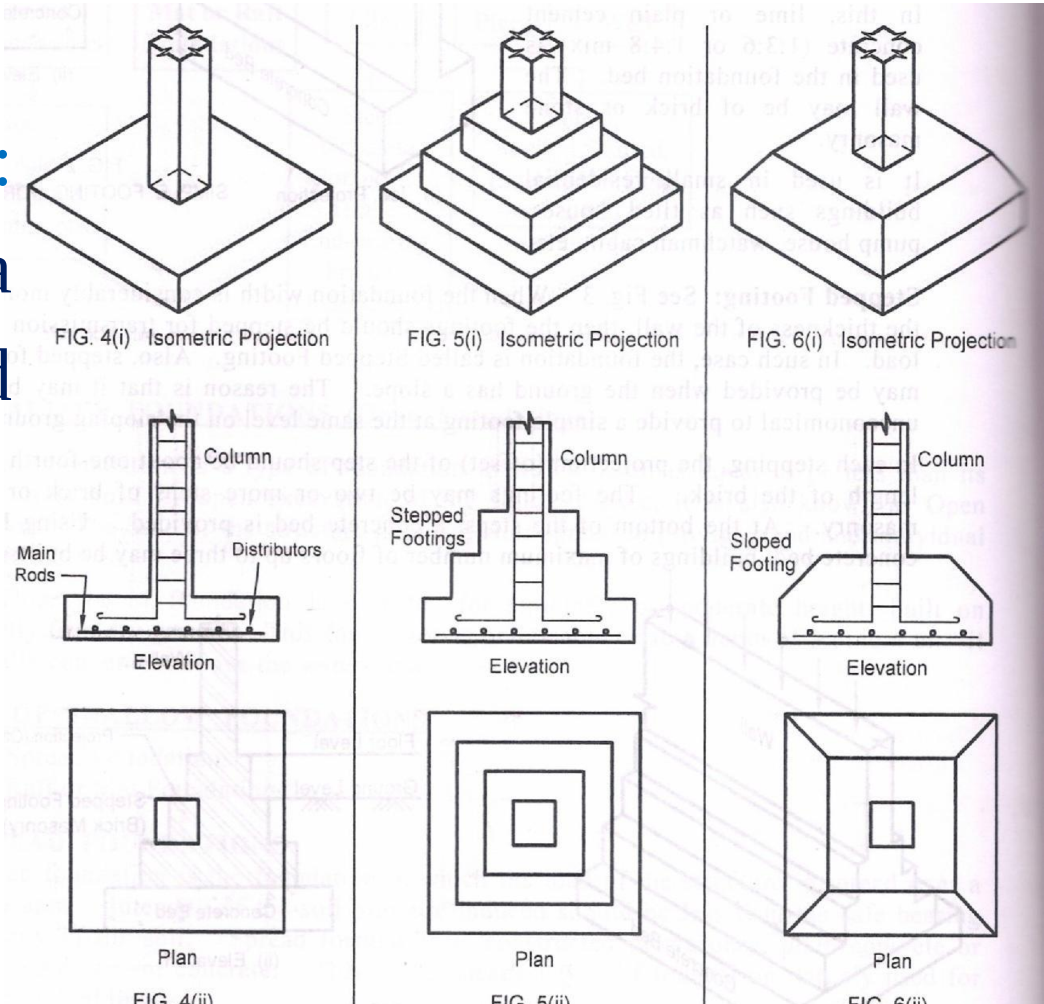


FIG. 4(ii) SIMPLE FOOTINGS

FIG. 5(ii) STEPPED FOOTINGS

FIG. 6(ii) SLOPED FOOTINGS

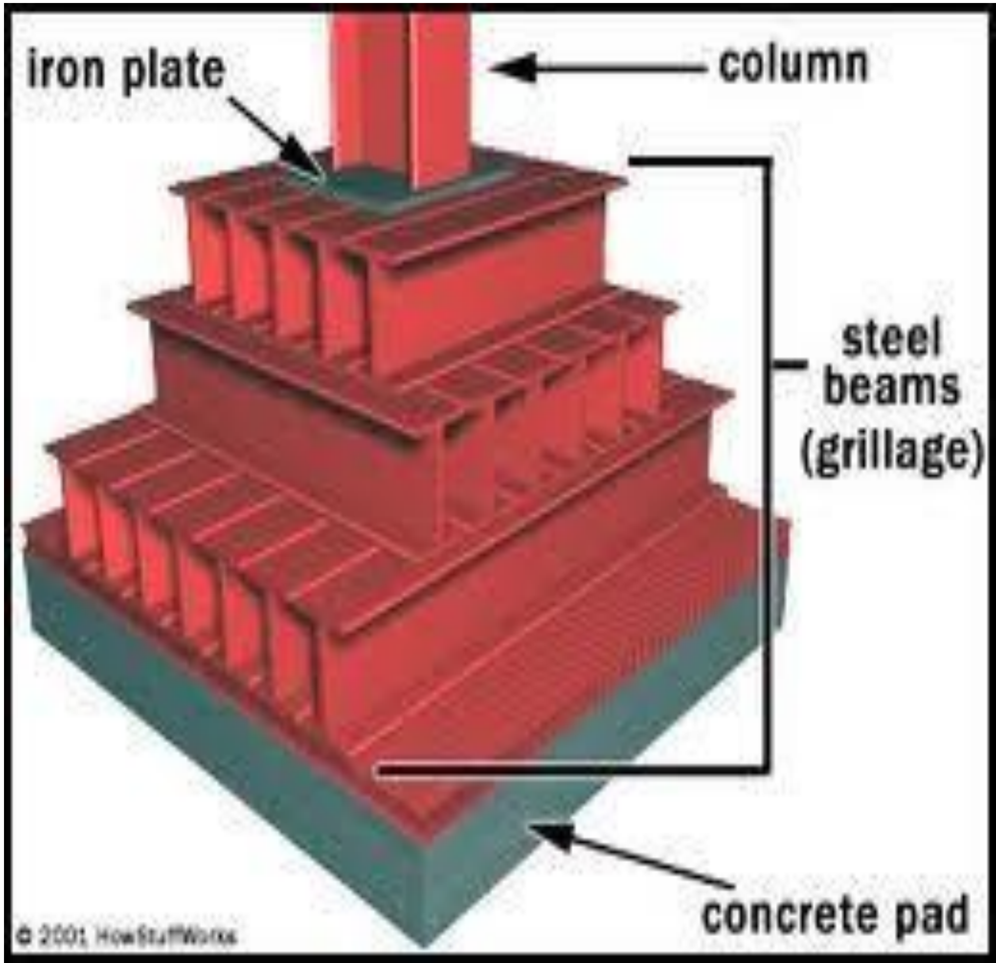
SHALLOW FOUNDATIONS

(Open Foundations)

b) **Isolated or Pad footing:**

Grillage Foundation:

Special type of isolated footing, generally provided for heavily loaded steel stanchions, specially in those locations where bearing capacity of soil is poor.



SHALLOW FOUNDATIONS

(Open Foundations)

ii) **Combined footing:** footing which supports two columns.

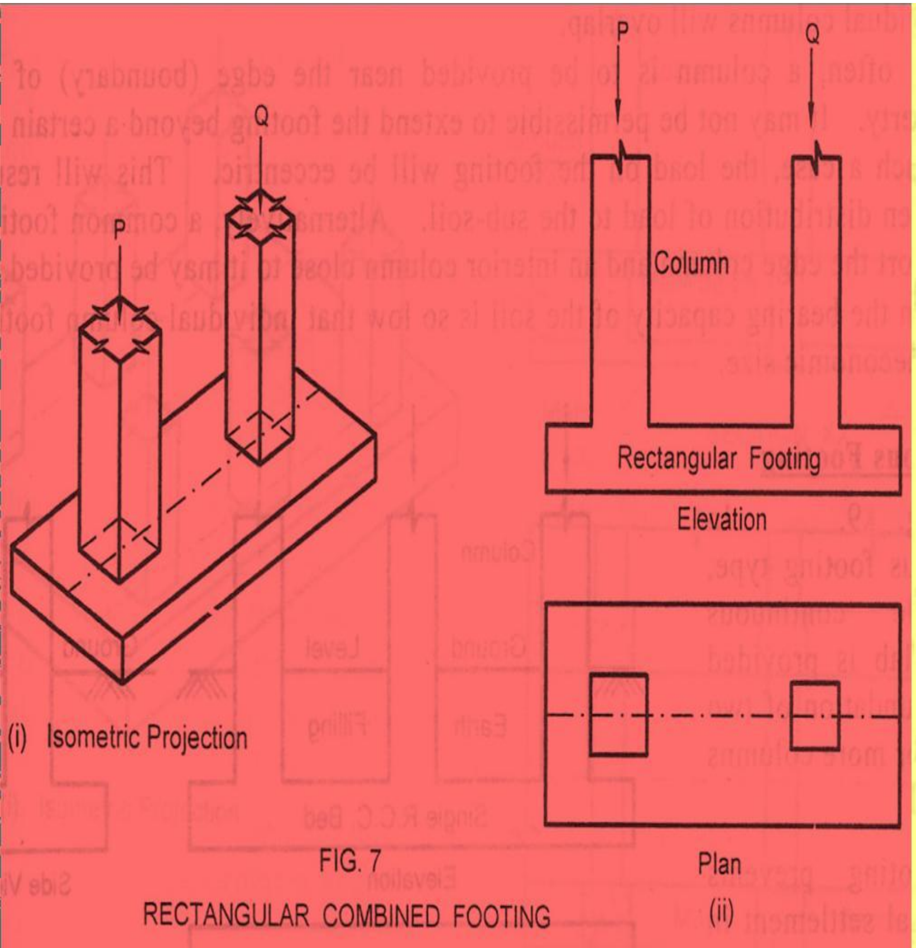


FIG. 7
RECTANGULAR COMBINED FOOTING

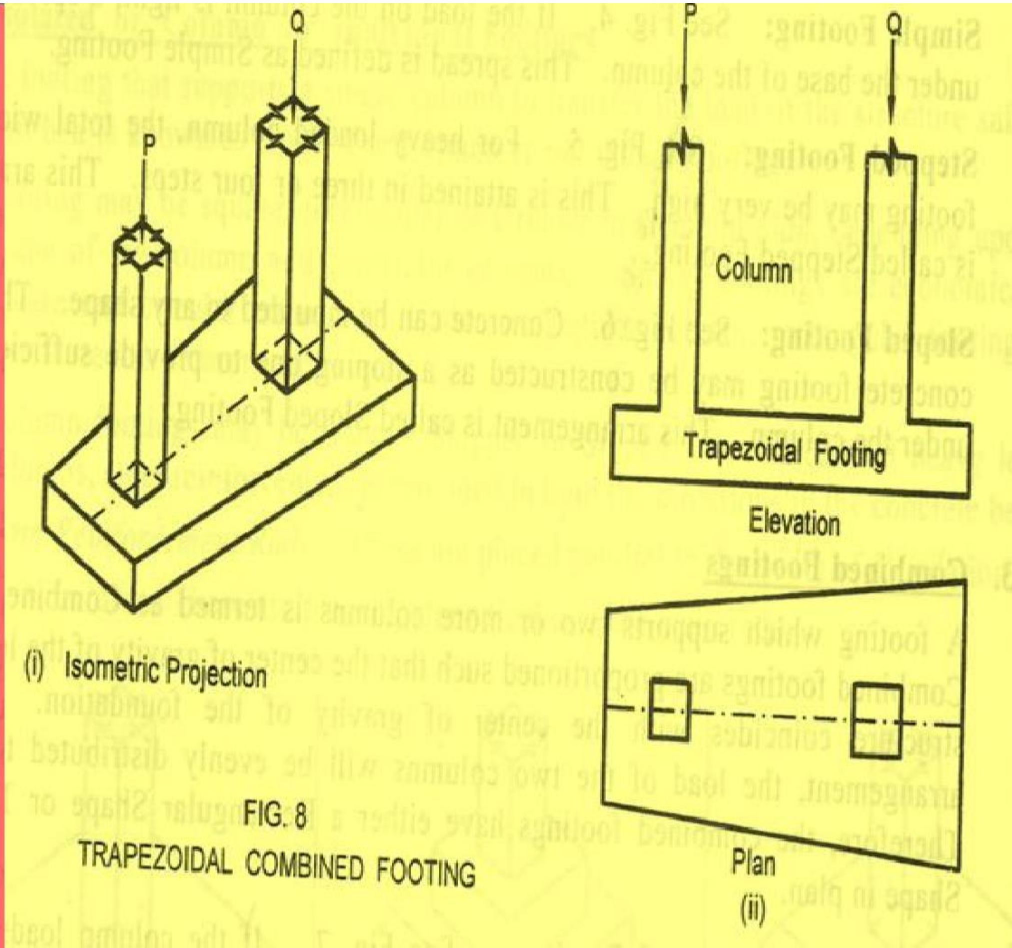


FIG. 8
TRAPEZOIDAL COMBINED FOOTING

SHALLOW FOUNDATIONS

(Open Foundations)

ii) **Combined footing**: footing which supports two columns.

Combined footings are used under the following circumstances:

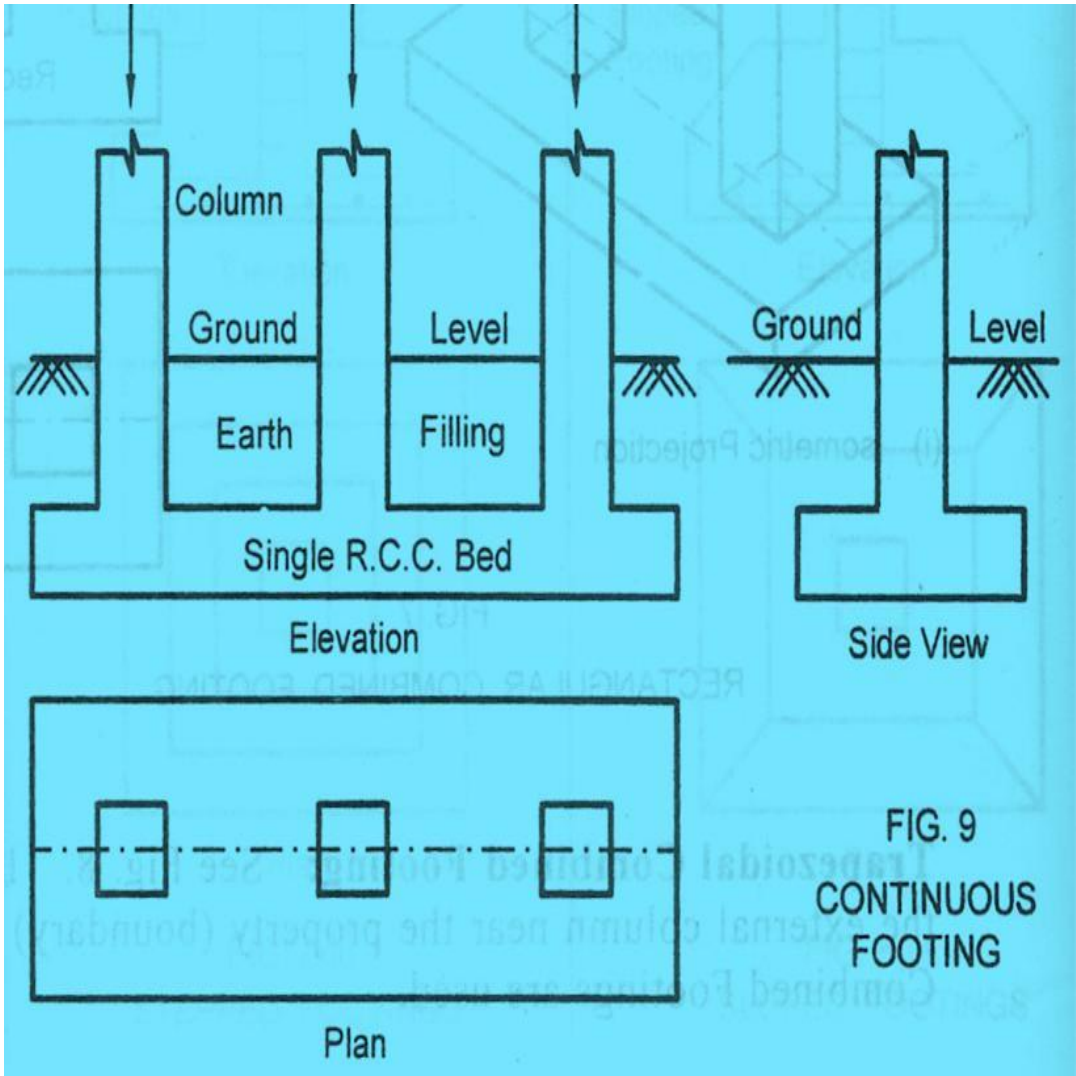
- When the space between two columns is so small that separate footings for individual columns will overlap.
- When the end column is near a property line so that its footing cannot spread in that direction.
- When the bearing capacity of the soil is so low that individual column footing is of uneconomic size.

SHALLOW FOUNDATIONS

(Open Foundations)

Continuous footing:

footing which supports more than two columns.

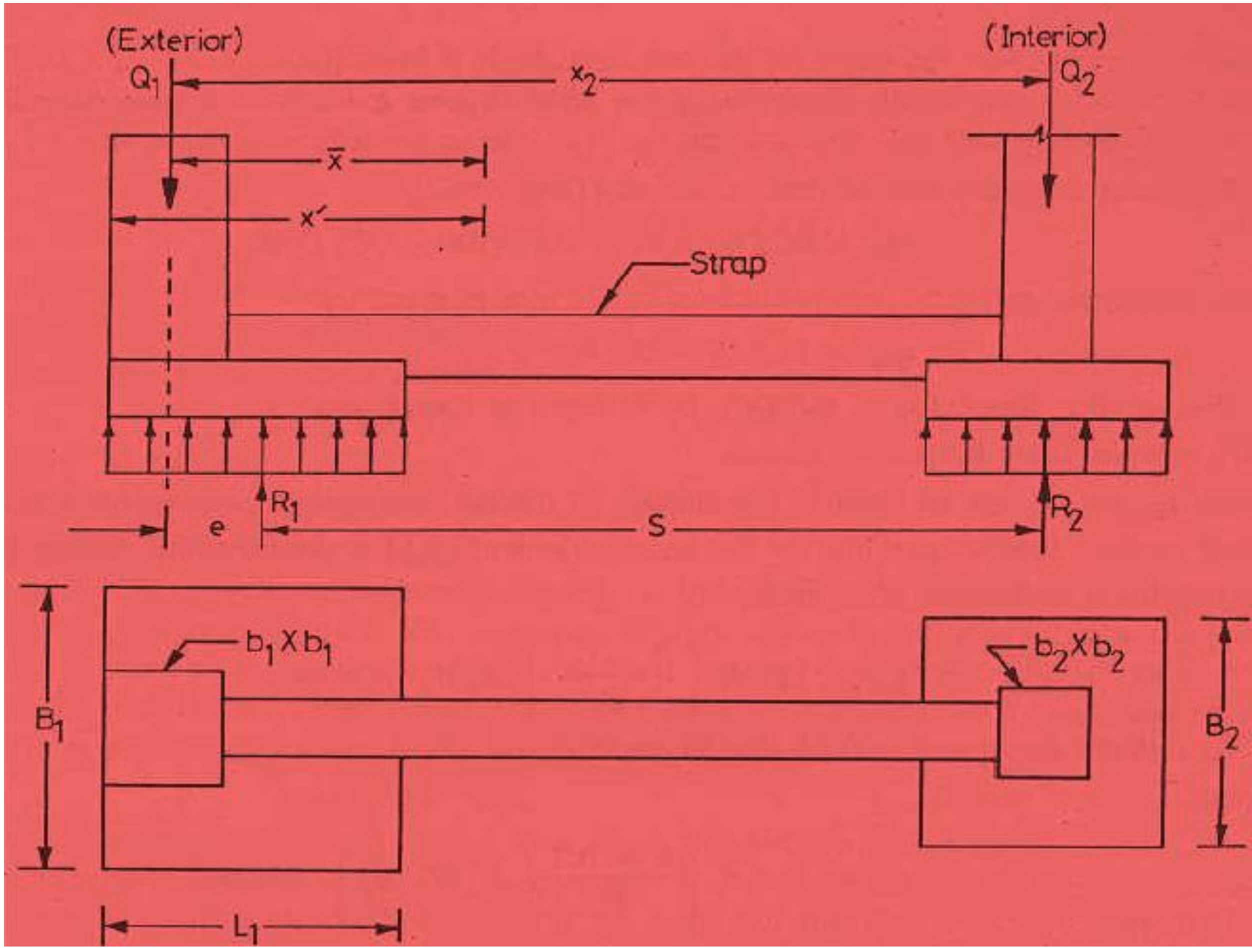


SHALLOW FOUNDATIONS

(Open Foundations)

(iii) Strap footing or Cantilever footing:

Two or more footings of individual columns, connected by a beam.



SHALLOW FOUNDATIONS

(Open Foundations)

(iv) Raft or Mat Foundations

A combined footing that covers the entire area beneath a structure and supports all the walls and columns.

Reduces the possibility of differential (unequal) settlement and provides a condition of uniform settlement.

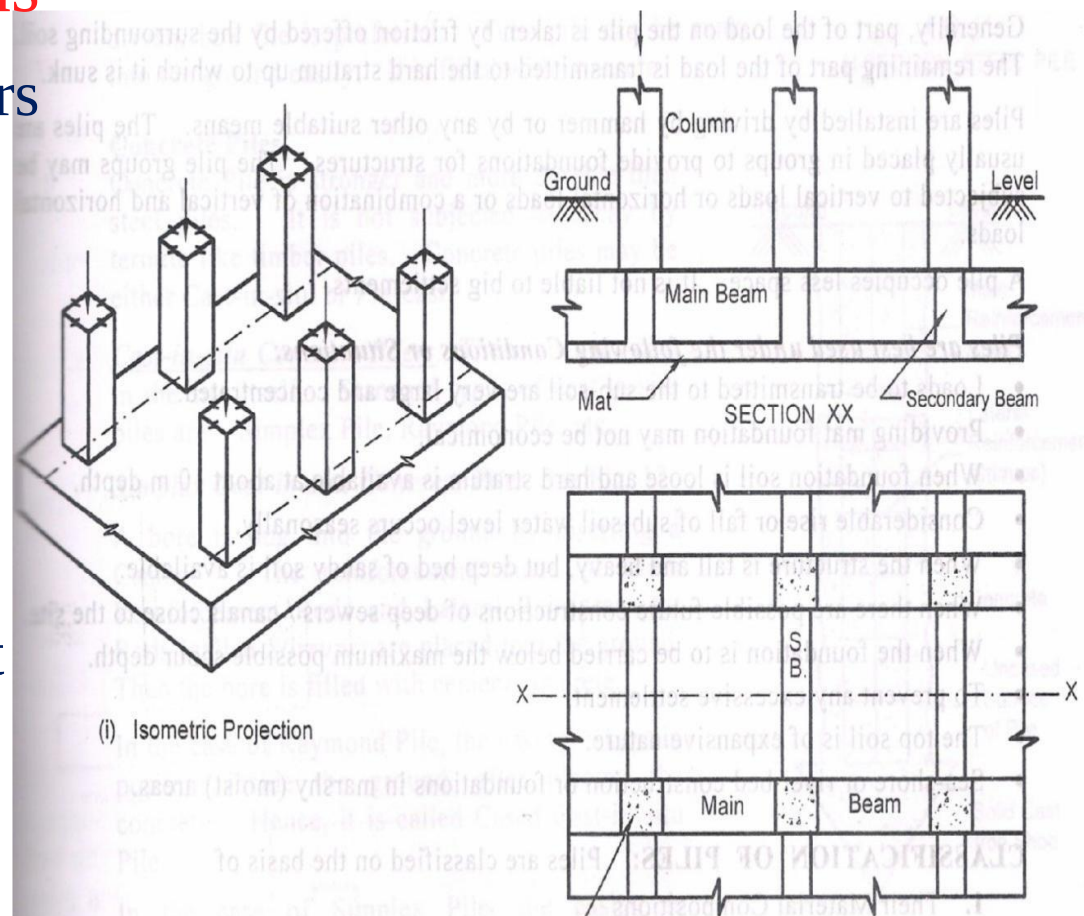


FIG. 10

RAFT OR MAT FOUNDATION

SHALLOW FOUNDATIONS

(Open Foundations)

(iv) Raft or Mat Foundations

Raft or Mat foundations are used

(i) When the column spacing is small.

(ii) When the load of the structure is heavy.

(iii) When the soil mass contains compressible lenses or soil is sufficiently erratic.

SHALLOW FOUNDATIONS (Open Foundations)
DEEP FOUNDATIONS

General forms of deep foundations are:

(i) Pile foundation

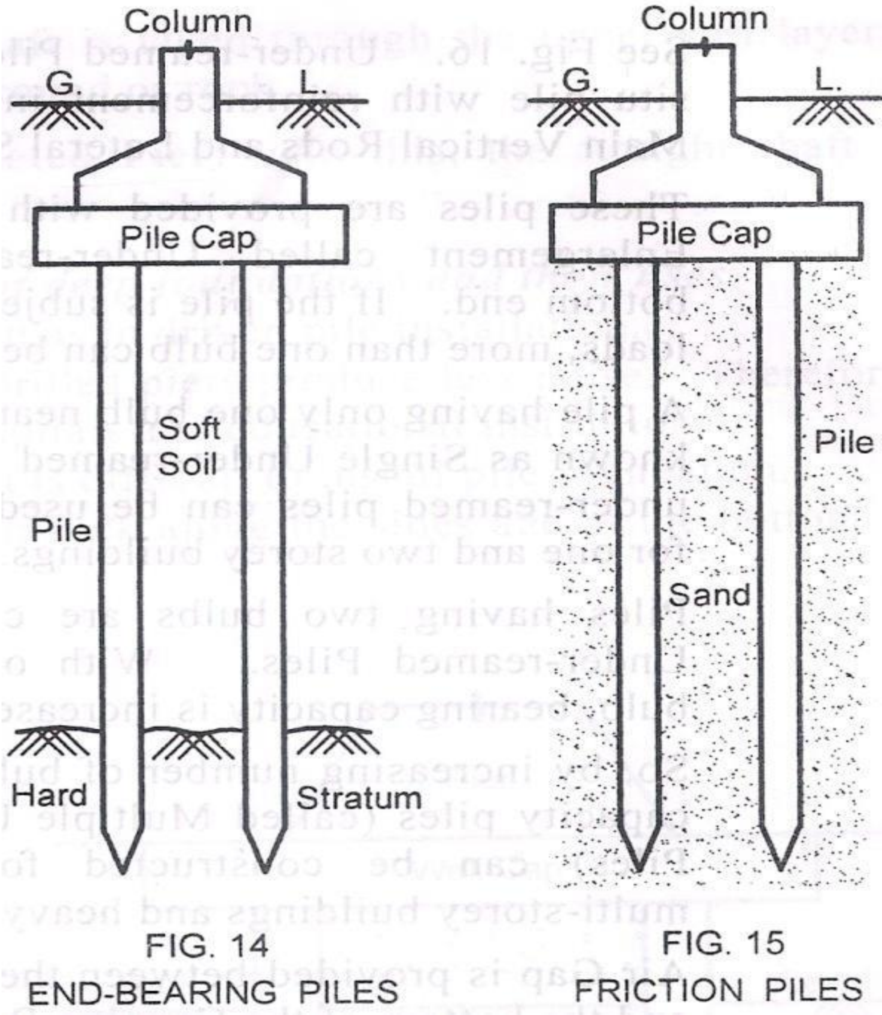
(ii) Pier foundation and

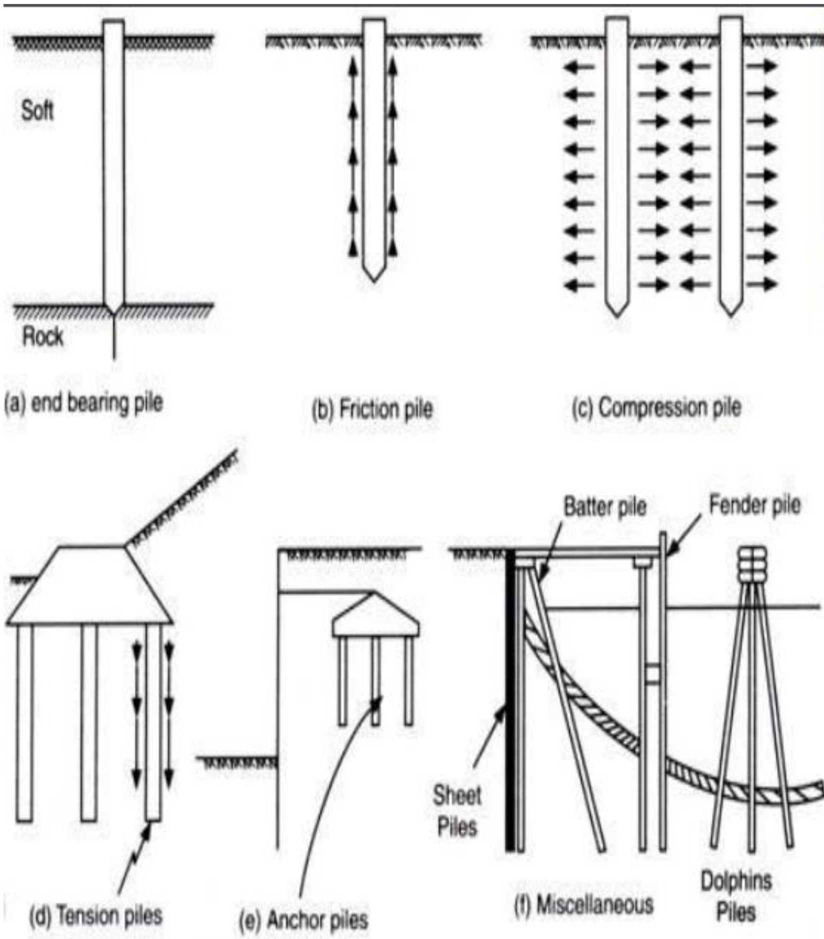
(iii) Caisson or Well foundation.

DEEP FOUNDATIONS

PILE FOUNDATION

Type of deep foundation in which the loads are taken to a low level by means of vertical members which may be of timber, concrete or steel.





TYPES OF PILES

Depending on function piles are classified as

- End bearing piles
- Friction piles
- Combined end bearing & friction piles
- Compaction piles
- Tension Piles or Uplift Piles
- Anchor piles
- Fender piles
- Batter piles
- Sheet piles

BASED ON INSTALLATION METHODS

(i) Bored piles:
Bored piles are constructed in pre-bored holes either using a casing or by circulating stabilizing agent like bentonite slurry.
Board piles are of following types:
Small diameter piles-up to 600 mm diameter;
large diameter piles-diameter greater than 600 mm;
under reamed piles.

(ii) Driven piles:
Driven piles may be of concrete, steel or timber. These piles are driven into the soil by the impact of hammer.

(iii) Driven and cast-in-situ piles:
It is a type of driven pile. They are constructed by driving a steel casing in to the ground. The hole is then filled with concrete by placing the reinforcement and the casing is gradually lifted.

PIER FOUNDATION:

A pier is a vertical column of a relatively larger cross-section than a pile. A pier is installed in a dry area by excavating a cylindrical hole of a large diameter to the desired depth and then backfilling it with concrete.

A distinction between a cast-in-situ pile and a pier is rather arbitrary. A cast-in-situ pile greater than 0.6 m diameter has generally termed a pier.

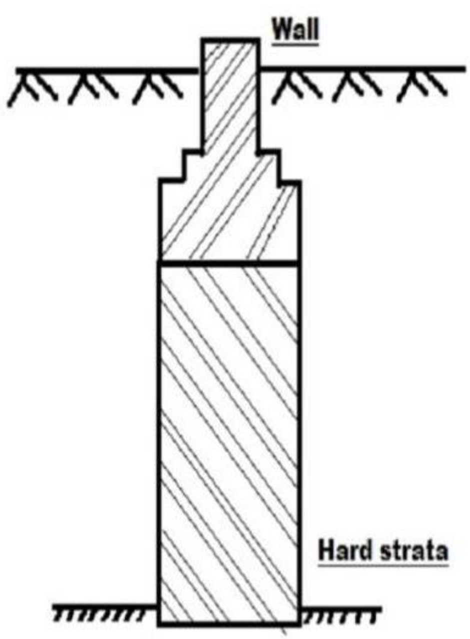
Generally, the pier foundation is shallower in-depth than the pile foundation. Pier foundation is preferred in a location where the top strata consist of decomposed rock overlying strata of sound rocks. In such a condition, it becomes difficult to drive the bearing piles through decomposed rock.

In the case of stiff clays, which offer large resistance to the driving of a bearing pile, a pier foundation can be conveniently constructed.

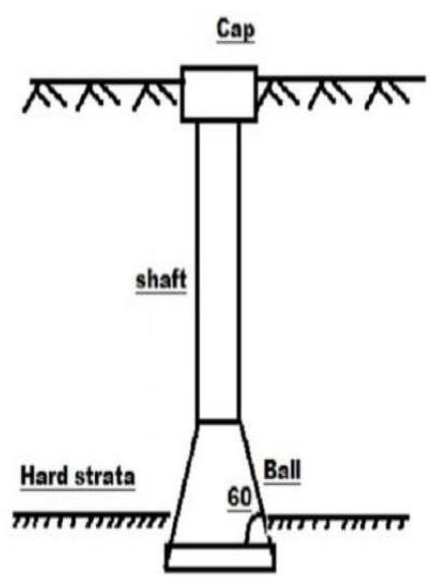
Types of pier foundation

Pier foundation may be of the following types

- Masonry or concrete pier
- Drilled caisson



Masonry pier



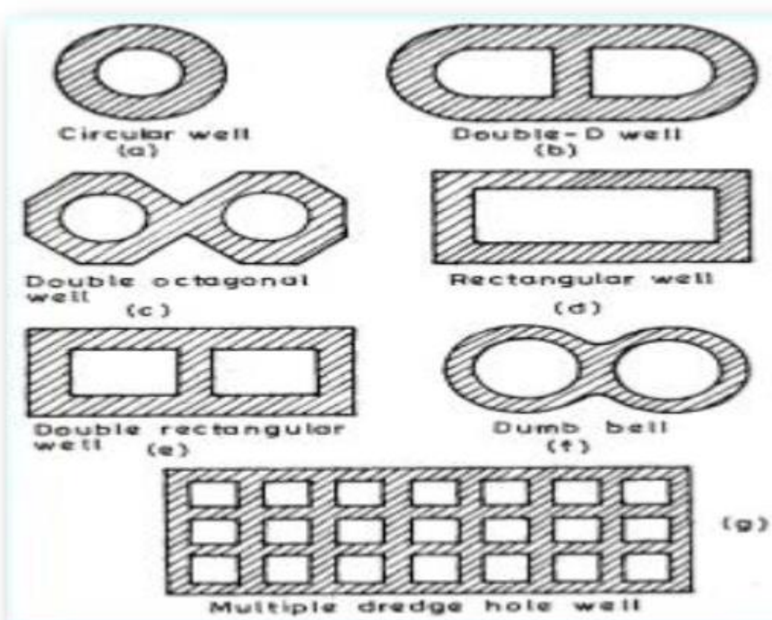
Drilled caisson of concrete

CAISSON OR WELL FOUNDATION

Caisson foundations, also known as pier foundations, are prefabricated hollow substructures designed to be constructed on or near the surface of the ground, sunk to the desired depth and then filled with concrete, thus ultimately becoming an integral part of the permanent structure.

Caisson is used in building bridge piers as it stays in water almost all the time. Caisson is constructed in connection with excavation for the foundation of piers and abutments in rivers and lake, bridges breakwater dock structures for the point of view of shore protection, lamp house etc.

Shapes of well foundation



Foundation Importance

1. To anchor the mass of the building.
2. To dispense load transferred and spread uniformly.
3. To lay out the lateral stability of the structure evenly.
4. To erupt movement of soil.
5. To protect from natural forces.
6. To suppress the growth of mold.
7. To provide insulation against heat and cold.
8. To resist the effects of settlement and subsidence.
9. To preserve the building from water and moisture damage.
10. To supply a sound barrier.

Factors to be considered in Selection of Foundation Type.

- Importance of the Building.
- Life of the Structure.
- Loads from superstructure.
- Type of construction materials to be used.
- Water table level.
- Type of adjoining structure.
- Soil condition.
- Location of building.

NOVEL AREAS

CONCEPTS OF AUTOMATION AND ROBOTICS IN CONSTRUCTION

Automation and robotics are increasingly being used in the construction industry to improve productivity, safety, and efficiency. Here are some key concepts of automation and robotics in construction

1. Automated machinery: Construction sites are now using automated machinery, such as bulldozers, excavators, and cranes, to perform tasks such as grading, excavation, and material handling. These machines can work faster, more precisely, and with less risk of error than human operators
2. Drones: Drones are being used in construction for tasks such as surveying, mapping, and inspections. Drones can capture high-resolution images and data that can be used to create 3D models, monitor progress, and identify potential issues
3. Building Information Modeling (BIM): BIM is a digital representation of a building or structure that includes information on the materials, components, and systems used in construction. BIM can be used to optimize construction processes, improve efficiency, and reduce waste
4. Robotics: Robots are being used in construction for tasks such as bricklaying, welding, and concrete spraying. Robots can work with a high level of precision, speed, and safety, reducing the need for human labor
5. Autonomous vehicles: Autonomous vehicles, such as self-driving trucks, are being used in construction to transport materials and equipment. These vehicles can operate 24/7, reducing the need for human drivers and improving efficiency.

APPLICATIONS OF ROBOTICS AND AUTOMATION IN THE CONSTRUCTION

1. Building construction: Robots and automation can be used in building construction for tasks such as bricklaying, welding, and concrete spraying. These robots can work with a high level of precision, speed, and safety, reducing the need for human labor and improving the quality of construction
2. Demolition and excavation: Robots can be used for demolition and excavation work,such as demolishing buildings or excavating foundations. These robots can work in tight spaces, reducing the need for human labor and improving safety
3. Material handling: Automated machinery, such as bulldozers, excavators, and cranes, can be used for material handling tasks, such as moving heavy objects and transporting materials. These machines can work faster, more precisely, and with less risk of error than human operators
4. Surveying and inspection: Drones can be used for surveying and inspecting construction sites, providing high-resolution images and data that can be used to create 3D models, monitor progress, and identify potential issues

5. Safety and monitoring: Robotics and automation can be used for safety and monitoring purposes, such as detecting hazards, monitoring equipment, and conducting safety inspections. These technologies can improve safety on construction sites and reduce the risk of accidents

BENEFITS OF AUTOMATION IN CONSTRUCTION

1. Increased productivity
2. Improved quality
3. Enhanced safety
4. Reduced labor costs
5. Improved efficiency
6. Improved sustainability
7. Increased accuracy
8. Access to difficult areas

SUSTAINABILITY IN CIVIL ENGINEERING

Sustainability in civil engineering refers to the practice of designing, constructing, operating, and maintaining infrastructure in a way that minimizes negative impacts on the environment and society while maximizing long-term economic benefit

The concept of sustainability in civil engineering encompasses three main pillars: environmental sustainability, social sustainability, and economic sustainability

1. Environmental sustainability: This refers to the ability to design and construct infrastructure in a way that minimizes negative impacts on the natural environment. This includes reducing greenhouse gas emissions, conserving natural resources such as water and energy, minimizing waste and pollution, and using sustainable materials
2. Social sustainability: This refers to the ability to design and construct infrastructure that meets the needs of communities and improves their quality of life. This includes designing infrastructure that is accessible and safe for all users, including those with disabilities, and that considers the cultural, social, and economic context of the community
3. Economic sustainability: This refers to the ability to design and construct infrastructure in a way that is cost-effective over the long term. This includes considering the life-cycle cost of the infrastructure, including construction, operation, and maintenance costs, as well as the economic benefits that the infrastructure will provide over time.

Different methods to achieve sustainability in civil engineering and its relevance to civil engineering

There are several methods that can be used to achieve sustainability in civil engineering. Below are some of the key methods and their relevance to civil engineering

1. Green infrastructure: Green infrastructure refers to the use of natural or semi-natural systems to manage storm water, reduce urban heat island effects, and provide habitat for wildlife. Civil engineers can design green infrastructure systems, such as green roofs, bioswales, and rain gardens, to help cities become more sustainable and resilient to climate change
2. Sustainable materials: Using sustainable materials in construction can help to reduce the environmental impact of buildings and infrastructure. Civil engineers can specify sustainable materials, such as recycled content materials, and ensure that they are sourced and manufactured in an environmentally responsible manner
3. Life-cycle assessment: Life-cycle assessment is a method for assessing the environmental impact of a product or system throughout its entire life cycle, from raw material extraction to disposal. Civil engineers can use life-cycle assessment to guide design decisions and identify opportunities to reduce the environmental impact of infrastructure project
4. Energy efficiency: Designing buildings and infrastructure to be energy efficient can help to reduce energy consumption and greenhouse gas emissions. Civil engineers can design buildings with passive solar features, specify energy-efficient lighting and HVAC systems, and incorporate renewable energy systems, such as solar panels and wind turbines
5. Sustainable transportation: Encouraging sustainable transportation, such as walking, cycling, and public transit, can help to reduce greenhouse gas emissions and improve air quality. Civil engineers can design pedestrian and cycling infrastructure, as well as public transit systems, to encourage sustainable transportation options

SUSTAINABLE GOALS PROVIDED BY UNITED NATIONS AND ITS RELEVANCE TO CIVIL ENGINEERING

The United Nations has provided 17 Sustainable Development Goals (SDGs) as part of the 2030 Agenda for Sustainable Development. These goals provide a comprehensive framework for achieving sustainable development across all sectors, including civil engineering. Below are some of the SDGs and their relevance to civil engineering

1. SDG 6 - Clean water and sanitation: Civil engineers play a crucial role in designing and implementing sustainable water and sanitation systems, including water treatment plants, wastewater treatment systems, and drainage system
2. SDG 7 - Affordable and clean energy: Civil engineers can design and implement sustainable energy systems, such as renewable energy sources like solar, wind, and hydroelectric power
3. SDG 9 - Industry, innovation and infrastructure: Civil engineers are responsible for designing and building infrastructure that supports sustainable economic growth, including transportation systems, buildings, and energy infrastructure
4. SDG 11 - Sustainable cities and communities: Civil engineers can help create sustainable urban environments by designing infrastructure that reduces energy consumption, promotes sustainable transportation, and enhances public space
5. SDG 13 - Climate action: Civil engineers can play a key role in mitigating climate change by designing infrastructure that reduces greenhouse gas emissions and is resilient to climate change impacts, such as sea-level rise and extreme weather event
6. SDG 15 - Life on land: Civil engineers can contribute to protecting and restoring terrestrial ecosystems by designing infrastructure that minimizes habitat fragmentation, reduces soil erosion, and conserves biodiversity.

SMART CITY

CONCEPT

The concept of smart city in civil engineering refers to the integration of advanced technology and infrastructure to enhance the quality of life, promote sustainable development, and improve the efficiency of urban services. Smart city initiatives typically involve the use of data and communication technologies to connect various urban systems, including transportation, energy, water, waste management, and public services.

Civil engineers play a critical role in the development of smart cities by designing and implementing infrastructure and systems that can support smart city initiatives. For example,civil engineers may design smart transportation systems that incorporate real-time data on traffic patterns and optimize traffic flow, or they may design and implement smart energy systems that use renewable energy sources and advanced monitoring and control systems to improve energy efficiency.

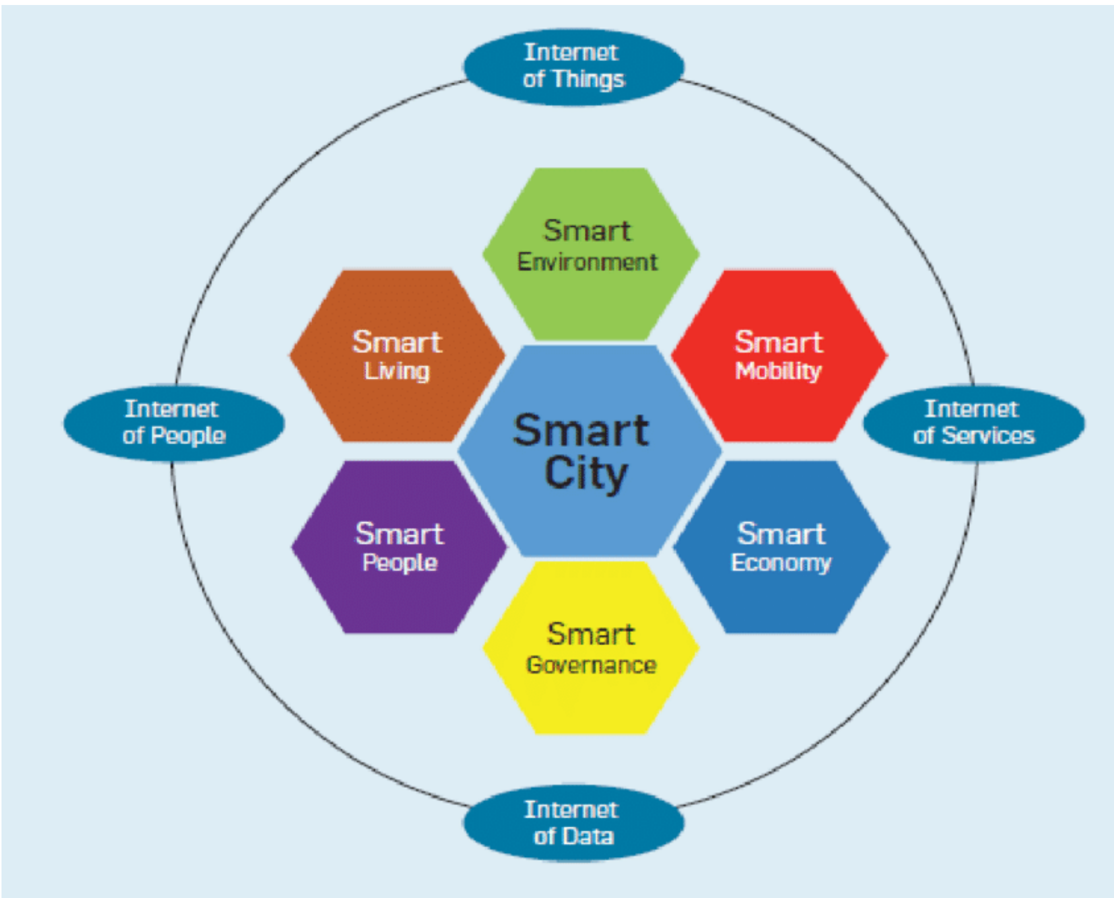
In addition, civil engineers are responsible for designing and constructing sustainable buildings and infrastructure that can support the long-term development of smart cities. This may involve designing green buildings that use advanced materials and construction techniques to reduce energy consumption and carbon emissions, or developing infrastructure that can support the use of electric vehicles and other sustainable transportation modes.

What makes a city smart in Indian context?

In the Indian context, a smart city is characterized by the use of advanced technology and innovative solutions to address the challenges of urbanization and improve the quality of life for its citizens. The Government of India's Smart Cities Mission is a flagship program that aims to promote sustainable and inclusive development in urban areas across the country.

1. Technology-enabled infrastructure: A smart city in India should have a robust and well-connected infrastructure that leverages technology to enhance efficiency and service delivery. This includes advanced transportation systems, smart energy grids, and digital connectivity
2. Citizen participation and engagement: A smart city should prioritize citizen participation and engagement, empowering citizens to have a say in how their city is developed and managed. This can be achieved through digital platforms, public consultations, and community engagement programs
3. Sustainable development: A smart city should promote sustainable development practices, such as the use of renewable energy sources, waste reduction, and greeninfrastructure. This can help reduce the carbon footprint of the city and mitigate the impacts of climate change
4. Efficient public services: A smart city should provide efficient and reliable public services, such as healthcare, education, and public safety. This can be achieved through the use of technology, data analytics, and effective governance
5. Economic growth and innovation: A smart city should foster economic growth and innovation by promoting entrepreneurship, creating job opportunities, and attracting investment. This can be achieved by developing a vibrant and inclusive business ecosystem that supports innovation and growth.

COMPONENTS OF SMART CITY



1. **In the context of urban and rural development, how would you describe a smart city? What makes a city smart?**

   A smart city is a city that uses technology and data-driven solutions to improve the quality of life for its residents, enhance sustainability, and improve efficiency. In a smart city, digital technology and data are used to manage and optimize a range of urban services, such as transportation, energy, waste management, and public safety.

   Some key characteristics that make a city smart include

   1. Digital infrastructure: A smart city requires a robust digital infrastructure, including high-speed broadband networks, sensors, and other technologies that can collect and analyze data from various sources
   2. Data-driven decision-making: Smart cities rely on data to make informed decisions about urban planning, service delivery, and resource allocation. Data is used to

optimize infrastructure, improve public services, and enhance the overall quality of life for residents

3. Integration of urban systems: Smart cities integrate different urban systems, such as transportation, energy, and waste management, to optimize efficiency and reduce waste
4. Citizen engagement: A smart city engages its citizens in decision-making processes and encourages their participation in shaping the city's future
5. Sustainability: Smart cities prioritize sustainability by using renewable energy sources, promoting green infrastructure, and reducing carbon emissions
6. Innovation: Smart cities are characterized by a culture of innovation, which is encouraged through collaboration between public and private sectors, research institutions, and startups.

SAFE AND CLEAN CITY

Concept

The concept of a safe and clean city is important to civil engineering as it encompasses the design, construction, and maintenance of infrastructure that supports a healthy and sustainable environment for residents

From a civil engineering perspective, a safe and clean city involves

1. Safe buildings and infrastructure: Civil engineers play a vital role in ensuring that buildings and infrastructure are designed and constructed to be safe and resilient to natural disasters, such as earthquakes, hurricanes, and floods. This includes designing structures to withstand the forces of nature and ensuring that they are constructed to meet safety codes and standards
2. Sustainable transportation: Civil engineers are responsible for designing and maintaining transportation systems that are safe, efficient, and environmentally sustainable. This includes promoting the use of public transportation, bicycles, and pedestrian-friendly infrastructure to reduce traffic congestion and air pollution
3. Efficient water and waste management: Civil engineers design and implement systems for managing water and waste, such as storm water management, wastewater treatment, and solid waste management. These systems are essential for maintaining a clean and healthy environment, preventing water pollution and minimizing the risk of diseaseoutbreaks
4. Green infrastructure: Civil engineers are increasingly incorporating green infrastructure elements, such as green roofs, rain gardens, and bios wales, into their designs to improve

the quality of urban life. These elements help to reduce the urban heat island effect, improve air and water quality, and promote biodiversity in cities.

COMPONENTS

1. Adequate infrastructure: This includes well-maintained roads, sidewalks, public transportation, and buildings that are up to code
2. Efficient waste management: The city must have an effective system for managing and disposing of waste to ensure clean streets and waterways
3. Access to clean water: The city should provide clean drinking water to its residents and have a system for monitoring and ensuring the quality of the water supply
4. Effective public transportation: A well-designed public transportation system can reduce traffic congestion and air pollution while improving accessibility and mobility for residents
5. Adequate lighting: Adequate lighting is important for pedestrian and driver safety and can also discourage criminal activity
6. Clean air: The city should take measures to reduce air pollution and promote clean air through programs such as public transportation and the use of renewable energy sources
7. Access to green spaces: The city should have parks and other green spaces for residents to enjoy, which can also help improve air quality and reduce the urban heat island effect
8. Active community engagement: Residents should have a say in the decisions that affect their community, and the city should promote transparency and collaboration between government officials and community member.

CHALLENGES AND WAY FORWARD

Challenges

1. Limited funding: Developing and maintaining safe and clean cities requires significant investment, which can be difficult to secure in the face of competing priorities
2. Population growth: Rapid urbanization can lead to increased pollution, traffic congestion, and strain on resources such as water and energy
3. Lack of public awareness: Residents may not be aware of the impact of their actions on the environment and public health, which can hinder efforts to create clean and safe cities
4. Insufficient infrastructure: Inadequate infrastructure can lead to poor waste management, unsafe buildings, and limited access to clean water and transportation
5. Limited public participation: Residents may feel disconnected from decision-making processes and lack a sense of ownership over their communities, which can limit community engagement and collaboration

   Way forward

1. Investing in infrastructure: Governments can allocate resources to build and maintain the necessary infrastructure to ensure safe and clean cities, including roads, public transportation, and waste management systems
2. Promoting public awareness: Governments can educate residents about the importance of environmental protection and public health, and provide informationon how individuals can contribute to the effort
3. Encouraging public participation: Governments can create opportunities for residents to participate in decision-making processes and collaborate on community initiatives
4. Supporting innovation: Governments can support research and development of new technologies and approaches to creating safe and clean cities, such as renewable energy sources and smart waste management systems
5. Collaboration and partnerships: Governments, private sector, and civil society organizations can work together to pool resources and expertise to achieve shared goals of creating safe and clean cities.