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EFFECTS OF VARIATIONS IN THE DESIGN PARAMETERS OF CANTILEVER RETAINING WALL

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Abstract
Natural disasters are becoming more frequent both in India and globally in recent years. Retaining walls are structures that are accustomed retain earth (or the other material) in a position wherever the ground level changes suddenly.Analysis of the soundness of earth retaining structures in such slopes and embankments could be a tough geotechnical task. The software package GEO5 permits engineers to hold out stability analysis of the retaining wall designed. The lateral force because of earth pressure is that the main force that acts on the retaining wall which has the tendency to bend, slide and overturn it. This research involves an analytical study of external stability of retaining walls. The stability involves checking, sliding, overturning, and bearing capacity of the retaining walls.
The 'cantilever wall' is that the most common variety of retaining wall and is economical up to regarding 8 m. Counter fort walls are appropriate for holding wall heights 8.0m to 10.0m. The lateral force because of earth pressure is the main force that acts on the retaining wall which has the tendency to bend, slide and overturn it. This paper shows the application of the tool (GEO5) slope stability software package to evaluate stability of the retaining wall designed.
For this type of analysis we take the help of software, and we use GEO5 which permits engineers to hold out the stability analysis of the retaining wall designed. This tool consists of individual programs with a unified and easy to use interface. Many factors like height and inclination, back fill soil slope, and surface surcharge are studied in this research. More than 3000 points are taken in account for analyzing. Flow charts are prepared which can be used as a guide for rapid and easy checking the external stability of retaining walls with some limitations.

Keywords:
Cantilever Retaining Wall, Stability

I. Introduction

The type of wall we will examine is cantilever type of retaining wall. Cantilever type of retaining walls are constructed from reinforced Portland cement concrete. It is predominant type of rigid retaining walls used from about the 1920s to the 1970s. This type of wall displaced the traditional gravity wall are constructed of stone blocks or unreinforced cement concrete, which may prove to be not so economical for height above 3m, due to superior economics in the use of material and support backfill up to 7.5m high (Oyenuga, 2005)
The present research work will focuses on the stability analysis and designing the cantilever retaining wall. The main discussions are the external stability of the section and the adherence to the recommendations of IS 456:2000. This study aims to understand how changes in design factors affect the stability of retaining walls using advanced software.
We're exploring variables like wall height, inclination, and different soil types to see their impact on structural performance. By using cutting-edge tools like GEO5 software, we want to pinpoint the most critical design parameters that affecting the safety and effectiveness of retaining walls. This research seeks to provide practical insights for engineers, offering recommendations on optimizing designs for

various scenarios. Ultimately, the goal is to enhance our understanding of retaining wall behaviour and contribute to more resilient and efficient structural designs.

II. Literature

2.1. Design and Analysis of Retaining Wall (2021)

Authors: D.R. Dhamdhere, Dr. V. R. Rathi, Dr. P. K. Kolase
Journal: International Conference on Emerging Trends in Science, Engineering & Technology
Description: This paper delves into the design and analysis of cantilever and relieving platform retaining walls, comparing their performance in terms of cost, economy, stability, and bending moment. With a focus on walls ranging from 3m to 10m in height with a specific soil bearing capacity, it concludes that relieving platform walls exhibit superior economic efficiency, stability, and effectiveness in reducing bending moments compared to cantilever walls.

2.2 Pressure Distribution Law on Vertical Plate of Cellular-Counterfort Retaining Structure (2021)

Authors: Ningyu Zhaoa, b, Yong Xu, Shun Xiangb, Yi Song
Journal: Alexandria Engineering Journal
Description: This study concentrates on the cellular-counterfort retaining structure, investigating non-uniform soil pressure on the vertical plate due to counterfort rib plates. The paper derives formulas for soil pressure distribution on the vertical and bottom plates, considering factors such as fill layers and friction. Validation through centrifugal model tests confirms the formula accuracy, revealing pressure distribution patterns influenced by counterfort spacing.

2.3 Stability Analysis of Retaining Wall Using GEO5 (2021)

Authors: Md. Furqan Hussin, Prof. Vishal .M, Prof. Sharanakkumar B.M
Journal: International Research Journal of Modernization in Engineering Technology and Science
Description: This study employs GEO5 software for stability analysis of retaining walls, specifically addressing challenges posed by natural disasters. The software accommodates cantilever walls up to 8 meters and counterfort walls from 8 to 10 meters, addressing transverse forces from Earth pressure to prevent sliding. The study emphasizes the use of fine particle grinder powder for enhanced stability and cost-effectiveness of backfill material.

2.4 Cantilever Retaining Wall using GEO5 Software - A REVIEW (2020)

Authors: K. Harish Kumar, B. Rama Krishna, T. V. Siva Prasad
Journal: Proceedings of National Conference on Emerging Trends in Civil Engineering
Description: This paper reviews the global application of GEO5 software in addressing earth pressure challenges in geotechnical engineering, particularly for retaining walls. It emphasizes the software's role in ensuring safety and structural integrity through various analysis methods such as Rankine and Coulomb's theory.

2.5 Classification and Inspection of Reinforced Concrete Elements for Use in Retaining Walls Using Ultrasound Tests (2020)

Authors: Rodrigo Rogerio Cerqueira da Silva, Raquel Gonçalves, Cinthya Bertoldo
Journal: Construction and Building Materials
Description: This research evaluates the use of ultrasound testing for precast retaining walls, specifically for sorting and inspecting elements before and after installation. Ultrasound testing proves effective, especially for stiffness and specific aggregate models, compared to strength and general models.

2.6. Optimum Design of Reinforced Concrete Counterfort Retaining Walls using TLBO, Jaya Algorithm (2020)

Authors: HasanTahsin Öztürka, Tayfun Dedeb, Emel Türkerb
Journal: Structures

Description: The study investigates the minimum-cost optimal design of reinforced concrete counterfort retaining walls using TLBO and Jaya algorithms. It employs SAP2000-API for realistic structural analysis and demonstrates TLBO's superiority over Jaya with 46 constraints considered.

2.7 Earth Retaining Structures (2016)

Author: Ruwan Rajapakse

Journal: Geotechnical Engineering Calculations and Rules of Thumb

Description: This paper provides an overview of earth retaining structures, highlighting their importance during soil cutting for road or building construction. It discusses various types of earth retaining structures, including gravity walls, cantilever walls, counterfort walls, and gabion walls.

2.8 Analytical Study for Stability of Gabion Walls (2010)

Authors: Ciyamand T. Peerdawood, Yousif I. Mawlood

Journal: Journal of Pure and Applied Sciences / Salahaddin University - Hawler

Description: This research conducts an analytical study of external stability in gabion walls, examining factors such as height, inclination, backfill soil slope, and surcharge. Utilizing 150 data points, the study creates flow charts as stability guides with specified limitations.

2.9 Economic Design of Retaining Wall Using Particle Swarm Optimization with Passive Congregation (2010)

Authors: Mohammad Khajehzadeh, Mohd. Raihan Taha, Ahmed El-Shafie, Mahdiyeh Eslami

Journal: Australian Journal of Basic and Applied Sciences

Description: The paper introduces an optimization approach using particle swarm optimization with passive congregation for nonlinear constrained retaining structure optimization. It demonstrates the method's effectiveness in cost reduction and constraint handling compared to standard methods.

2.10 Design Basis and Economic Aspects of Different Types of Retaining Walls (2004)

Authors: A. J. Khan, M. Sikder

Journal: Journal of Civil Engineering (IEB)

Description: This paper outlines the design procedures and economic advantages of internally stabilized walls over externally stabilized walls for retaining soil. Emphasizing cost-effectiveness, especially with increasing wall height, it provides insights into the adoption of these walls in Bangladesh.

2.11. Behavior of Cantilever Retaining Walls Under Seismic Conditions (2011)

Authors: Anurag UPADHYAY, A. MURALI KRISHNA, K.D. SINGH

Journal: 5th International Conference on Earthquake Geotechnical Engineering

Description: This paper addresses the significance of analyzing the behavior of cantilever retaining walls under seismic conditions, emphasizing the instability related to earth pressure distribution and the dynamic response of walls. The study employs a finite element method-based numerical model to simulate the dynamic behavior of the walls, verifying and validating the model against existing physical model studies. The validated model is then subjected to seismic records with varying predominant frequencies, and the methodology and results of parametric studies are discussed.

2.12. Design of Cantilever Retaining Wall with 4m Height (2015)

Authors: Tamadher Abood, Hatem E. Younis Eldawi, Faeza R. Elnaji Abdulrahim

Journal: International Journal of Civil and Structural Engineering Research

Description: This study focuses on the analysis and design of a cantilever retaining wall with a height of 4m. The wall is constructed from steel-reinforced, cast-in-place concrete, with a design resembling an inverted T. The paper covers the estimation of primary dimensions, factor of safety calculations against sliding, overturning, and bearing. Checks for shear resistance at the base, tension stresses in the stem, tension stresses for the base, and reinforcement calculations are conducted. All analyses and designs adhere to the ACI code.

2.13. A Critical Review on Design of RCC Cantilever Retaining Wall (2022)

Authors: Taring Sanjay, Talkeshwar Ray

Journal: International Journal of Scientific Research in Science and Technology

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Description: This paper provides an in-depth review of the design and dynamics of RCC Cantilever Retaining Walls in soil strata, especially in hilly and mountainous areas like the Himalayan range. The review is based on previous research using different software tools. It addresses the significance of understanding the dynamic behavior of soil and retaining structures, particularly in highly seismic zones. The paper emphasizes the essential role of RCC Cantilever Retaining Walls in controlling flood, landslide, and natural phenomena for economic purposes. Various methods used by researchers in different software for RCC Cantilever Retaining structure are discussed.

2.14 Conclusion from Literature Survey:

In synthesizing findings from a diverse range of studies on retaining wall design and analysis, several key insights emerge. Notably, investigations into the economic efficiency of different wall types underscore the superiority of relieving platform walls in terms of cost-effectiveness, stability, and reduced bending moments when compared to cantilever walls. Advanced software applications, such as GEO5, play a pivotal role in stability analyses, addressing challenges posed by natural disasters and enhancing overall stability and cost-effectiveness. Innovative optimization approaches, like particle swarm optimization with passive congregation, demonstrate effectiveness in reducing costs and managing nonlinear constraints in retaining wall design. Material testing methods, specifically ultrasound testing, prove reliable for sorting and inspecting precast retaining wall elements, particularly for stiffness and specific aggregate models. Seismic considerations are paramount, with studies emphasizing the importance of understanding retaining wall behavior under seismic conditions through numerical models and finite element methods. Addressing geotechnical challenges, research delves into stability in gabion walls, non-uniform soil pressure distribution in cellular-counterfort structures, and the dynamic response of cantilever walls. Moreover, the literature provides valuable design recommendations, advocating for internally stabilized walls over externally stabilized walls for increased cost-effectiveness and offering considerations for retaining walls in challenging terrains. Collectively, these insights underscore the multidimensional nature of retaining wall design, emphasizing the need for a comprehensive approach that considers economic, geotechnical, and seismic factors to achieve robust and efficient structural solutions.

III. Methodology

This study will evaluate the outcomes of varying design parameters in retaining walls with the assistance of GEO5 software.

Phase I: Literature Review

In this initial step, we delve into existing research to understand what's known about retaining walls. We look at academic papers, journals, and conference findings to identify trends, gaps in knowledge, and get a solid understanding of how retaining walls are currently designed and assessed.

Phase II: Design of Retaining Wall

The objective is to develop a comprehensive design for the retaining wall and explore variations in key parameters to optimize its overall effectiveness. This includes determining the optimal height, considering safety and stability factors, and varying surcharge loads to assess their impact on the design. Additionally, experiments with different slope angles are conducted to identify the most effective configuration, and soil properties are analyzed and modified to enhance overall stability. The outputs of this phase include detailed design documentation specifying parameters and configurations, accompanied by drawings and schematics illustrating various proposed retaining wall variations.

Parameter	Abbrivation	Ranges of Parameter
Height (m)	H	4, 5, 6, 7
Surcharge (KN/m2)	q	0, 10, 20, 30
Slope Angle (Degree)	β	0, 5, 10, 15
Backfill Angle (Degree)	A	0, 5, 10, 15

Table 3.1: Parameters Studied

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Phase III: Safety Factor Analysis

Here, the objective shifts to the evaluation of safety factors associated with the designed retaining wall. Tasks involve assessing safety factors against overturning to ensure resistance to tipping, checking safety against sliding to prevent undesirable horizontal movement, and verifying bearing capacity to ensure the foundation can support applied loads. The outputs include a comprehensive safety factor analysis report for overturning, sliding, and bearing capacity, along with recommendations for adjustments if any safety factor falls below acceptable thresholds.

Phase IV: Result Analysis Using Excel

The focus is on analyzing and interpreting the results obtained from the design and safety factor assessments. This phase involves utilizing Excel or similar programs for systematic result analysis, calculating and tabulating data from each phase, creating plots and charts to visualize relationships between different parameters, and connecting variables of trials to identify patterns and trends. The outputs comprise a comprehensive result analysis report, Excel sheets containing calculated values, plots, and charts, along with conclusions regarding the effectiveness of different design variations. This phase ensures a thorough understanding of the project outcomes and informs any further refinements or adjustments to the retaining wall design.

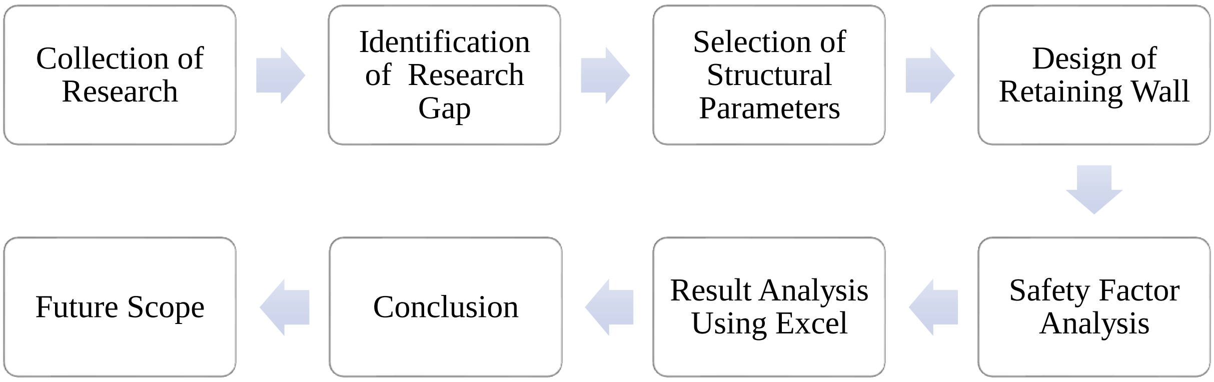

Table 3.2: Flowchart of Methodology

IV. Validation

To validate the model in GEO5 considering past experimental study for checking the accuracy the experimental paper chosen for validation is "Design of Cantilever Retaining Wall with 4m Height" by Tamadher Abood, Hatem E.Younis Eldawi, Faeza R. Elnaji Abdulrahim (International Journal of Civil and Structural Engineering Research) Vol. 3, Issue 1, pp: (318-326) (2015)''. An Investigation on the Software performance comparison with experimental data of varying parameters of cantilever retaining wall are studied. The software GEO5 allows engineers to carry out limit equilibrium slope stability analysis of existing natural slopes, unreinforced man – made slopes or slopes with soil reinforcement. It cooperates with all programs for analysis of retaining wall designs. Overall stability analysis of all retaining wall types can be performed directly with the slope stability program. Foundations can be analyzed using the spread footing or pile programs.

Below table shows the material and structural properties of wall considered for modelling taken by the author Tamadher Abood (2015)

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Parameter	**Notation**	**Value**
The height of wall	h	4m
The density of back fill soil	γs	17.5 kN/m^3
the angle of internal friction of back fill soil	$\emptyset$	30^0
Density of concerte	γc	25 kN/m^3
the assumed surcharge load	q	50 kN/m^2
The bearing capacity of soil under the wall	qa	200 kN/m^2
the angle of internal friction of fondation soil	$\emptyset$	32
The cohesion of foundation soil	C	10 kN/m^2
Compressive strength of concrete	fc'	21Mpa
The yield stress of steel	fy	347Mpa

Table 4.1 Propeties of Cantilever Retaining Wall

4.1 Modelling

To model the wall, IS 456: 2000 I used.

New Model
↓
Select Code
↓
Create Geometry
↓
Define Material Properties
↓
Assign Property
↓
Define Model
↓
Analyse
↓
Verification
↓
Results

4.2 Analysis

As per table 4.2, the values obtained from the GEO5 and the results obtained by experimental study are overlapped. Hence, after comparing the software result and experimental values, for factor of safety against overturing, sliding and bearing, it is clear that the software application and the experimental findings were in good concordance.

FOS	**Tamadher Abood et al. (20**	**Present Study**	**% of variation**
Overturning	2.8	3.05	8.19
Sliding	1.67	1.50	10.17
Bearing	2.69	2.82	4.6

Table 4.2 Comparison of results

4.2 Summary

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After performing the same test on software, it is observed that result of the experimental data and software are correctly matched.

1. Results are validated with experimental data by pe1forming the analysis in software GEO5.
2. FOS for overturning obtained by software is 2.8 while obtained by experimental study was 3.05 which is almost same, that means it shows the accurate bonding between experimental and software application.
3. FOS for bearing obtained by software is 2.82 and obtained by experimental study was 2.69. It shows that approximately 95% of the results are same.
4. FOS for sliding obtained by software is almost same with the experimental study.

V. MODELLING AND ANALYSIS IN GEO5

5.1 Model of the Structure

It covers design procedure for cantilever retaining walls and the calculation of the overturning moment and sliding forces, using numerical method and verify from GEO5 software.

5.2 Design of Cantilever Retaining Wall

In the process of designing cantilever wall we use earth pressure co-efficient are calculated based on the theory of Rankine's and coulomb's backfill earth. We will assume that a triangular pressure distribution is developed on the back of the wall due to the backfill earth. All earth pressure will be considered to act on a vertical plane, which passes through the rear end of the base slab.

The design parameters for Stability Analysis:

The height of the retaining wall was taken to be less than 7m for economical design and Width of the footing (B) was taken to be in the range of 0.5 to 1.0 of wall height, Wall thickness, b = B/6, toe width, c as 1/3 of B) and width of heel, d was also used as 0.5B.

In the process of designing the retaining walls, and design engineer must assume some of the dimensions for calculations called proportioning, such assumptions allow the engineer to check trial sections of the walls for stability, if stability check give undesirable result then section will be changed and then rechecked.

Surcharge pressure on backfill, Ws (KN/m^2), loads are not to be considered so zero is taken.

Slope of backfill, β (0) with the horizontal angle made by backfill soil with the horizontal.

Unit weight of the soil (γ) –assumed as, it is found to be 500 KN/m^2

Concrete density taken – 25 KN/m^2

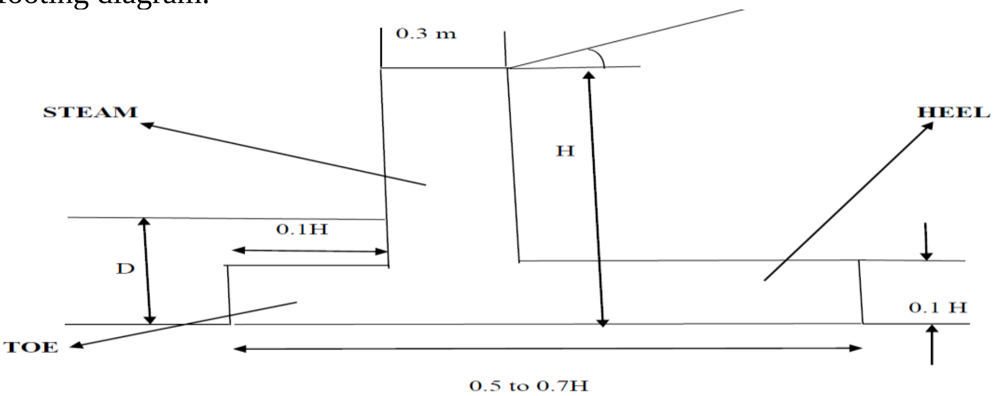
Bearing capacity of soil is taken as 200 KN/m^2

Base thickness in mm –the thickness of base slab is taken as 8-12% of total height (H) of wall.

For initial design considerations, the length of heel slab is taken as H√Ka/3 (According to Pillai and Menon, Reinforced Concrete Design, 2011). The length of toe slab is in m.

5.3 Elements of Cantilever Retaining Wall

The retaining wall has been divided into three parts: stem, heel, and toe as shown for the following cantilever footing diagram.



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In the above diagram the approximate dimensions for various components of retaining wall for initial stability checks.

VI. RESULT AND DISCUSSION

6.1 General

Excel program is used in calculating and plotting the analysis results. Trials are done to prepare one chart to connect the group of variables to check factor of safety for overturning, sliding and bearing in rapid and easy ways, in result flow charts for each factor against overturning, sliding and bearing capacity are achieved as shown in following tables and figures. These charts can be used as guides for rapid check the external stability of cantilver retaining walls with limitations and conditions mentioned previously.

		FOS Overturning				FOS Sliding				FOS Bearing			
	α↓ β →	0	5	10	15	0	5	10	15	0	5	10	15
Q= 0 KN/m2	0	4.86	4.43	4.04	3.82	2.2	2.05	1.9	1.79	3.09	2.97	2.82	2.69
	5	4.86	4.42	4.04	3.82	2.2	2.04	1.9	1.79	3.09	2.97	2.82	2.69
	10	4.85	4.41	4.03	3.81	2.19	2.03	1.89	1.78	3.09	2.97	2.82	2.69
	15	4.85	4.4	4.02	3.8	2.18	2.02	1.89	1.77	3.09	2.97	2.82	2.69
Q= 10 KN/m2	0	4.03	3.72	3.41	3.11	1.94	1.82	1.69	1.57	2.78	2.61	2.44	2.26
	5	4.02	3.71	3.4	3.1	1.93	1.81	1.68	1.56	2.78	2.61	2.44	2.26
	10	4.01	3.7	3.39	8.99	1.92	1.8	1.67	1.55	2.78	2.61	2.44	2.26
	15	4	3.7	3.88	3.08	1.91	1.79	1.66	1.55	2.78	2.61	2.44	2.26
Q= 20 KN/m2	0	3.38	3.16	2.92	2.68	1.72	1.62	1.52	1.42	2.43	2.26	2.1	1.93
	5	3.37	3.15	2.91	2.67	1.71	1.6	1.51	1.41	2.43	2.26	2.1	1.93
	10	3.36	3.14	2.9	2.66	1.71	1.6	1.5	1.4	2.43	2.26	2.1	1.93
	15	3.36	3.13	2.89	2.65	1.7	1.59	1.49	1.39	2.43	2.26	2.1	1.93
Q= 30 KN/m2	0	2.94	2.78	2.6	2.41	1.56	1.47	1.39	1.3	2.13	1.98	1.82	1.66
	5	2.92	2.76	2.59	2.4	1.55	1.46	1.38	1.29	2.13	1.98	1.82	1.66
	10	2.92	2.76	2.58	2.39	1.54	1.45	1.37	1.25	2.13	1.98	1.82	1.66
	15	2.91	2.75	2.57	2.38	1.54	1.44	1.37	1.28	2.13	1.98	1.82	1.66

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Table 6.1 Data for cantilever retaining wall for height H = 4m

		FOS Overturning				**FOS Sliding**				**FOS Bearing**			
	α↓ β →	0	5	10	15	0	5	10	15	0	5	10	15
Q= 0 KN/m2	0	4.95	4.55	4.16	3.77	2.06	1.92	1.79	1.65	3.35	3.21	3.08	2.95
	5	4.94	4.54	4.13	3.75	2.05	1.91	1.78	1.63	3.35	3.21	3.08	2.95
	10	4.93	4.53	4.11	3.75	2.04	1.9	1.75	1.62	3.35	3.21	3.08	2.95
	15	4.89	4.51	4.1	3.74	2.04	1.89	1.75	1.61	3.35	3.21	3.08	2.95
Q= 10 KN/m2	0	4.07	3.79	3.5	3.2	1.81	1.7	1.59	1.47	3.1	2.96	2.82	2.61
	5	4.06	3.78	3.49	3.19	1.8	1.69	1.59	1.46	3.1	2.96	2.82	2.61
	10	4.03	3.77	3.47	3.18	1.79	1.68	1.58	1.45	3.1	2.96	2.82	2.61
	15	4.02	3.76	3.44	3.17	1.78	1.67	1.57	1.44	3.1	2.96	2.82	2.61
Q= 20 KN/m2	0	3.39	3.2	2.98	2.76	1.63	1.51	1.42	1.33	2.81	2.63	2.45	2.25
	5	3.38	3.19	2.97	2.75	1.62	1.51	1.4	1.32	2.81	2.63	2.45	2.25
	10	3.37	3.18	2.96	2.75	1.61	1.51	1.4	1.31	2.81	2.63	2.45	2.25
	15	3.35	3.17	2.95	2.74	1.6	1.5	1.39	1.3	2.81	2.63	2.45	2.25
Q= 30 KN/m2	0	2.94	2.79	2.63	2.46	1.45	1.37	1.3	1.22	2.48	2.63	2.45	2.25
	5	2.93	2.78	2.63	2.45	1.44	1.37	1.29	1.22	2.48	2.63	2.45	2.25
	10	2.92	2.76	2.61	2.44	1.44	1.35	1.28	1.21	2.48	2.63	2.45	2.25
	15	2.91	2.76	2.6	2.43	1.42	1.34	1.28	1.21	2.48	2.63	2.45	2.25

Table 6.2 Data for cantilever retaining wall for height H = 5m

		FOS Overturning				**FOS Sliding**				**FOS Bearing**			
	α↓ β →	0	5	10	15	0	5	10	15	0	5	10	15
Q= 0 KN/m2	0	4.66	4.3	3.95	3.64	2.04	1.91	1.78	1.66	2.57	2.46	2.37	2.24

	5	4.65	4.29	3.94	3.64	2.04	1.91	1.77	1.65	2.57	2.46	2.37	2.24
	10	4.64	4.28	3.92	3.63	2.03	1.9	1.76	1.64	2.57	2.46	2.37	2.24
	15	4.63	4.27	3.92	3.62	2.02	1.89	1.75	1.63	2.57	2.46	2.37	2.24
Q= 10 KN/m2	0	3.98	3.71	3.43	3.15	1.84	1.72	1.61	1.5	2.39	2.25	2.11	1.97
	5	3.98	3.7	3.42	3.14	1.82	1.7	1.6	1.48	2.39	2.25	2.11	1.97
	10	3.98	3.69	3.41	3.13	1.82	1.69	1.59	1.45	2.39	2.25	2.11	1.97
	15	3.97	3.68	3.4	3.12	1.81	1.68	1.58	1.45	2.39	2.25	2.11	1.97
Q= 20 KN/m2	0	3.42	3.22	3	3.78	1.67	1.56	1.47	1.38	2.14	2.01	1.87	1.73
	5	3.4	3.21	2.99	2.77	1.66	1.55	1.46	1.37	2.14	2.01	1.87	1.73
	10	3.39	3.2	2.99	2.76	1.65	1.55	1.45	1.36	2.14	2.01	1.87	1.73
	15	3.38	3.19	2.98	2.75	1.64	1.54	1.44	1.35	2.14	2.01	1.87	1.73
Q= 30 KN/m2	0	3.03	2.87	2.7	2.51	1.53	1.45	1.37	1.28	1.92	1.8	1.67	1.53
	5	3.02	2.86	2.7	2.5	1.52	1.45	1.36	1.27	1.92	1.8	1.67	1.53
	10	3.01	2.86	2.69	2.49	1.52	1.43	1.35	1.26	1.92	1.8	1.67	1.53
	15	3.01	2.85	2.68	2.48	1.51	1.42	1.34	1.26	1.92	1.8	1.67	1.53

Table 6.3 Data for cantilever retaining wall for height H = 6m

		FOS Overturning				**FOS Sliding**				**FOS Bearing**			
	α↓ β →	0	5	10	15	0	5	10	15	0	5	10	15
Q= 0 KN/m2	0	4.42	4.11	3.8	3.49	1.98	1.86	1.74	1.62	2.13	2.04	1.93	1.81
	5	4.41	4.1	3.79	3.49	1.97	1.85	1.73	1.61	2.13	2.04	1.93	1.81
	10	4.4	4.09	3.78	3.48	1.96	1.84	1.72	1.6	2.13	2.04	1.93	1.81
	15	4.39	4.08	3.78	3.47	1.95	1.83	1.71	1.59	2.13	2.04	1.93	1.81
Q= 10 KN/m2	0	3.84	3.6	3.35	3.09	1.81	1.7	1.59	1.49	1.96	1.85	1.74	1.62
	5	3.83	3.59	3.34	3.08	1.8	1.69	1.58	1.48	1.96	1.85	1.74	1.62

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	10	3.82	3.58	3.33	3.07	1.79	1.68	1.57	1.47	1.96	1.85	1.74	1.62
	15	3.81	3.57	3.32	3.06	1.78	1.67	1.56	1.46	1.96	1.85	1.74	1.62
Q= 20 KN/m2	0	3.36	3.17	2.97	2.76	1.66	1.56	1.47	1.38	1.78	1.68	1.56	1.45
	5	3.35	3.17	2.96	2.75	1.65	1.54	1.46	1.38	1.78	1.68	1.56	1.45
	10	3.34	3.16	2.95	2.75	1.64	1.53	1.45	1.38	1.78	1.68	1.56	1.45
	15	3.33	3.15	2.94	2.74	1.83	1.52	1.44	1.37	1.78	1.68	1.56	1.45
Q= 30 KN/m2	0	3.01	2.46	2.69	2.52	1.54	1.46	1.38	1.29	1.62	1.52	1.41	1.3
	5	3.01	2.45	2.69	2.52	1.53	1.46	1.38	1.29	1.62	1.52	1.41	1.3
	10	3	2.45	2.68	2.52	1.52	1.46	1.37	1.29	1.62	1.52	1.41	1.3
	15	3	2.44	2.68	2.52	1.52	1.45	1.37	1.29	1.62	1.52	1.41	1.3

Table 6.4 Data for cantilever retaining wall for height H = 7m

6.2 Study with respect to factor of safety:

The design of wall with different values of various varying parameters is done to prepare a design chart for the construction of cantilever retaining wall. In this chapter, the results of all the studies are explained in detail in the form of graphs. Because of lot of data, only a part of results for cantilever height H= 6m are presented the graphs of this research, are chosen as a sample for presentation.

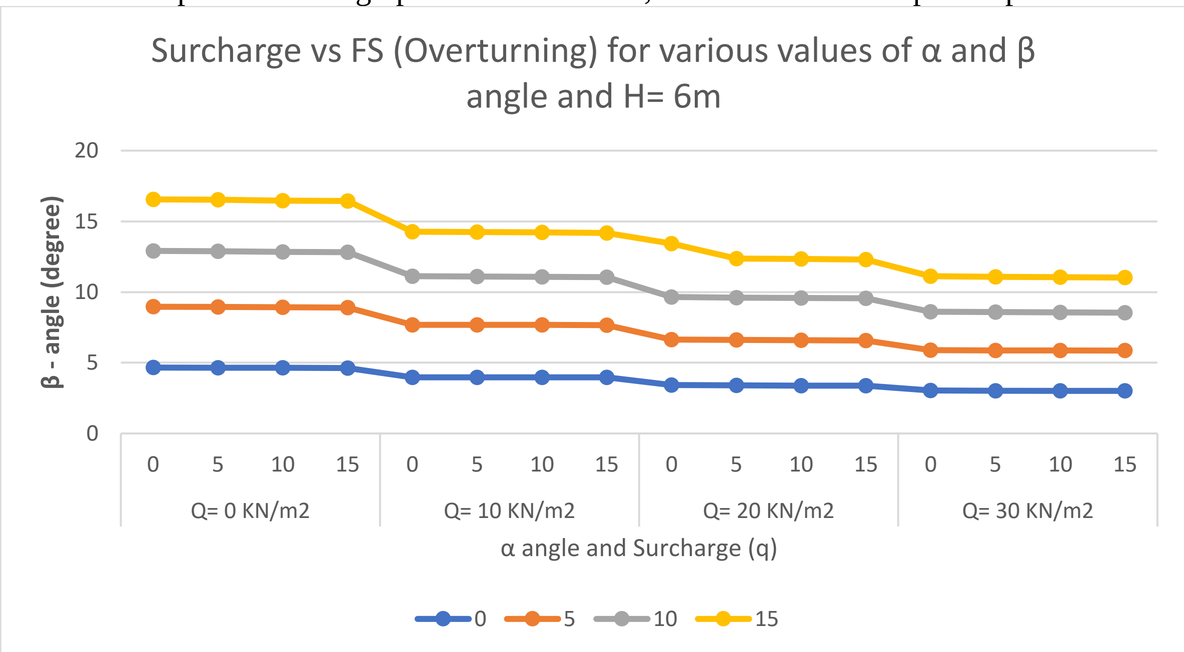

Figure 6.1 Surcharge vs FS (Overturning) for various values of α and β angle and H= 6m

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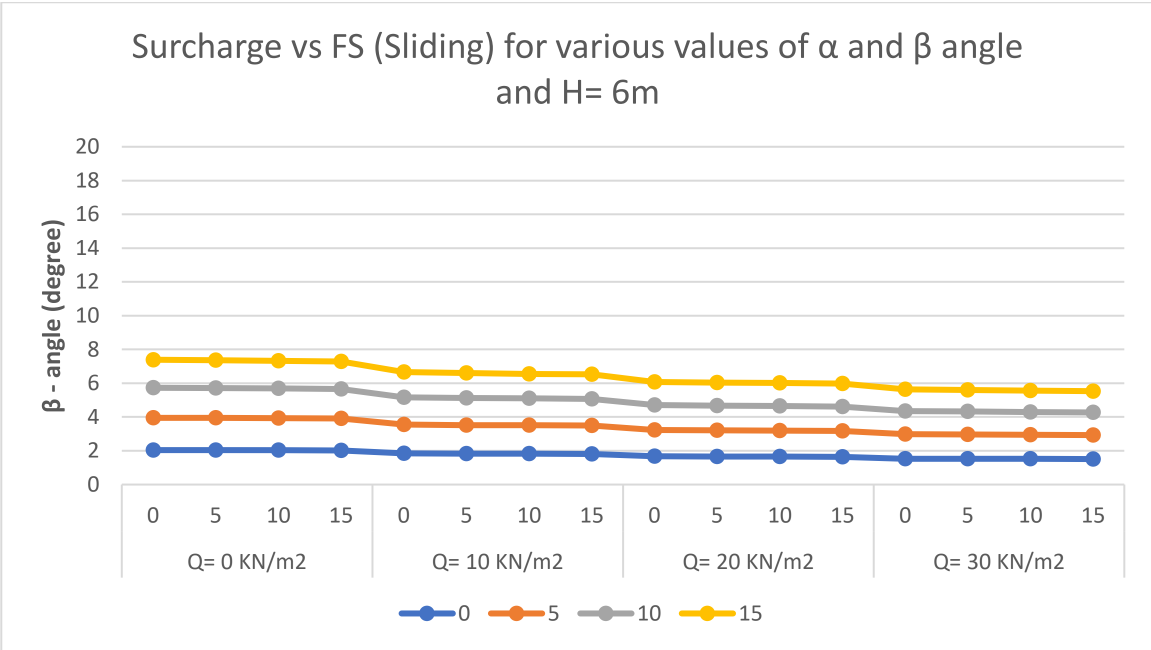

Figure 6.2 Surcharge vs FS (Sliding) for various values of α and β angle and H= 6m

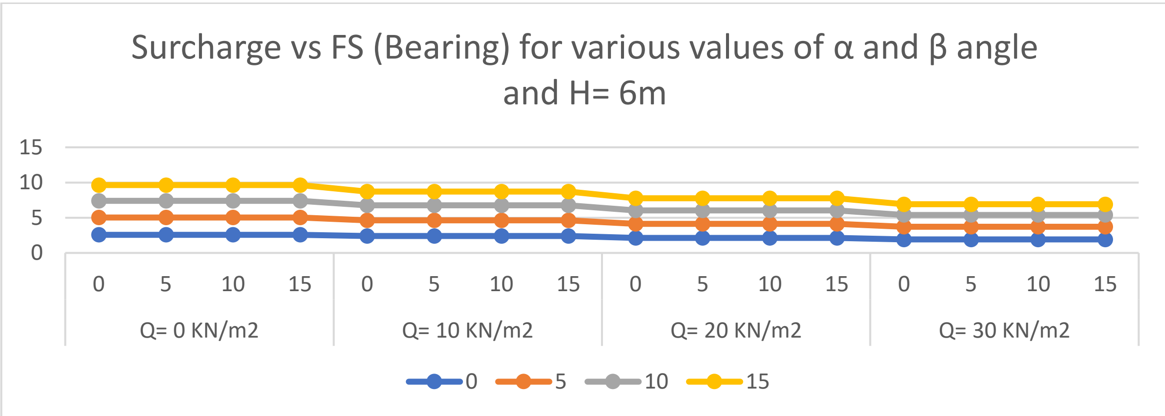

Figure 6.3 Surcharge vs FS (Bearing) for various values of α and β angle and H= 6m

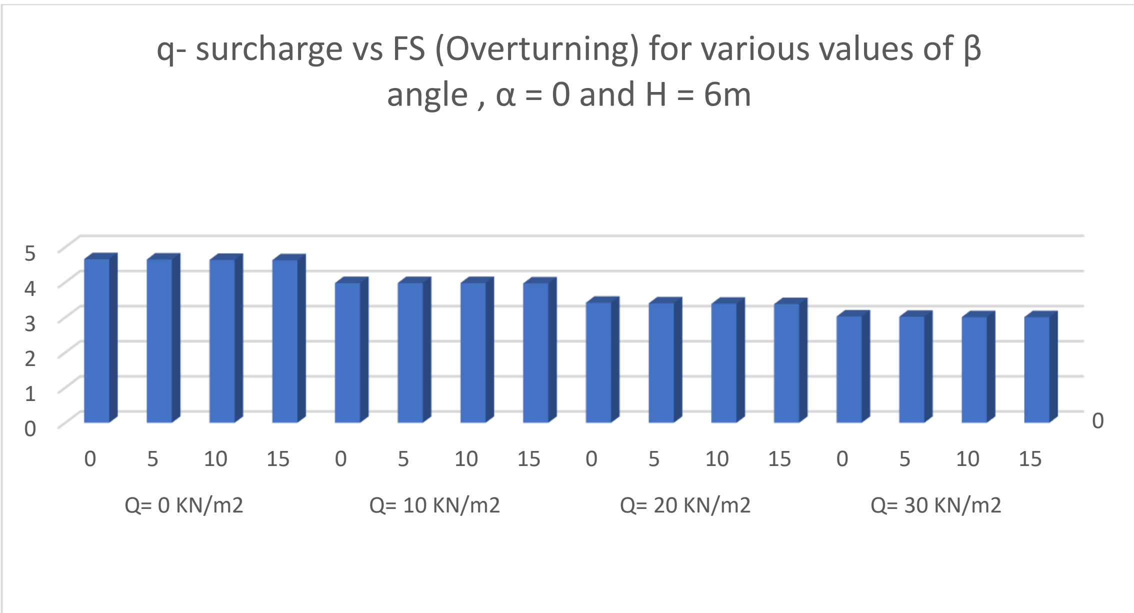

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Figure 6.3 q- surcharge vs FS (Overturning) for various values of β angle, α = 0 and H = 6m

6.3 The Analysis Results:

1. Effect of wall inclination (β): As β- angle increases the value of FS (slid) and FS(OT) decreases, this fact is correct for all values of surcharge (q) and α angle for all the studied heights, while the behavior of FS (bearing) is completely different for similar variables.
2. Effect of backfill slope (α): As α - angle increases the value of FS (slid) and FS(OT) decreases, this fact is correct for all values of surcharge (q) and β angle for all the studied heights, while the behavior of FS (bearing) is completely different for similar variables. FS(Bearing) slightly changes with respect to this angle.
3. Effect of surcharge (q): As surcharge pressure increases, all the three values i.e FS (slid), FS (OT) and FS(bearing) decreases, this fact is correct for all values of and β angle for all the studied heights.
4. Effect of wall Height (H): The effect of cantilever wall height H has a smaller effect on factor of safety against sliding and overturning, while has greater effect on factor of safety against bearing capacity.

VII. CONCLUSION

7.1 General

The stability analysis of the cantilever retaining wall for defining designed is carried out with the GEO5 software. Performa of the stability of whole wall under the service loads, which include overturning, sliding and bearing failure modes, have been checked and performed successfully. The stability analysis of the cantilever retaining wall for defining designed is carried out with the GEO5 software. Performa of the stability of whole wall under the service loads, which include overturning, sliding and bearing failure modes, have been checked and performed successfully. The design and analysis for the cantilever retaining wall are as per recommendations of IS 456: 2000.

7.2 Conclusion

1. The factor of safety will remain unchanged in the variation of backfill inclination.
2. Surcharge inclination is inversely proportional to FS(Bearing)
3. Sliding FOS fails the IS code 456:2000, criteria (clause no. 20) of defining the width of wall for increasing in height and surcharge.
4. With increase in width of wall, under constant load, FOS for bearing does not have major change.

7.3 Future Scope

Flow charts for rapid and easy checking for each factor of safety against sliding, overturning, and bearing capacity for cantilever retaining walls are prepared as an alternative method for calculation these factors using Coulomb theory. These charts connecting variables such as height, surcharge, backfill angle, inclination angle can be used with some limitations.

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