DESIGN OF REINFORCED EARTH RETAINING WALL USING PYTHON CODE

A project report submitted in partial fulfillment of the requirements for the award of degree of

Bachelor of Technology

in

Civil Engineering

Submitted by

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DEPARTMENT OF CIVIL ENGINEERING

MVGR COLLEGE OF ENGINEERING (Autonomous)

Approved by AICTE - New Delhi, accredited by NBA (Tier) of AICTE and NAAC of UGC, listed under 2 (F), 12 (B) of UGC Act, permanently affiliated to JNTU Kakinada

VIZIANAGARAM-535005

April 2023

DEPARTMENT OF CIVIL ENGINEERING

Vision of Department:

To become a pre-eminent Department of Civil Engineering that brings out technically competent, ethically sound and globally employable professionals capable of addressing societal challenges by providing sustainable solutions

Mission of Department:

Aspire to reach higher quality benchmarks in training students on all skills expected of a computer professional through a meticulously planned yet flexible learning process administered:

M1. Design and develop curriculum for UG and PG programs of Civil Engineering that adds value to student competencies abreast with changing industry needs

M2. Impart students with knowledge of Civil Engineering and use of modern tools and provide the best learning resources

M3. Provide an enabling environment to equip students to serve the society as leading professionals, academicians, innovators and entrepreneurs

M4. Promote and undertake academic research to address societal challenges.

M5. Provide testing and design consulting services to the industry and create Industry-Academia synergy for improving employability of students

Program Educational Objectives (PEOs):

PEO 1: DOMAIN KNOWLEDGE Graduates will have the fundamental knowledge of mathematics, science, economics and computing and in-depth knowledge in Civil Engineering concepts through theoretical, laboratory and project-based experiences so as to design, develop and solve engineering problems.

PEO 2: EMPLOYMENT Graduates will get employed in national and international; government and private organizations, and will succeed in their chosen engineering careers through their skills, knowledge, personality and aptitude for innovation.

PEO 3: HIGHER STUDIES & LIFELONG EDUCATION Graduates will pursue advanced degrees in engineering and other fields; and will have skills of continued, independent and life-long learning to become experts in their profession by self-instilled passion and systematic approach.

PEO 4: PROFESSIONAL CITIZENSHIP Graduates will organize and present information, write and speak well, work effectively with strong organizational skills in multidisciplinary teams on team-based engineering projects and practice ethics and have a sense of social responsibility.

PEO 5: MODERN TOOLS: Graduates will plan, design, execute, maintain and rehabilitate civil engineering structures / systems and solve civil engineering problems using analytical methods or modern tools and techniques

Mapping of Mission statements with PEO's:

MISSION STATEMENTS OF THE DEPARTMENT	PEO 1	PEO 2	PEO 3	PEO 4	PEO 5
M1	3	3	3	2	1
M2	3	-	2	1	3
M3	2	3	-	3	-
M4	1	2	3	2	1
M5	1	3	2	3	2

(3-Highly Relevant, 2-Medium, 1-Low)

PO's and PSO's

PO's

1. **Engineering Knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

2. **Problem Analysis:** Identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

3. **Design/development of Solutions:** Design solutions for complex engineering problems and design system components or processes that meet t h e specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

4. **Conduct Investigations of Complex Problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

5. **Modern Tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

6. **The Engineer and Society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

7. **Environment and Sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts & demonstrate the knowledge and need for sustainable development.

8. **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

9. **Individual and Team Work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

10. **Communication:** Communicate effectively on complex engineering activities with the engineering community & with society at large, such as, being able to comprehend & write effective reports & design documentation, make effective presentations & give & receive clear instructions.

11. **Project Management and Finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one’s own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

12. **Life-long Learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

PSO's

1. Able to synergize domain knowledge, problem solving skills and emerging tools to develop sustainable solutions in their chosen civil engineering verticals.

2. Able to communicate and apply civil engineering knowledge for addressing societal challenges.

Project Outcomes:

Students will be able to,

1. Identify & formulate the problem statement for the project based on literature survey.
2. Describe a methodology to be adopted for solving the problem.
3. Apply modern tools and techniques for developing solutions to identified problems.
4. Plan, analyze, design and develop solution for Civil Engineering Problems.
5. Develop communication and report writing skills effectively.
6. Practice to work in teams effectively.
7. Appreciate the need for following ethical principles and practices in carrying out the project.

Mapping of Expected Project Outcomes with PO's and PSO's:

PO Attainment for project work															
Project outcomes	**C O**	**PO-1**	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**	**PO-7**	**PO-8**	**PO-9**	**PO-10**	**PO-11**	**PO-12**	**PSO-1**	**PSO-2**
	CO-1	2	3											2	3
	CO-2	2	3	2										2	3
	CO-3	2	3	2		3							2	2	3
	CO-4	2	3	2										2	3
	CO-5										3				
	CO-6									3					
	CO-7								3				2		

DECLARATION

We hereby declare that the project titled **"DESIGN OF REINFORCED EARTH RETAINING WALL USING PYTHON CODE"** is the work done under the guidance of Mr. B.Ramu, Assistant professor, during 2022-2023 in partial fulfillment of the requirement for the award of degree of **'Bachelor of technology'** in **'Civil Engineering'**.

We ensure that the project is not submitted by any other student in our college.

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MANSAS

CERTIFICATE

This is to certify that the project report entitled **"DESIGN OF REINFORCED EARTH RETAINING WALL USING PYTHON CODE"** being submitted to the Department of Civil Engineering, MVGR College of Engineering (Autonomous), Vizianagaram in partial fulfillment of the requirements for the award of degree of '**Bachelor of Technology**' in '**CIVIL ENGINEERING**' is the bonafide work carried during the academic year 2022-2023 by **"A. Raj Kumar (20335A0101), S. Sai Rakesh (20335A0113), M. Devi Prasanna (19331A0161), V. Abhishek (19331A0194) "** under the guidance of **Mr. B. Ramu**, Assistant Professor of Civil Engineering.

HoD – Civil Engineering | **Project Guide**

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Dr. P. Markandeya Raju
Professor

Mr. B. Ramu
Assistant Professor

External Examiner

(Signature)

Name:
Designation:
Date of Conduct of Viva-voce :

ACKNOWLEDGEMENT

We would like to take this opportunity to express our sincere thanks to our guide **Mr.B.Ramu,** Assistant professor, Department of Civil Engineering for his valuable guidance and assistance. Without him the accomplishment of this task would have never been possible. We also thank him for giving us the opportunity of doing such a wonderful project which is a major requirement of present society.

We express our sincere thanks to **Dr.P.Markandeya Raju,** HOD, for their support in completing the project. We also thank all faculty and lab-in-charges for providing an opportunity to work on this project and helping us in completion of the project.

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ABSTRACT

Soil retention systems are very important elements. Different types of soil retaining systems have evolved over the last two to three decades. For many years retaining structures were made of reinforced concrete. The cost of conventional retaining walls increases rapidly with increase in height of wall. Reinforced earth walls are cost effective soil retaining structures and can tolerate larger settlements than conventional concrete retaining walls. Due to this reason Reinforced earth technology has completely replaced conventional concrete retaining structures. The main design for Reinforced Earth wall is by length of reinforcement, vertical spacing between reinforcement and tensile force of reinforcements.The length of reinforcement is fixed by external stability analysis. They are Factor of safety against sliding, Overturning, Bearing pressure and deep overall stability. Vertical spacing and tensile force of reinforcement are designed by internal stability analysis. These are Pull out capacity and allowable tensile force of reinforcement, bulging, connection failure.

Design of reinforced earth wall is performed using Python code as per guidelines of BS 8006-2010 (code of practice for strengthened /reinforced soil and other fills) for dry horizontal cohesionless backfill for Dead load+Live load condition & Dead load+Live load+Horizontal & Vertical line load condition. The code will take input parameters such as soil properties, wall geometry, and loads, and will output the reinforcement requirements & factor of safety against rupture and pullout resistance. The developed code will be validated against existing design examples and will provide a more efficient and accurate design process compared to traditional manual methods.

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The following symbols are used in this report:

Symbol	**Name**
ϕ	Angle of internal friction
γ_γ	Density of reinforced backfill
α	Slope angle of wall
μ	Coefficient of friction
K_a	Coefficient of active earth pressure
K_P	Coefficient of passive earth pressure
D_f	Depth of foundation
sbc	Safe bearing capacity of soil
H	Overall depth of wall
L	Length of reinforcement
V_1	Vertical line load
F_1	Horizontal line load
σH	Horizontal stress at some depth
σV	Vertical stress at some depth
Rf1	Sliding force
M_O	Overturning moment
M_R	Resisting moment
σv	Total vertical stress
σv_j	Vertical stress in pullout resistance
e	Eccentricity
ϕ_r	Angle of internal friction for reinforced backfill
ϕ_f	Angle of internal friction for retained backfill
γ_b	Density of retained backfill
q_L	Live load
q_d	Dead load
q_a	Allowable bearing pressure
K_{ar}	Coefficient of lateral earth pressure for reinforced backfill
K_{af}	Coefficient of lateral earth pressure for retained backfill
S_v	Vertical spacing of reinforcement

h	Position of reinforcement from top of the soil in tension
h_j	Position of reinforcement from top of soil in pullout resistance
L_{aj}	Length of reinforcement in active zone
L_{ej}	Length of reinforcement in resistant zone
C_{fg}	Coverage ratio
C_i	Coefficient to account for the effect of creep
P	Pullout resistance
T	Tension in reinforcement
Td	Grade of reinforcement

CHAPTER - 1

INTRODUCTION

1.1 RETAINING WALL :

A retaining wall is a structure that retains any material, usually earth and prevents it from sliding or eroding away. Retaining walls provide lateral support to vertical slopes of soil. They retain soil which would otherwise collapse. The retained soil is referred to as backfill.

Fig. 1.1 Retaining wall (Blocks)

Fig. 1.2 Retaining wall

1.2 REASONS TO PROVIDE RETAINING WALL :

All highways which were constructed in and around any cities/towns almost reached their design capacity due to messy growth of Indian cities/towns and traffic therein especially at intersections. In this scenario, traveling on highways with design speed is practically not possible and time taken by travelers from one place to another is more than desired. To get rid of this problem, Highway Design Engineers started thinking to reduce the time of travel. For this, time consumed at intersections needs to be reduced. This gives them an idea to elevate the highway from one another i.e. introduction of grade separated intersections.

In earlier days, land was not in that scarcity & the cost of land was also less, therefore natural slopes on approaches of structures were preferred. But this idea fails in cities and towns due to non-availability of land for natural slopes on embankments and approaches of structures. To fulfill these requirements, we developed an idea to construct a masonry wall. Then after, further development stages came in mind to restrain the approach with Reinforced Cement Concrete (RCC) Retaining Wall. Construction of RCC Retaining Wall requires huge steel, concrete, formwork and manpower. In order to economize highway construction, the concept of Reinforced Earth Wall (RE Wall) was developed. Construction of RE Wall is time wise economical also as compared to RCC wall. Other application of retaining structure include safety from washed out due to storm water in heavy rainfall area, in water logged area, in flood prone zone, in cut or fill section to avoid rock falling or to avoid movement of rock, development of park, gardens in hilly area, to construct the walkway along the river or seashore, to facilitate the parking capacity with aesthetic view in hilly areas.

Main Objectives of Retaining wall is,

- ➢ To prevent soil from eroding and from spilling out.
- ➢ To prevent flooding in the landscape.
- ➢ To keep surrounding structures safe from elements that would damage them.
- ➢ To reduce the amount of maintenance required due to erosion.

1.3 TYPES OF RETAINING WALL :

1. Gravity wall.
2. Semi gravity wall.
3. Cantilever wall.
4. Counterfort retaining wall.
5. Buttressed retaining wall.
6. Reinforced earth retaining wall.

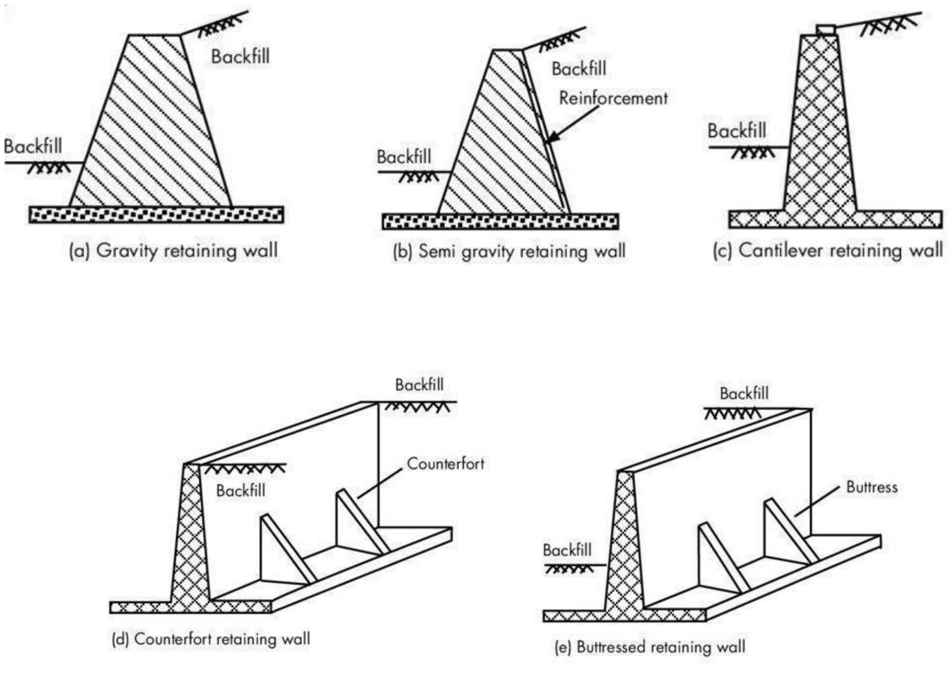

Fig. 1.3 Types of retaining walls

<u>Gravity wall</u>: Gravity walls are the earliest known retaining structures. They are built from solid concrete or rock rubble mortared together. The lateral force from backfill is resisted by weight of the wall itself and due to their massive nature they develop little or no tension. Therefore, they are usually not reinforced with steel. Gravity walls are economical for heights up to 3 m (10ft).

Semi-gravity wall: A specialized form of gravity wall is a semi-gravity retaining wall. These have some tension reinforcing steel included so as to minimize the thickness of the wall without requiring extensive reinforcement. They are a blend of the gravity wall and the cantilever wall designs.

Cantilever wall: Cantilever retaining walls are constructed of reinforced concrete. They consist of a relatively thin stem and a base slab. The base is also divided into two parts, the heel and toe. The heel is the part of the base under the backfill. The toe is the other part of the base. Generally economical up to about 25 ft. in height. The resistance to sliding of a cantilever type of retaining wall is sometimes increased by providing vertical projection known as key at the base.

Counterfort retaining wall: Counterfort retaining walls are similar to cantilever walls except they have thin vertical concrete webs at regular intervals along the backside of the wall. These webs are known as counterforts. Counterfort retaining walls are more economical than cantilever walls for heights above 25 ft.

Buttressed wall: A buttressed wall is similar to the counterfort type of wall but in this case counterforts are placed on the front of the wall and are known as buttresses rather than counterforts. In this type of wall heel projection is small and hence backfill contributes less to the stability of the wall. Also buttresses reduce clearance in front of the wall. These types of walls are rarely used.

Reinforced earth retaining wall: An earth retaining wall is a composite structure consisting of alternating layers of compacted backfill and soil reinforcement elements, fixed to a wall facing. The stability of the wall system is derived from the interaction between the backfill and soil reinforcements, involving friction and tension. The wall facing is relatively thin, with the primary function of preventing erosion of the structural backfill. The result is a coherent gravity structure that is flexible and can carry a variety of heavy loads.

Reinforced Earth is composite material formed by cohesion less soil and flexible metal reinforcing strips. The earth and the reinforcement are combined through friction.

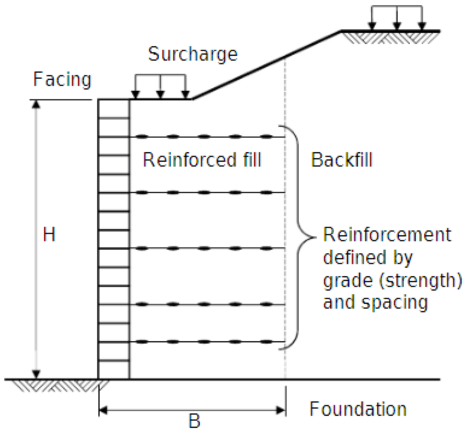

Fig. 1.4 RE retaining wall

The result is a monolithic mass that acts cohesively, supporting its own weight and applied loads. Reinforcement placed in horizontal layers throughout the height of the wall provides the tensile strength to hold the soil together.

1.4 ADVANTAGES OF REINFORCED EARTH WALLS :

- ➢ High load carrying capacity.
- ➢ Structural flexibility.
- ➢ Less skilled labor.
- ➢ Fast track constructions.
- ➢ Long term durability.
- ➢ Cost effective.
- ➢ Aesthetic appearance.
- ➢ Good Drainage condition.
- ➢ Earth embankments/slopes are commonly required on railways, roads, etc.

1.4.1 EXCEPTIONAL WALL HEIGHT:

Theoretically, Reinforced Earth can be constructed to any height. Irrespective of the wall height, the details and technique used in the construction of Reinforced Earth wall remain the same. This allows for uniformity in construction control and monitoring.

On the other hand, the detailing for conventional walls vary substantially with the height, as the design changes from a cantilever wall to counterfort wall.

1.4.2 HIGH LOAD-CARRYING CAPACITY:

Reinforced Earth wall is capable of supporting large loading, and is most suitable for use in bridge abutment construction. In abutment where cross beams the bridge loading are structurally supported on piles, reinforced Earth wall and embankments are used as a working platform to support the loading and dead loads during the casting of the or bank seats.

1.4.3 STRUCTURAL FLEXIBILITY :

The modular nature of the Reinforced Earth wall and the reinforced granular backfill allows for significant differential movement along the wall. Its flexible mass produces uniform bearing pressure at the base, resulting in lower design bearing pressure, hence requiring lesser foundation treatment at the base.

1.4.4 FAST-TRACK CONSTRUCTION:

In the construction of highways, the construction time is directly related to the cost of construction. Speedy construction helps to cut down machinery costs and overheads.

1.4.5 MINIMUM WORKING AREA:

Highways interchanges are mostly required in developed areas, where working area is limited. Reinforced Earth is constructed from the rear side, and requires very little working area in front of the wall. This minimizes traffic disruption, and allows for uninterrupted construction.

1.4.6 LONG-TERM DURABILITY:

Reinforced Earth walls can be designed to have a 100 years design life or more. Highway operators are often required to take responsibility for the highway for the duration of their operation, which sometimes exceeds 30 years.

1.4.7 COST EFFECTIVENESS:

Reinforced Earth designs are optimized to ensure maximum cost effectiveness. Its simple and repetitive construction technique simplifies control and management, and helps to minimize wastage and pilferage on site

1.4.8 AESTHETIC APPEARANCE:

Precast Reinforced Earth panels can be easily modified to allow for specific architectural finishes. Combinations of geometrical shapes (such as ribbed, embossed, logo) and concrete textures (such as plain, rock finishes) provide for infinite possibilities in the finished product.

1.4.9 GOOD DRAINAGE CONDITION:

Sub surface drainage will be provided near panels. Since most retaining walls are impervious, which means water cannot pass through the wall itself, efficient drainage is crucial. When drainage goes unaddressed hydrostatic pressure will build up behind the wall and cause damage such as bulging or cracking. There are a number of ways to ensure proper drainage of water from behind a retaining wall. First, is to make sure your landscaping contractor backfills at least a foot of space behind the wall with gravel. Second, is having a perforated pipe installed along the inside, or backfilled, bottom of the wall. And third, is to ask if weep holes will be needed to allow water to drain through the wall.

1.5 COMPONENTS OF RE RETAINING WALL :

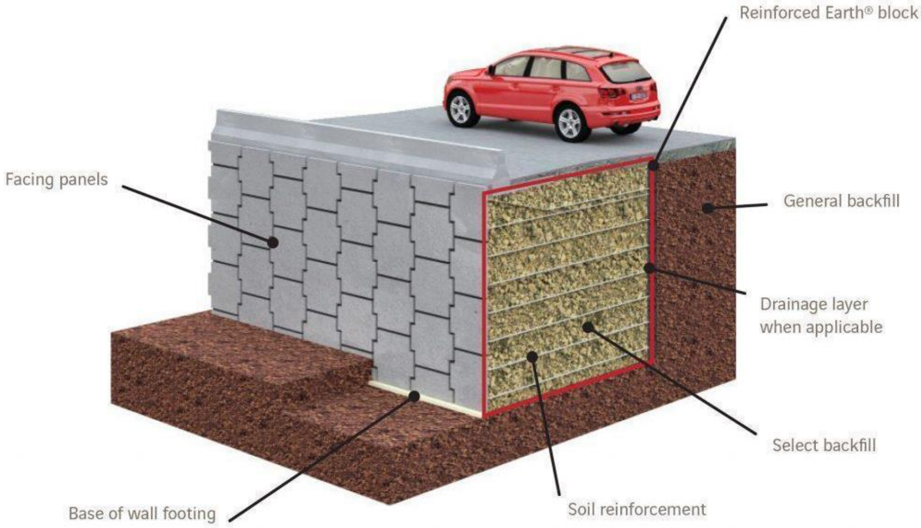

Fig. 1.5 Components of reinforced earth wall

Main components of RE Retaining wall include,

1. Subgrade or foundation soil.
2. Leveling pad.
3. Backfill.
4. Facing Elements.
5. Reinforcement

1.5.1 SUBGRADE:

The subgrade is the native material under the constructed pavement. This is also called "formation level". Subgrade is commonly compacted before the construction of a road, pavement or railway track. And sometimes subgrade is stabilized by the addition of asphalt, lime, Portland cement or other modifiers. The subgrade is the foundation of the pavement structure, on which the subbase is laid.

The load bearing strength of subgrade is measured by :

1. California bearing ratio (CBR) test
2. California resisting value test
3. Plate load test
4. Triaxial compression test

FUNCTIONS:

- ➢ Carries the entire load that has been imposed from the structure above it.
- ➢ Provide strength and support to the overlying pavement.
- ➢ Provide drainage and frost protection.
- ➢ Provide adequate support to the retaining wall even under adverse climate and loading conditions.

1.5.2 LEVELING PAD:

The leveling pad is placed to hold the soil stiff enough for wall support. Aggregate base material or concrete used as a foundation for the blocks.

Fig. 1.6 Leveling pad (Laying)

Fig. 1.7 Leveling pad

This is to avoid punching failure below the blocks. The leveling pad is a non-reinforced concrete pad used to provide a level, consistent surface at the proper grade to place the first row of panels.

FUNCTIONS:

- ➢ The leveling pad sets the horizontal and vertical alignment of the wall.
- ➢ It must be in the correct horizontal position, level and at the correct grade.
- ➢ Supports the blocks in the retaining wall structure.
- ➢ To avoid the direct load on the soil.

1.5.3 BACKFILL:

The backfill material used for the retaining wall is Pond ash. This is one of the byproducts of thermal power plants.

POND ASH: Pond ash is a waste product from most coal based thermal power plants. The coarser material, which falls into furnace bottoms in modern large thermal power plants and constitute about 20% of total ash content of the coal fed in the boilers. Pond ash produced as a by-product of the coal based thermal plants whose disposal is often a major environmental and economic issue. Reinforced earth wall is preferred over conventional RCC rigid retaining wall as it is not only cost effective but also has better performances during earthquakes.

Fig. 1.8 Pond ash

FUNCTIONS:

- ➢ Low Value High Volume: Pond ash can be used for land and mine filling.
- ➢ Medium Value Medium Volume: - For manufacturing bricks, blocks, paver blocks.
- ➢ Acidic land (soil) can be improved by using pond ash.
- ➢ Geotechnical application as a substitute for earth dust.
- ➢ Road construction, embankment and flyovers.

1.5.4 FACING ELEMENTS:

The facing elements used for the retaining wall construction are blocks, panels.

BLOCKS: The blocks are the one type of material used as retaining walls. It is made from the composition of ordinary Portland cement (OPC) and ground granulated blast furnace slag (GGBS), with a water cement ratio of 0.5. The blocks made from the 10mm passed aggregate size used is 50% & remaining quarry dust is 50%.

Fig. 1.9 Blocks

Fig. 1.10 Panels

The retaining wall construction using blocks is easy, economical and low transportation cost. Generally, we use M35 grade for the blocks for construction of retaining walls.

PANELS: The panels are another type of material used as retaining walls. And the common dimensions are 1.5m high, 1.5m or 3m wide, and at least 140mm thick. Custom panel dimensions and thicknesses can be manufactured if necessary based on project needs such as geometry, extreme wall height, or for protective structures. Joints between the panels have a ship lap, as well as geotextile on the back face, to provide adequate drainage of the structure while preventing loss of backfill. A catalog of corner elements and slip joint covers allow for complex horizontal alignments and added capacity for differential settlement.

1.5.5 REINFORCEMENT USED IN RETAINING WALL :

Geosynthetics are polymeric materials used with soil, rock, earth, or other geotechnical engineering-related material inorder to act as reinforcement, separation, drainage, containment, barrier & for management of surface erosion.

TYPES OF GEOSYNTHETICS :

Fig. 1.11 Types of geosynthetic reinforcement

Polymer reinforcement type			Strength(kN/m)
Geo textiles	Non-woven	Melt-bonded	3-25
		Needle-punched	7-90
		Resin-bonded	5-30
	Woven	Monofilament	20-80
		Multifilament	40-800
		Tape	8-90
	Knitted	Weft	2-5
		Warp	20-120
	Stitch-Bonded		30-1000
Geo grids	Cross-laid strips		25-200
	Punched sheets		10-110
Composites	Strips		20-150
	Bars		20-500

Table 1.1 Typical reinforcement of polymer strength

GEOGRID :

Geogrid is the major geosynthetic material made from polymers such as polyethylene or polyester, formed by means of intersecting grids, used to reinforce soils. A planar, polymeric structure consisting of a regular open network of integrally connected tensile elements, which may be linked by extrusion, bonding or interlacing, whose openings are larger. They provide stability to the embankment. In pavements the geogrids have their membrane action which includes tensile forces, control deformations and significantly improve their performance. The soil reinforcement used in vertical walls and steep slopes for prevention of slip.

FUNCTIONS:

- Low Value High Volume: Pond ash can be used for land and mine filling.
- Medium Value Medium Volume: - For manufacturing bricks, blocks, paver blocks.
- Acidic land (soil) can be improved by using pond ash.
- Geotechnical application as a substitute for earth dust.
- Road construction, embankment and flyovers.

APPLICATIONS OF GEOGRID :

- Retaining walls & Embankments.
- Reinforced steep slopes.
- Highway infrastructure.
- Landfill construction.
- Erosion control.

Fig. 1.12 Geogrid

Fig. 1.13 GeoTextile

GEOTEXTILE :

It is a permeable textile material used to increase soil stability, provide erosion control or aid in drainage and stabilize the loose soil. These are made from polypropylene or polyester, geotextile fabrics come in three basic forms: woven (resembling mail bag sacking), needle punched (resembling felt), or heat bonded (resembling ironed felt).

FUNCTIONS:

- ➢ Geotextiles are placed at the tension surface to strengthen the soil.
- ➢ To separate the reinforcement and backfill material.
- ➢ Geotextiles are also used for sand dune armoring to protect upland coastal property from storm surge, wave action and flooding.
- ➢ These are mainly for erosion control, soil stabilization due to the fabric's substantial mechanical strength.
- ➢ Geotextiles can improve soil strength at a lower cost than conventional soil nailing.

1.6 ABOUT THE PROGRAMMING LANGUAGE :

Fig. 1.14 Python programming

1.6.1 INTRODUCTION TO PYTHON :

Python is an interpreted high-level programming language for general-purpose programming. Created by Guido van Rossum and first released in 1991. Python has a design philosophy that emphasizes code readability and a syntax that allows programmers to express concepts in fewer lines of code, notably using significant whitespace. It provides constructs that enable clear programming on both small and large scales.

Python features a dynamic type system and automatic memory management. It supports multiple programming paradigms, including object-oriented, imperative, functional and procedural, and has a large and comprehensive standard library. Python interpreters are available for many operating systems.

1.6.2 NECESSITY OF PROGRAMMING LANGUAGE IN DESIGN OF RE WALL :

Python is becoming increasingly popular in the design of reinforced earth retaining walls and other geotechnical applications due to its ability to automate tasks, perform complex calculations, and analyze large datasets. The use of Python can help reduce the potential for human error, increase efficiency, and improve the overall accuracy of the design process. Additionally, Python offers a wide range of libraries and modules that can be used for geotechnical engineering analysis, making it a valuable tool for designers. Overall, the use of Python in the design of reinforced earth retaining walls is becoming more necessary due to its flexibility, cost-effectiveness, and ability to streamline the design process.

CHAPTER - 2

LITERATURE REVIEW

J.B.Kennedy (1980): This paper is studied on analysis to estimate the maximum tensile force in the rein-forcing elements when the reinforced earth retaining wall was subjected to a vertical surcharge strip load. The method was based on modification of elastic theory and use of a reduction factor to determine the tension stresses along the wall height according to the stiffness characteristic of the soil backfill and reinforcing elements. Since such a reduction factor depends upon a number of influencing parameters (e.g. modulus of elasticity of the backfill), its exact evaluation is cumbersome and not convenient in practical application. Consequently, the new design method presented in this paper does not use Kennedy's reduction factor. Based on experimental results, Kennedy et al. (1980) observed that under the action of a vertical surcharge strip load the maximum tensile forces in the reinforcing elements developed at points in close proximity to the potential failure plane predicted by Culmann's method.

J.T.Laba (1984): This is studied on structural response of a reinforced earth retaining wall model subjected to the combined action of vertical and horizontal surcharge strip loads aligned parallel to the wall head. The stress distribution pattern in the reinforcing elements and in the reinforced earth medium was studied. Experimental results were compared with the theoretical stress distribution that exists in a semi-infinite elastic medium, and also with the design procedure currently in use for reinforced earth retaining walls under horizontal surcharge strip loading. Significant differences were found between the results based on the design method now in use and those obtained from the model study. It appears that a more realistic design method is required to take into consideration the stress redistribution in the reinforced earth backfill resulting from the deflection of the flexible wall face. In this paper, such a design method, reflecting more accurately the actual behavior of the reinforced earth retaining wall system under vertical and horizontal strip surcharge loads.

Izzaldin Almohd (2014): The paper explained about internal stability which is examined by satisfying the local stability of reinforcements at each level based on the predetermined critical slip plane (line of maximums) and the tributary area of each reinforcing layer. Recent research aimed at incorporating the contributions of the various elements of reinforced earth walls, some of which are mostly based on statistical correlations. The German code of practice for design/analysis of reinforced earth walls and slopes offers a slightly different methodology for analyzing the internal stability of the reinforcement. It is mainly based on investigating numerous circular and random slip surfaces, within and beyond the reinforcement zone (internal and external), while accommodating the axial (resistance) forces provided by all reinforcement layers intercepting these surfaces. This paper presents some of the technical and design considerations and possible improvements on design methodology for reinforced soil walls and slopes.

Dr. P. D. Hiwase (2018): The article discusses the various factors that affect the design of earth retaining walls, including soil properties, wall height, and backfill conditions. It emphasizes the importance of accurate and efficient design methods to ensure the safety and stability of the retaining wall. The authors propose the use of programming codes in the design process to improve the accuracy and efficiency of the design. They highlight the advantages of using programming codes, such as the ability to handle complex calculations, automate repetitive tasks, and ensure consistency in the design process. The article also presents a case study of the design of a retaining wall using programming codes in different backfill conditions. The results demonstrate the effectiveness of the proposed approach in producing safe and efficient retaining wall designs. Overall, the article highlights the potential benefits of using programming codes in the design of earth retaining walls and provides valuable insights into the design process for engineers and researchers in the field of geotechnical engineering.

IRC-SP:102-(2014): The document covered various aspects of reinforced soil walls, including types of reinforcement, types of facing systems, design methodologies, construction practices, and quality control measures. It emphasized the importance of proper design and construction techniques to ensure the safety, durability, and functionality of the retaining wall. The publication included detailed design procedures, equations, and charts to help engineers and designers calculate the various parameters involved in the design of reinforced soil walls. It also provided guidance on the selection of appropriate materials for use in reinforced soil walls, including soil, reinforcement, and facing systems. Overall, IRC:SP:102-2014 was a valuable resource for engineers, contractors, and other professionals involved in the design and construction of reinforced soil walls. It provided a comprehensive set of guidelines and design procedures to help ensure the safe and effective construction of retaining walls for infrastructure projects.

CHAPTER - 3

METHODOLOGY

3.1 STEPS IN DESIGN OF REINFORCED EARTH WALL:

1. Establish project requirements.
    a. Sample collection.
2. Establish project parameters.
    a. Soil parameters are obtained with below tests,
        i. Light weight compaction (IS 2720-part 7,1980)
        ii. Modified proctor's compaction (ASTM D1557 and AASHTO T180-D)
        iii. Specific gravity (IS 2720–part 3,1980)
        iv. Direct shear test (IS 2720-part 13,1986)
        v. Sieve analysis (IS 2720-part 4,1985)
3. Evaluate external stability of retaining wall,
    a. Factor of safety against sliding.
    b. Factor of safety against overturning.
    c. Limiting Eccentricity.
    d. Factor of safety against bearing pressure.
4. Evaluate internal stability of retaining wall,
    a. Estimate critical failure surface.
    b. Establish vertical layout of soil reinforcements.
    c. Calculate horizontal stress, vertical stress and maximum tension at each reinforcement level.
    d. Factor of safety against rupture.
    e. Evaluate pullout resistance of soil reinforcement.
    f. Factor of safety against pullout resistance.

3.2 STEPS IN DESIGN OF REINFORCED EARTH WALL USING PYTHON CODE:

3.2.1 DEAD LOAD+LIVE LOAD CONDITION :

1. Develop Python code for the entire design of Reinforced Earth Retaining Wall as per BS 8006-2010 considering dead load and live load.
2. Input parameters include,
    a. Angle of internal friction (ϕ)
    b. Density of backfill (KN/m^3)
    c. Reinforcement length of wall (m)
    d. Height of Retaining wall (m)
    e. Dead load due to surcharge (KN/m^2)
    f. Live load (KN/m^2)
    g. Safe bearing capacity of soil (KN/m^2)
3. Output include,
    a. Length of reinforcement.
    b. Spacing of reinforcement at each layer.
    c. Grading of reinforcement at each layer.

3.2.2 DEAD LOAD+LIVE LOAD+HORIZONTAL & VERTICAL LINE CONDITION :

1. Develop Python code for the entire design of Reinforced Earth Retaining Wall as per IS 8006-2010 considering dead load, live load, horizontal & vertical line loads.
2. Input parameters include,
    a. Angle of internal friction (ϕ)
    b. Density of backfill (KN/m^3)
    c. Reinforcement length of wall (m)
    d. Height of Retaining wall (m)
    e. Dead load due to surcharge (KN/m^2)
    f. Live load (KN/m^2)
    g. Horizontal line Load (KN/m)
    h. Vertical line Load (KN/m)

i. Width of Strip (m)
j. Distance of wall to center of strip (m)
k. Safe bearing capacity of soil (KN/m^2)

3. Output include,
    a. Length of reinforcement.
    b. Spacing of reinforcement at each layer.
    c. Grading of reinforcement at each layer.

CHAPTER - 4

DESIGN OF REINFORCED EARTH RETAINING WALL

A number of design methods have been developed by different agencies in different geographical regions using reinforced soil techniques. These methods address issues such as availability of construction materials, particular type of reinforced element, adaptation of the technique to the local conditions.

The design procedures are laid on BS 8006-1:2010 (code of practice for strengthened /reinforced soil and other fills). Based on this the design RE wall is done.

4.1 PRINCIPLES OF DESIGN :

The reinforced soil structure must be checked with respect to two forms of stability,

1. External Stability
2. Internal Stability

External stability governs reinforced length and must have adequate safety against outward sliding, overturning, bearing failure, and deep seated failure, without any one layer in the reinforced zone being overstressed.

Hence external stability is checked against factor of safety of :

1. Outward sliding.
2. Overturning.
3. Bearing failure.

Internal stability governs reinforced spacing. This depends on the method used for design of reinforcement layout. Two methods of design:

1. Tie back wedge method.
2. Coherent gravity method.

Retaining wall must have adequate wedge stability & pullout resistance.
Hence the internal stability is checked for :

1. Wedge Stability.
2. Pullout resistance.

4.2 EXTERNAL STABILITY :

The external stability of a reinforced soil is assessed in the same way as that of a conventional gravity retaining wall. Considering the reinforced zone as a monolith, the mechanisms of overall failure must be checked.

It is assumed that the wall fill and the underlying foundation soil have different properties. When this is the case , value of coefficients of earth pressure should relate to the appropriate soil zones .

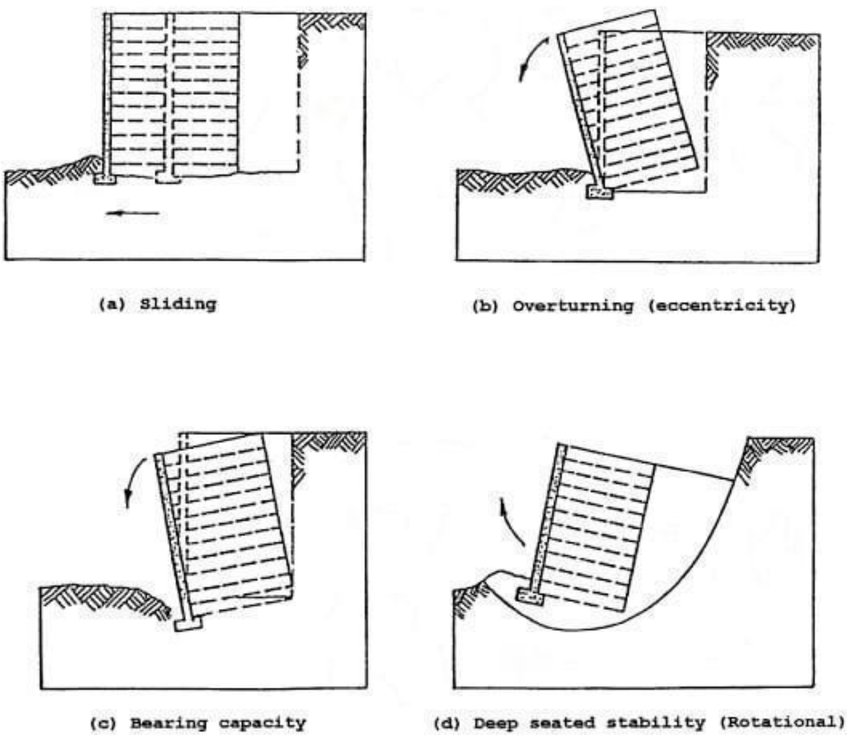

Fig.4.1 External stability failures

In order to ensure the external stability of a retaining wall, it is important to understand the forces acting on the wall. The main forces acting on a retaining wall are:

1. **Lateral Earth Pressure:** Lateral earth pressure is the force exerted by the soil against the wall. It is caused by the weight of the soil and any other surcharge on top of it, as well as any water pressure that may be present. Lateral earth pressure is the most significant force acting on a retaining wall and can cause overturning, sliding, and bearing failure.
2. **Hydrostatic Pressure**: Hydrostatic pressure is the force exerted by water against the wall. It can be caused by water that has infiltrated behind the wall or by a high water table. Hydrostatic pressure can cause sliding, bearing failure, and cracking in the wall.

3. **Seismic Forces:** Seismic forces are caused by earthquakes and can cause the wall to vibrate or move. The magnitude and frequency of these forces depend on the seismic activity in the area and the characteristics of the soil.
4. **Wind Loads:** Wind loads can cause the wall to vibrate or move. The magnitude of these forces depends on the wind speed and the surface area of the wall that is exposed to the wind.
5. **Surcharge Loads:** Surcharge loads are additional loads that are placed on top of the soil behind the wall, such as buildings, vehicles, or storage piles. Surcharge loads can increase the lateral earth pressure and cause the wall to fail.

To ensure the external stability of a retaining wall, it is important to consider all of these forces and design the wall accordingly. The wall must be able to resist the lateral earth pressure and any other forces that may be acting on it, and must be designed with appropriate reinforcement and foundation conditions to ensure its stability.

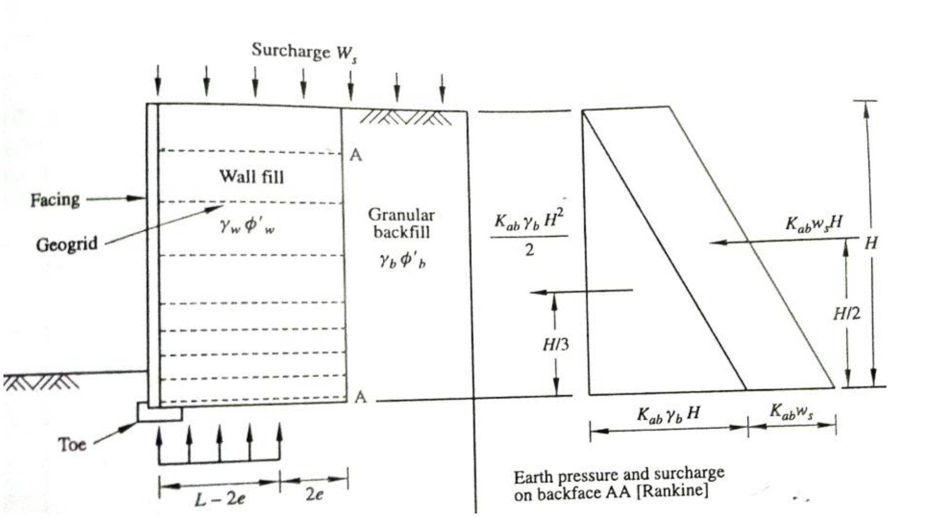

Fig.4.2 Forces acting on retaining wall for external stability consideration

4.2.1 FACTOR OF SAFETY AGAINST SLIDING :

Outward sliding is initiated by the thrust of the unreinforced backfill,and is most likely to occur on a plane just above or below the lowest level of reinforcement. This is because the coefficient of friction will generally be lower between sail and reinforcement than soil and soil. The Factor of safety against outward sliding is based on simple of forces ,as a ratio of sliding forces to resisting forces given by,

$$FOS = \frac{\mu(\gamma_\gamma HL+q_dL)}{(K_aq_dH+K_a\gamma_bH^2/2)} \quad \text{(Dead load Condition)}$$

$$FOS = \frac{\mu(\gamma_\gamma HL+q_dL)}{(K_aq_dH+K_aq_LH+K_a\gamma_bH^2/2)} \quad \text{(Dead load+Live load Condition)}$$

$$FOS = \frac{\mu[(\gamma_\gamma HL+q_dL)+V_1]}{(K_aq_dH+K_aq_LH+K_a\gamma_bH^2/2)+F_1} \quad \text{(Dead load+Live load+Horizontal \& Vertical line load Condition)}$$

Where $K_a = (1-\sin\phi)/(1+\sin\phi)$ for active condition

- A minimum value of 1.5 is specified.

4.2.2 FACTOR OF SAFETY AGAINST OVERTURNING :

Overturning is initiated by the thrust of the unreinforced backfill, causing the reinforced block to topple forward. The Factor of safety is calculated from the overturning moment and restoring moments above the toe of the wall and is given by,

$$FOS = \frac{\gamma_\gamma HL(L/2)+q_dL(L/2)}{(K_aq_dH^2/2+0.5K_a\gamma_bH^3/3)} \quad \text{(Dead load Condition)}$$

$$FOS = \frac{\gamma_\gamma HL(L/2)+q_dL(L/2)}{(K_aq_dH^2/2+K_aq_LH^2/2+0.5K_a\gamma_bH^3/3)} \quad \text{(Dead load+Live load Condition)}$$

$$FOS = \frac{\gamma_\gamma HL(L/2)+q_dL(L/2)+V_1d}{(K_aq_dH^2/2+K_aq_LH^2/2+0.5K_a\gamma_bH^3/3+F_1H)} \quad \text{(Dead load+Live load+Horizontal \& Vertical line load Condition)}$$

➢ A minimum value of 2 is specified.

4.2.3 FACTOR OF SAFETY AGAINST BEARING FAILURE :

Bearing failure occurs if the maximum vertical stress exerted by the reinforced soil block exceeds the bearing capacity of the underlying soil. The normal practice is to estimate the vertical stress distribution on the base of the wall and compare this with the allowable bearing pressure, qa.

In case of a flexible structure such as a reinforced soil wall, there is a redistribution of stresses and the contact pressure at the bottom is uniform. This is characterized by the Meyerhoff distribution.

This distribution is used to estimate the vertical stress distribution instead of the conventional trapezoidal pressure distribution. The pressure is exerted over the area (L-2e) per unit length of the wall. Accordingly, allowable bearing pressure is given by,

$$q_a = \frac{(\gamma_\gamma HL + q_d L)}{(L-2e)} \quad \text{(Dead load Condition)}$$

$$q_a = \frac{(\gamma_\gamma HL + q_d L + q_L L)}{(L-2e)} \quad \text{(Dead load+Live load Condition)}$$

$$q_a = \frac{(\gamma_\gamma HL + q_d L + q_L L + V_1)}{(L-2e)} \quad \text{(Dead load+Live load+Horizontal \& Vertical line load Condition)}$$

Where e is the eccentricity with respect to the center-line and the line of action of the resultant and is calculated as ratio of overturning moment to the vertical load.

$$e = (L/2) - \frac{(M_R - M_O)}{(\gamma_\gamma HL + q_d L)} \quad \text{(Dead load Condition, Dead load+Live load Condition)}$$

$$e = (L/2) - \frac{(M_R - M_O)}{(\gamma_\gamma HL + q_d L + V_1)} \quad \text{(Dead load+Live load+Horizontal \& Vertical line load Condition)}$$

➢ Eccentricity should be less than or equal to L/6.

The allowable bearing pressure may be estimated using bearing capacity theories. If bearing capacity is inadequate, the designer may consider using a reinforced soil foundation under the wall. This involves excavation of the subsoil to a particular depth, and replacement by layers of granular fill and geotextile/geogrid. Alternatively, a cellular mattress can be constructed with interlocking vertical sheets of geo-grid, backfilled with sand and gravel.

4.3 INTERNAL STABILITY :

Internal stability of the retaining wall is checked by doing wedge stability checks and pull out resistance.

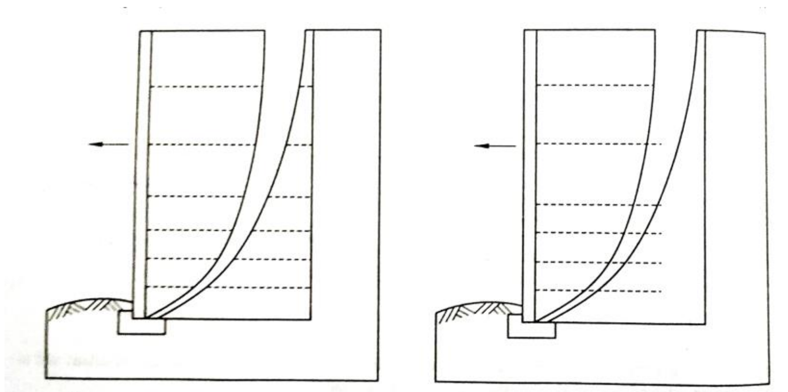

Fig.4.3 Mechanisms of internal failures in RE wall

Internal stability design of a Reinforced Earth structure consists of the determination of soil reinforcement type, size and quantity. Reinforced Earth structures are typically designed utilizing standard reinforcing strips attached to precast concrete facing panels with tie strip connections. Thus, the essence of the internal stability design process is the determination of the required number (density) and lengths of the reinforcing strips.

Internal stability for static governs reinforced spacing zone. This depends on the method used for design of reinforcement layout.

Two analytical methods of design:

1. Tie back wedge method.

2. Coherent gravity method.

Tie-back wedge method :

The tie-back wedge method is a widely used and effective technique in reinforced earth retaining wall design because it provides a cost-effective solution that can be customized to suit the specific site conditions and design requirements. In this method, a reinforced earth retaining wall is constructed by using a series of layers of compacted soil and geosynthetic reinforcement, which are anchored to a tie-back system.

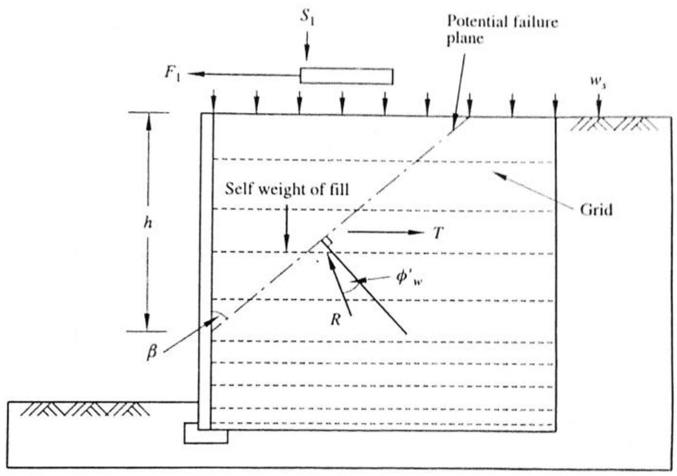

Fig.4.4 Forces required for wedge stability assessment

The maximum ultimate limit state tensile force T to be resisted by a particular layer of reinforcement will be summation of lateral pressure arising due to self-weight of the fill, surcharge caused by external loading, strip loading applied on the top of the fill and shear applied at the contact of the strip loading. The internal stability calculation is normally carried out by one of two methods: tie-back wedge or two-part wedge. The majority of published design guidelines use the tie-back wedge method, where design is generally based on assuming a single internal failure mechanism.

The stability of the wedge at each level of reinforcement should be checked. Wedge stability ensures that friction and tensile resistance due to the bond of the reinforcement is sufficient to resist the loads tending to cause the movement. It must be checked with respect to tensile failure which occurs when tensile capacity of reinforcement is exceeded. Tension failure is checked for each layer taking into account the self-weight of the fill, uniform surcharge, vertical and horizontal line loads on the crest, and bending moments caused by external loading.

4.3.1 TENSION FAILURE :

Tension failure will occur if the reinforcement strength is insufficient to carry the horizontal loads. Each layer is assumed to carry the local horizontal stresses, acting over an area equal to half the vertical spacing on either side of the layer per meter run of the wall.

Horizontal line load : They are carried directly by the reinforcements in the upper portion of the wall. The horizontal stress distribution which results on the front face of the wall varies linearly from $2F_h/Z_h$ at top of the wall to zero at depth of Z_h. Accordingly at some depth the horizontal stress is given by,

$$\sigma H = 2F_h/Z_h\,[1 - (Z/Z_h)]$$

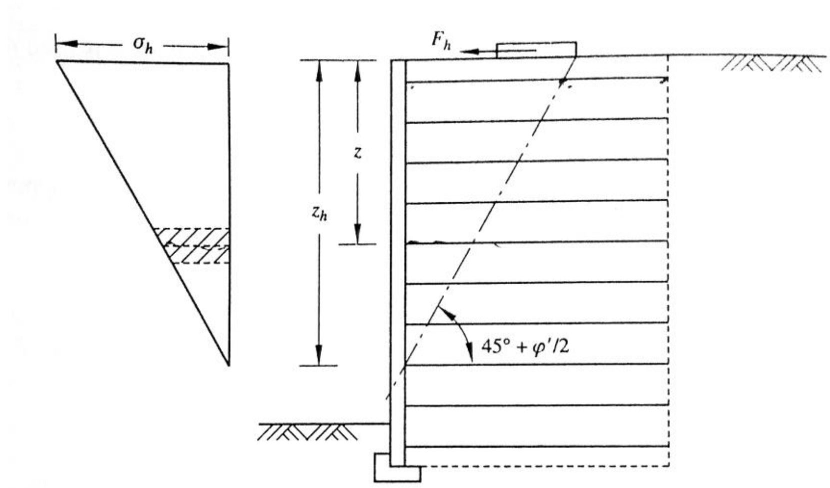

Fig.4.5 Dispersal of horizontal line load

Vertical line load : They may arise if the wall is being used as a bridge abutment to support a bank seat. Loads are assumed to disperse with depth at a conventional spread of 1:2 (H:V). The vertical stress at some depth is given by,

$$\sigma V = V_1/b$$

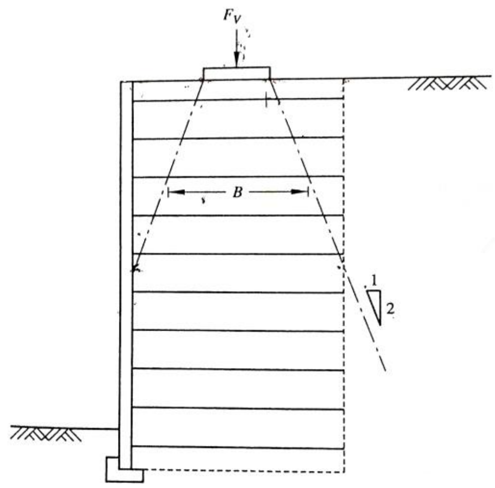

Fig.4.6 Dispersal of vertical line load

For wedge height 'h'

1. Vertical stress (σv) is given by,
   a. $\sigma v = \gamma_\gamma h + q_d$ (Dead load condition)
   b. $\sigma v = \gamma_\gamma h + q_d + q_L$ (Dead load+Live load condition)
   c. $\sigma v = \gamma_\gamma h + q_d + q_L + V_1/b$ (Dead load+Live load+Horizontal & Vertical line load condition)

2. Tension (T) is given by,
   a. $T = K_a \sigma v S_v$ (Dead load condition, Dead load+Live load condition)
   b. $T = (K_a \sigma v + \sigma H) S_v$ (Dead load+Live load+Horizontal & Vertical line load condition)

3. Factor of safety against Rupture is given by,
   a. $Fos = T_D/T$

4.3.2 PULLOUT RESISTANCE :

Pull-out failure occurs when length of reinforcement is less and enough bond capacity is not mobilized to hold the reinforcement in position. Pull-out failure is checked by considering both pull-out capacity of individual layers and the equilibrium of planar wedge mechanisms through reinforced zones. For each layer, bond lengths beyond the point of maximum tension assessed. Bond or anchorage lengths beyond critical wedges must be sufficient to prevent pull-out.

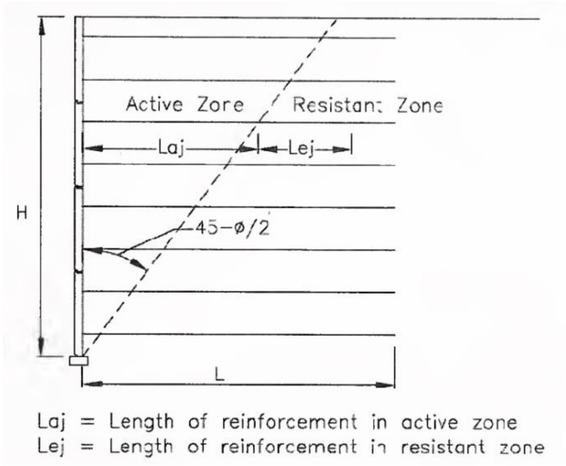

Fig.4.7 Pullout resistance check

For wedge height 'h_j'

1. Vertical stress (σv_j) is given by,
    a. $\sigma v_j = \gamma_\gamma h_j + q_d$ (Dead load condition, Dead load+Live load condition)
    b. $\sigma v_j = \gamma_\gamma h_j + q_d + V_1$ (Dead load+Live load+Horizontal & Vertical line load condition)
2. Pullout Resistance (P) is given by,
    a. $P = 2L_{ej}C_{fg}\sigma v_j C_i \alpha \tan\phi$
        i. $L_{ej} = L-(h_i \tan\theta)$
        ii. $\theta = 90-(45+\phi/2)$
        iii. $C_{fg} = 1$
        iv. $C_i = 0.85$
3. Factor of safety for pullout resistance is given by,
    a. $Fos = P/T$

CHAPTER - 5

PYTHON CODE FOR DESIGN OF REINFORCED EARTH RETAINING WALL

5.1 CASE 1 - DEAD LOAD+LIVE LOAD CONDITION :

Dead load refers to the weight of the retaining wall itself and any other permanent structures or features that are supported by the wall, such as soil or pavement. This load is always present and does not change over time. Live load, on the other hand, refers to any temporary or variable loads that may act on the retaining wall, such as vehicular or pedestrian traffic, or the weight of materials being stored behind the wall. This load can vary over time and is not always present. Both dead load and live load must be taken into consideration when designing a reinforced earth retaining wall, as they can affect the stability and integrity of the structure. The design must be able to accommodate both types of loads and ensure that the wall can withstand the maximum loads that may act on it.

5.1.1 INPUTTING DESIGN PARAMETERS :

```
import math
pi= float((input("Enter angle of internal friction : ")))
Vb = float((input("Enter Density of backfill (KN/m3) : ")))
L = float((input("Enter Reinforcement length of wall (m) : ")))
H = float((input("Enter Height of Retaining wall (m) : ")))
Qd = float((input("Enter Dead load due to surcharge (KN/m2) : ")))
Ql = float((input("Enter Live load (KN/m2) : ")))
sbc = float((input("Enter Safe bearing capacity of soil (KN/m2) : ")))
mue = 0.9*(math.tan(math.radians(pi)))
teta = 90-((45)+(pi/2))
Cfg = 1
Ci = 0.85
alpa = 0.8
ka = (1 - math.sin(math.radians(pi)))/(1 + math.sin(math.radians(pi)))
print("Coefficient of active earth pressure is", ka)
```

5.1.2 FACTOR OF SAFETY AGAINST SLIDING :

```
Pv1 = Vb*H*L

Pv2 = Qd*L

Rf1 = Pv1+Pv2

Rf = Rf1+(Ql*L)

Rh = ((ka*Qd*H)+(ka*Ql*H)+(0.5*ka*Vb*H*H))

Fos1 = (mue*Rf1)/Rh

print("Factor of safety against sliding is", Fos1)

if Fos1>1.5:

    print("Fos>1.5, Hence Safe against sliding")

else :

    print("Not Safe against sliding")
```

5.1.3 FACTOR OF SAFETY AGAINST OVERTURNING :

```
Mr = (Pv1*(L/2)+Pv2*(L/2))

Mo = ((ka*Qd*0.5*H*H)+(ka*Ql*0.5*H*H)+(0.5*ka*Vb*H*H*H/3))

Fos2 = Mr/Mo

print("Factor of safety against Overturning is", Fos2)

if Fos2>2:

    print("Fos>2, Hence Safe against overturning")

else :

    print("Not Safe against overturning")
```

5.1.4 LIMITING ECCENTRICITY :

```
e = (L/2)-((Mr-Mo)/Rf1)

print("Eccentricity is", e)

if e<=(L/6):

    print("e<L/6, Hence Safe against eccentricity")

else :
```

```
    print("Not safe against eccentricity")
```

5.1.5 BEARING PRESSURE :

```
Qb = Rf/(L-2*e)
print("Bearing Pressure is", Qb)
if Qb<sbc:
    print("Qb<sbc, Hence Safe in Bearing")
else :
    print("Not safe against bearing")
```

5.1.6 FACTOR OF SAFETY AGAINST RUPTURE :

```
if Fos1>1.5 and Fos2>2 and  e<=(L/6) and  Qb<sbc:
  print("%-12s %-12s %-15s %-10s %-12s %-15s" %("Height (h)","Spacing(Sv)","Vertical
.   Stress(V)","Tension(T)","Design Strength(Td)","FOS"))
    h = 0.25
    while h < =H-0.25 :
        if h == 0.25 :
            Sv = 0.625
        elif H-h <= 0.75 :
            Sv = (0.75/2)+(H-h)
        else :
            Sv = 0.75
        V = (Vb*h)+Qd+Ql
        T = ka*V*Sv
        Td = 20
        Fos3 = Td/T
        if Fos3>1.5 :
            Td = 20
        else :
            Td = Td+20
```

```
        Fos3 = Td/T
    if Fos3<1.5 :
        Td = Td+20
        Fos3 = Td/T
        if Fos3<1.5 :
            Td = Td+20
            Fos3 = Td/T
            if Fos3<1.5 :
                Td = Td+20
                Fos3 = Td/T
                if Fos3<1.5 :
                    Td = Td+20
                    Fos3 = Td/T
                    if Fos3<1.5 :
                        Td = Td+20
                        Fos3 = Td/T
                        if Fos3<1.5 :
                            Td = Td+20
                            Fos3 = Td/T
                            if Fos3<1.5 :
                                Td = Td+20
                                Fos3 = Td/T
                                if Fos3<1.5 :
                                    Td = Td+20
                                    Fos3 = Td/T
print("%-15s %-15s %-15s %-15s %-10s %-10s%('%.2f'%h,'%.3f'%Sv,'%.2f'%V,'%.2f'%T
,'%.f'%Td,'%.2f'%Fos3))
h = h+0.75
```

5.1.7 FACTOR OF SAFETY AGAINST PULLOUT RESISTANCE :

```
print("%-8s %-10s %-8s %-6s %-20s %-16s %-20s" %("hi","Laj","Lej","hj",
"Vertical stress(Vj)","Pullout(P)","FOS"))
 hi = H-0.25
 hj = 0.25
 h = 0.25
 while hi>=0.25 and h < =H-0.25 :
     Laj = math.tan(math.radians(teta))*hi
     Lej = L-Laj
     Vj = (hj*Vb)+Qd
     P = 2*Lej*Cfg*Vj*Ci*alpa*math.tan(math.radians(pi))
     if h == 0.25 :
         Sv = 0.625
     elif H-h <= 0.75 :
         Sv = (0.75/2)+(H-h)
     else :
         Sv = 0.75
     V = (Vb*h)+Qd+Ql
     T = ka*V*Sv
     Fos4 = P/T
print("%-8s %-10s %-8s %-13s %-16s %-13s %-16s"%('%.3f'%hi,'%.3f'%Laj,'%.3f'%Lej,
'%.2f'%hj,'%.2f'%Vj,'%.2f'%P,'%.2f'%Fos4))
hi = hi-0.75
hj = hj+0.75
 h = h+0.75
 print("Hence safe against Rupture & Pullout Resistance")
 print("Provide length of reinforcement:", L,"m")
 print("Provide spacing of reinforcement: 0.625m at top layer",",",Sv,"m at bottom layer and
0.75m at remaining layers with appropriate grade of reinforcement as shown above")
else :
 print("Hence not safe, increase length of reinforcement")
```

5.2 CASE 2 - DEAD LOAD+LIVE LOAD +HORIZONTAL & VERTICAL LINE LOAD CONDITION :

Strip load should be considered in the design of a retaining wall whenever there is a possibility of heavy equipment, vehicles or structures being placed on top of the wall including loading docks, bridges, or other structures that are located adjacent to the retaining wall. In addition, if the retaining wall is being used to support a roadway or parking lot, strip loads should also be considered. Once the strip load has been determined, the retaining wall design can be modified to ensure that it can resist the maximum loads that may act on it, including the strip load. This may involve increasing the size or reinforcement of the retaining wall, or using specialized soil reinforcement techniques to enhance the wall's performance under strip loading.

5.2.1 INPUTTING DESIGN PARAMETERS :

```
import math
pi= float((input("Enter angle of internal friction : ")))
Vb = float((input("Enter Density of backfill (KN/m3) : ")))
L = float((input("Enter Reinforcement length of wall (m) : ")))
H = float((input("Enter Height of Retaining wall (m) : ")))
Qd = float((input("Enter Dead load due to surcharge (KN/m2) : ")))
Ql = float((input("Enter Live load (KN/m2) : ")))
F1 = float((input("Enter Horizontal line Load (KN/m) : ")))
V1 = float((input("Enter Vertical line Load (KN/m) : ")))
b = float((input("Enter Width of Strip (m)  : ")))
d = float((input("Enter Distance of wall to center of strip (m) : ")))
sbc = float((input("Enter Safe bearing capacity of soil (KN/m2) : ")))
mue = 0.9*(math.tan(math.radians(pi)))
teta = 90-((45)+(pi/2))
Cfg = 1
Ci = 0.85
alpa = 0.8
c = d+(b/2)
```

```
L1 = (d+(b/2))*math.tan(math.radians(45+(pi/2)))
Hmax = (2*F1)/L1
ka = (1 - math.sin(math.radians(pi)))/(1 + math.sin(math.radians(pi)))
print("Coefficient of active earth pressure is", ka)
```

5.2.2 FACTOR OF SAFETY AGAINST SLIDING :

```
Pv1 = Vb*H*L
Pv2 = Qd*L
Pv3 = V1
Rf1 = Pv1+Pv2+Pv3
Rf = Pv1+Pv2+(Ql*L)+V1
Rh = ((ka*Qd*H)+(ka*Ql*H)+(0.5*ka*Vb*H*H))
Fos1 = (mue*(Rf1+V1))/(Rh+F1)
print("Factor of safety against sliding is", Fos1)
if Fos1>1.5:
    print("Fos>1.5, Hence Safe against sliding")
else :
    print("Not Safe against sliding")
```

5.2.3 FACTOR OF SAFETY AGAINST OVERTURNING :

```
Mr = (Pv1*(L/2)+Pv2*(L/2)+V1*d)
Mo = ((ka*Qd*0.5*H*H)+(ka*Ql*0.5*H*H)+(0.5*ka*Vb*H*H*H/3)+(F1*H))
Fos2 = Mr/Mo
print("Factor of safety against Overturning is", Fos2)
if Fos2>2:
    print("Fos>2, Hence Safe against overturning")
else :
    print("Not Safe against overturning")
```

5.2.4 LIMITING ECCENTRICITY :

```
e = (L/2)-((Mr-Mo)/Rf1)
print("Eccentricity is", e)
if e<=(L/6):
    print("e<L/6, Hence Safe against eccentricity")
else :
    print("Not safe against eccentricity")
```

5.2.5 BEARING PRESSURE :

```
Qb = Rf/(L-2*e)
print("Bearing Pressure is", Qb)
if Qb<sbc:
    print("Qb<sbc, Hence Safe in Bearing")
else :
    print("Not safe against bearing")
```

5.2.6 FACTOR OF SAFETY AGAINST RUPTURE :

```
if Fos1>1.5 and Fos2>2 and  e<=(L/6) and  Qb<sbc:
    print("%-9s %-9s %-4s %-4s %-9s %-9s %-7s %-7s %-7s"
%("Height(h)","Spacing(Sv)","□H","V1/b","Stress(V)","Stress(H)","Tension(T)",
 "Strength(Td)","FOS"))
    h = 0.25
    while h <= H-0.25 :
        if h == 0.25 :
            Sv = 0.625
        elif H-h <= 0.75 :
            Sv = (0.75/2)+(H-h)
        else :
            Sv = 0.75
```

```
b1 = b+(4*h)
if b1 < L :
    b1 = b1
else :
    b1 = L
if h < L1 :
    Hl = Hmax*(L1-h)/L1
else :
    Hl = 0
V = (Vb*h)+Qd+Ql+(V1/b1)
H1 = (ka*V)+Hl
T = H1*Sv
Td = 20
Fos3 = Td/T
if Fos3>1.5 :
    Td = 20
else :
    Td = Td+20
    Fos3 = Td/T
if Fos3<1.5 :
    Td = Td+20
    Fos3 = Td/T
    if Fos3<1.5 :
        Td = Td+20
        Fos3 = Td/T
        if Fos3<1.5 :
            Td = Td+20
            Fos3 = Td/T
            if Fos3<1.5 :
                Td = Td+20
```

```
            Fos3 = Td/T
            if Fos3<1.5 :
                Td = Td+20
                Fos3 = Td/T
                if Fos3<1.5 :
                    Td = Td+20
                    Fos3 = Td/T
                    if Fos3<1.5 :
                        Td = Td+20
                        Fos3 = Td/T
                        if Fos3<1.5 :
                            Td = Td+20
                            Fos3 = Td/T
    print("%-10s %-10s %-6s %-6s %-8s %-8s %-12s %-8s %-10s" %
          ('%.2f'%h,'%.3f'%Sv,'%.1f'%Hl,'%.2f'%(V1/b1),'%.2f'%V,'%.2f'%H1,
          '%.2f'%T,'%.f'%Td,'%.2f'%Fos3))
    h = h+0.75
```

5.2.7 FACTOR OF SAFETY AGAINST PULLOUT RESISTANCE :

```
print("%-8s %-10s %-8s %-6s %-20s %-20s %-20s" %("hi","Laj","Lej","hj","Vertical stress(Vj)","Pullout(P)","FOS"))
  hi = H-0.25
   hj = 0.25
   h = 0.25
   while hi>=0.25 and h < H-0.25 :
       Laj = math.tan(math.radians(teta))*hi
       Lej = L-Laj
       Vj = (hj*Vb)+Qd
       P = 2*Lej*Cfg*Vj*Ci*alpa*math.tan(math.radians(pi))
       if h == 0.25 :
```

```
            Sv = 0.625
        elif H-h <= 0.75 :
            Sv = (0.75/2)+(H-h)
        else :
            Sv = 0.75
        V = (Vb*h)+Qd+Ql
        b1 = b+(4*h)
        if b1 < L :
            b1 = b1
        else :
            b1 = L
        if h < L1 :
            Hl = Hmax*(L1-h)/L1
        else :
            Hl = 0
        V = (Vb*h)+Qd+Ql+(V1/b1)
        H1 = (ka*V)+Hl
        T = H1*Sv
        Fos4 = P/T
   print("%-8s %-10s %-8s %-13s %-15s %-16s %-20s" %('%.3f'%hi,'%.3f'%Laj,
'%.3f'%Lej,'%.2f'%hj,'%.2f'%Vj,'%.2f'%P,'%.2f'%Fos4))
        hi = hi-0.75
    hj = hj+0.75
    h = h+0.75
    print("Hence safe against Rupture & Pullout Resistance")
    print("Provide length of reinforcement:", L,"m")
    print("Provide spacing of reinforcement: 0.625m at top layer",",",Sv,"m at bottom layer and
0.75m at remaining layers with appropriate grade of reinforcement as shown above")
else :
    print("Hence not safe, increase length of reinforcement")
```

CHAPTER - 6

TESTING & ANALYSIS OF CODE

6.1 CASE 1 - DEAD LOAD+LIVE LOAD CONDITION :

6.1.1 PROBLEM :

Design reinforced earth wall with following data,

1. Angle of internal friction (ϕ) = 35
2. Density of backfill soil = 20 KN/m^3
3. Reinforcement length of wall = 6m
4. Height of Retaining wall = 5m
5. Dead load due to surcharge = 15 KN/m^2
6. Live load = 20 KN/m^2
7. Safe bearing capacity of soil = 300 KN/m^2

6.1.2 OUTPUT :

Inputting design parameters :

Enter angle of internal friction : 35

Enter Density of backfill (KN/m3) : 20

Enter Reinforcement length of wall (m) : 6

Enter Height of Retaining wall (m) : 5

Enter Dead load due to surcharge (KN/m2) : 15

Enter Live load (KN/m2) : 20

Enter Safe bearing capacity of soil (KN/m2) : 300

Coefficient of active earth pressure is 0.27099005412014443

External stability checks :

Factor of safety against sliding is 3.775514133470499

Fos>1.5, Hence Safe against sliding

Factor of safety against Overturning is 8.942817632236466

Fos>2, Hence Safe against overturning

Eccentricity is 0.33546474090959

e<L/6, Hence Safe against eccentricity

Bearing Pressure is 151.99648742432325

Qb<sbc, Hence Safe in Bearing

Internal stability checks :

Height from top (h)	**Spacing (S_v)**	**Vertical stress (V)**	**Tension (T)**	**Design strength (T_d)**	**Factor of safety**
0.25	0.625	40.00	6.77	20	2.95
1.00	0.75	55.00	11.18	20	1.79
1.75	0.75	70.00	14.23	40	2.81
2.50	0.75	85.00	17.28	40	2.32
3.25	0.75	100.00	20.32	40	1.97
4.00	0.75	115.00	23.37	40	1.71
4.75	0.625	130.00	22.02	40	1.82

Table 6.1 Factor of safety against rupture

Reinforcement layer (h_i)	**L_{aj}**	**L_{ej}**	**Height from top (h_j)**	**Vertical stress (V_j)**	**Pullout resistance (P)**	**Factor of safety**
4.75	2.473	3.527	0.25	20.00	67.18	9.92
4.00	2.082	3.918	1.00	35.00	130.58	11.68
3.25	1.692	4.308	1.75	50.00	205.13	14.42
2.50	1.301	4.699	2.50	65.00	290.83	16.83
1.75	0.911	5.089	3.25	80.00	387.69	19.08
1.00	0.521	5.479	4.00	95.00	495.71	21.21
0.25	0.13	5.87	4.75	110.00	614.87	27.93

Table 6.2 Factor of safety against pullout resistance

Hence safe against Rupture & Pullout Resistance

Provide length of reinforcement: 6.0 m

Provide spacing of reinforcement: 0.625m at top layer , 0.625 m at bottom layer and 0.75m at remaining layers with appropriate grade of reinforcement as shown above.

6.2 CASE 2 - DEAD LOAD+LIVE LOAD+HORIZONTAL & VERTICAL LINE LOAD CONDITION :

6.2.1 PROBLEM :

Design reinforced earth wall with following data,

1. Angle of internal friction (ϕ) = 36
2. Density of backfill = 20 KN/m^3
3. Reinforcement length of wall = 8m
4. Height of Retaining wall = 7m
5. Dead load due to surcharge = 20 KN/m^2
6. Live load = 15 KN/m^2
7. Horizontal line Load = 50 KN/m
8. Vertical line Load = 200 KN/m
9. Width of Strip = 1.2m
10. Distance of wall to center of strip = 0.9m
11. Safe bearing capacity of soil = 300 KN/m^2

6.2.2 OUTPUT :

Inputting design parameters :

Enter angle of internal friction : 36

Enter Density of backfill (KN/m3) : 20

Enter Reinforcement length of wall (m) : 8

Enter Height of Retaining wall (m) : 7

Enter Dead load due to surcharge (KN/m2) : 20

Enter Live load (KN/m2) : 15

Enter Horizontal line Load (KN/m) : 50

Enter Vertical line Load (KN/m) : 200

Enter Width of Strip (m) : 1.2

Enter Distance of wall to center of strip (m) : 0.9

Enter Safe bearing capacity of soil (KN/m2) : 300

Coefficient of active earth pressure is 0.2596161836824997

External stability checks :

Factor of safety against sliding is 4.561672222547368

Fos>1.5, Hence Safe against sliding

Factor of safety against Overturning is 6.0958167095223175

Fos>2, Hence Safe against overturning

Eccentricity is 1.006384266341037

e<L/6, Hence Safe against eccentricity

Bearing Pressure is 267.23536725343024

Qb<sbc, Hence Safe in Bearing

Internal stability checks :

Height from top (h)	**Spacing (S_v)**	**Horizontal line load (σH)**	**V1/b**	**Vertical stress (V)**	**Horizontal stress (H)**	**Tension (T)**	**Design strength (T_d)**	**Factor of safety**
0.25	0.625	31.1	90.91	130.91	65.07	40.67	80	1.97
1.00	0.75	22.4	38.46	93.46	46.69	35.02	60	1.71
1.75	0.75	13.8	25.00	95.00	38.44	28.83	60	2.08
2.50	0.75	5.1	25.00	110.00	33.68	25.26	40	1.58
3.25	0.75	0.0	25.00	125.00	32.45	24.34	40	1.64
4.00	0.75	0.0	25.00	140.00	36.35	27.26	60	2.20
4.75	0.75	0.0	25.00	155.00	40.24	30.18	60	1.99
5.50	0.75	0.0	25.00	170.00	44.13	33.10	60	1.81
6.25	1.125	0.0	25.00	185.00	48.03	54.03	100	1.85

Table 6.3 Factor of safety against rupture

Reinforcement layer (h_i)	L_{aj}	L_{ej}	Height from top (h_j)	Vertical stress (V_j)	Pullout resistance (P)	Factor of safety
6.75	3.439	4.561	0.25	25.00	112.66	2.77
6.00	3.057	4.943	1.00	40.00	195.36	5.58
5.25	2.675	5.325	1.75	55.00	289.39	10.04
4.50	2.293	5.707	2.50	70.00	394.74	15.63
3.75	1.911	6.089	3.25	85.00	511.43	21.01
3.00	1.529	6.471	4.00	100.00	639.44	23.46
2.25	1.146	6.854	4.75	115.00	778.78	25.80
1.50	0.764	7.236	5.50	130.00	929.45	28.08
0.75	0.382	7.618	6.25	145.00	1091.44	20.20

Table 6.4 : Factor of safety against pullout resistance

Hence safe against Rupture & Pullout Resistance

Provide length of reinforcement: 8.0 m

Provide spacing of reinforcement: 0.625m at top layer , 1.125 m at bottom layer and 0.75m at remaining layers with appropriate grade of reinforcement as shown above

CHAPTER - 7

RESULTS & DISCUSSION

CASE 1 - DEAD LOAD+LIVE LOAD CONDITION :

EXTERNAL STABILITY :

1. **Sliding:**
   a. The factor of safety obtained is 3.775 which is greater than 1.5 hence the design of retaining wall is safe against sliding.
2. **Overturning:**
   a. The factor of safety against overturning is 8.942 which is greater than 2 hence safe against overturning.
3. **Limiting eccentricity:**
   a. Eccentricity is 0.335 which is less than L/6 hence safe against eccentricity.
4. **Bearing pressure:**
   a. The bearing pressure for the sample is 151.99 KN/m2 which is less than 300 KN/m2 hence it is safe against bearing pressure.

INTERNAL STABILITY :

Height from top (h)	Spacing (S_v) in m	Design strength (T_d)	Factor of safety
0.25	0.625	20	2.95 > 1.5
1.00	0.75	20	1.79 > 1.5
1.75	0.75	40	2.81 > 1.5
2.50	0.75	40	2.32 > 1.5
3.25	0.75	40	1.97 > 1.5
4.00	0.75	40	1.71 > 1.5
4.75	0.625	40	1.82 > 1.5

Table 7.1 Spacing of reinforcement

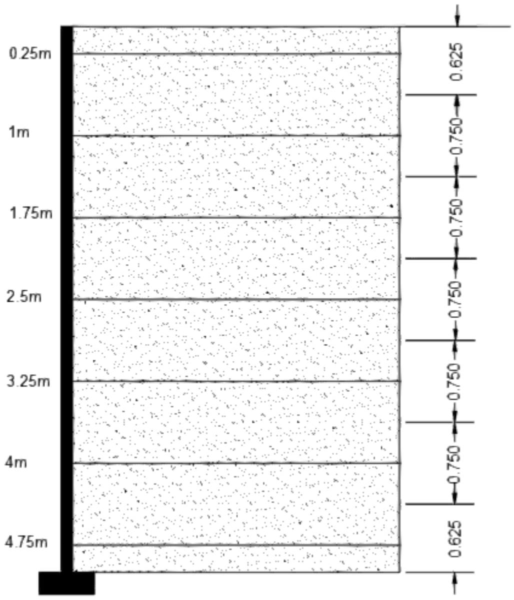

Fig.7.1 Spacing of reinforcement

Factor of safety against rupture and pullout resistance values are greater than 1.5, hence safe. Provide 6m length of reinforcement with 0.625m spacing at top and bottom layers, 0.75m spacing for remaining layers with required design tensile strength.

CASE 2 - DEAD LOAD+LIVE LOAD+HORIZONTAL & VERTICAL LINE LOAD CONDITION :

EXTERNAL STABILITY :

5. **Sliding:**
   a. The factor of safety obtained is 4.561 which is greater than 1.5 hence the design of retaining wall is safe against sliding.
6. **Overturning:**
   a. The factor of safety against overturning is 6.095 which is greater than 2 hence safe against overturning.
7. **Limiting eccentricity:**
   a. Eccentricity is 1.006 which is less than L/6 hence safe against eccentricity.
8. **Bearing pressure:**
   a. The bearing pressure for the sample is 267.235 KN/m2 which is less than 300 KN/m2 hence it is safe against bearing pressure.

INTERNAL STABILITY :

Height from top (h)	Spacing (S_v) in m	Design strength (T_d)	Factor of safety
0.25	0.625	80	1.97 > 1.5
1.00	0.75	60	1.71 > 1.5
1.75	0.75	60	2.08 > 1.5
2.50	0.75	40	1.58 > 1.5
3.25	0.75	40	1.64 > 1.5
4.00	0.75	60	2.20 > 1.5
4.75	0.625	60	1.99 > 1.5
5.50	0.75	60	1.81 >1.5
6.25	1.125	100	1.85 >1.5

Table 7.2 Spacing of reinforcement

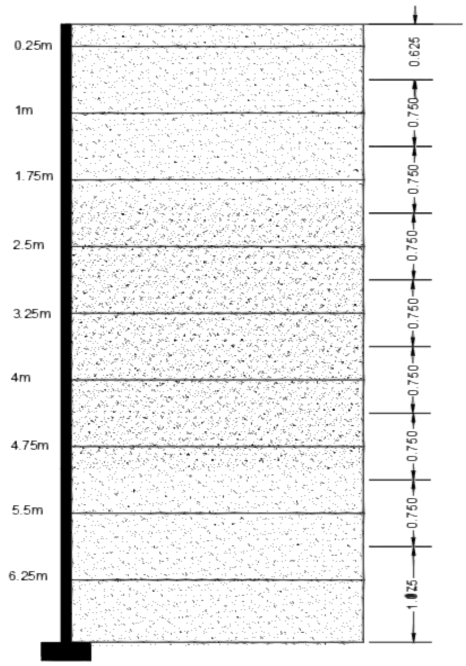

Fig.7.2 Spacing of reinforcement

Factor of safety against rupture and pullout resistance values are greater than 1.5, hence safe. Provide 8m length of reinforcement with 0.625m spacing at top, 1.125m spacing at bottom layer, 0.75m spacing for remaining layers with required design tensile strength.

CHAPTER - 8

CONCLUSION

1. In conclusion, our project successfully addressed the design of a reinforced earth retaining wall using Python code. Through our analysis and design process, we were able to achieve a safe and simple solution for stabilizing the slope and retaining the soil at the site.
2. This code can be adopted for dry cohesionless horizontal backfill for any height of retaining wall as per BS 8006-1:2010 (code of practice for strengthened /reinforced soil and other fills) for given below loading conditions,
    i. 1. Dead load+Live load condition.
    ii. 2. Dead load+Live load+Horizontal & Vertical line load condition.
3. The code will take input parameters such as soil properties, wall geometry, loads such as dead load, live load, horizontal & vertical line loads acting on the retaining wall, and will output the reinforcement requirements ensuring factor of safety against rupture and pullout resistance.
4. The findings of this project suggest that using Python code can significantly improve the accuracy and efficiency of reinforced earth retaining wall design. Our design methodology, which incorporated various soil parameters and reinforcement details, demonstrated the effectiveness of using Python code for complex engineering problems.
5. As a team, we learned a great deal from this project, including the importance of detailed analysis, collaboration, and effective communication. We also gained valuable experience in using Python code for civil engineering applications, which we believe will be beneficial for our future careers in the industry.
6. Overall, we believe that the design of reinforced earth retaining walls using Python code has immense potential for solving complex geotechnical challenges. We hope that our project will contribute to the growing body of knowledge in this field and inspire others to explore the possibilities of using advanced computational tools for civil engineering design.

REFERENCES

- The design procedures are lain on BS 8006-1:2010 (code of practice for strengthened/reinforced soil and other fills)
- J.T. Laba and J.B. Kennedy (1986) ‘Reinforced earth retaining wall analysis and design’, Windsor, Ont., Canada N9B 3P4.
- Lee, K.L., Admas, B. D., and Vagneron, J.J. (1973) ‘Reinforced earth retaining walls’, ASCE - Journal of the Soil Mechanics and Foundation Division, 99(SM10), pp. 745-764.
- Izzaldin Almohd (2014) ‘A Case Study of Efficient Solution for Very High Geogrid-Reinforced Retaining Wall’.
- Dr. P. D. Hiwase (2018) ‘Adoption of Programming Codes in the Design of Earth Retaining Wall in Different Backfill Conditions’ - The International Journal of Engineering and Science (IJES).
- IRC:SP:102- (2014) ‘Guidelines for design and construction of reinforced soil walls’.
- G L Sivakumar Babu, An introduction to soil reinforcement and Geosynthetics.
- Michael Dobie (2013) ‘Reinforced Soil Retaining Walls - An Outline of Design Methods and Sources of Conservatism’.
- MORTH Standard Data Book.
- AP SOR 2019-2020.