

ANALYSIS OF CANTILEVER AND COUNTERFORT RETAINING WALL THROUGH ETABS AND MATLAB INTERFACE

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Abstract— Retaining walls are important structures used to resist lateral earth pressure and maintain soil at different elevations. Among the different types of retaining walls, cantilever and counterfort retaining walls are widely used in civil engineering structures such as highways, bridge abutments, embankments, basements, and hill roads. The performance and stability of retaining walls depend on soil properties, wall dimensions, loading conditions, and seismic effects. This paper presents the analysis and design of cantilever and counterfort retaining walls using conventional methods, ETABS software, and MATLAB programming. The study includes stability checks against sliding, overturning, and bearing pressure under static and seismic loading conditions. Response spectrum analysis is also carried out to evaluate seismic behavior. MATLAB coding is used to automate calculations such as earth pressure, bending moment, shear force, factor of safety, and response spectrum generation. The comparison between ETABS and MATLAB results shows that both methods provide reliable and efficient solutions for retaining wall analysis. The counterfort retaining wall is found to be more economical and structurally efficient for higher wall heights, whereas cantilever retaining walls are suitable for medium-height structures. The study demonstrates that integrating software tools with conventional analysis improves design accuracy and reduces manual calculation effort.

Keywords—. Retaining wall, Cantilever retaining wall, Counterfort retaining wall, ETABS, MATLAB, Response spectrum analysis, Soil dynamics.

INTRODUCTION

Retaining walls are structures constructed to retain soil at different levels and prevent soil movement due to lateral earth pressure. These walls are commonly used in highways, railways, basement structures, bridge abutments, and hill areas. The major purpose of retaining walls is to provide stability and prevent soil erosion and landslides.

Among the various retaining wall systems, cantilever retaining walls and counter fort retaining walls are the most widely used reinforced concrete retaining structures. Cantilever retaining walls are economical for heights up to 6–8 m, whereas counterfort retaining walls are preferred for greater heights because they reduce bending moments and shear forces through counterfort action. The analysis of retaining walls traditionally involves manual calculations based on earth pressure theories such as Rankine and Coulomb methods. However, modern structural software such as ETABS and numerical programming tools like MATLAB help engineers automate the design process and improve accuracy.

In this study, both cantilever and counter fort retaining walls are analyzed using ETABS and MATLAB under static and seismic loading conditions. The research also includes response spectrum analysis for earthquake loading and compares the results obtained from software and conventional methods.

2. LITERATURE REVIEW

Several researchers have studied retaining wall behavior under static and seismic conditions.

Anjali Diwalkar (2020) used PLAXIS software to analyze retaining wall shapes and observed that optimized wall configurations improve structural stability.

Ali kavehl, kiarash biabani hamedani, taha bakshapoori(2022), This study by Kaveh, Biabani Hamedani, and Bakhshpoori focuses on optimize rc cantilever retaining walls, minimizing weight under static/dynamic loads (using ACI 318-05).

Cherubini (2019), studied the design of anchored sheet walls by using a probability based method. This means he considered different uncertainties to better understand how the wall would perform.

Donkada et.al(2023) Conducted optimal studies on Retaining wall with counter fort retaining with releasing platform they constructed for possible construction with low prices , with optimal studies were conducted.

Indrajit Chowdhury(2013), modeled the seismic performance of a thick, gravity based retaining wall holding dry, cohesion less ,sandy soil. Using finite element analysis the study analyzed the dynamic shear and flexural responses of wall, assuming a fixed base and lumped mass of soil that hydrostatic pressure.

InderKumar et.al(2019), after calculating the costs for each design they choose option that was to cheapest to build as best solution. They studied about gravity wall and counter fort walls to strongest and most significant design adopted. They evaluated the total concrete and steel needed each in model.

Medhekar's [1990], study looked at finding the most cost-effective design for free cantilever retaining walls (3 to 6 meters high) by comparing two scenarios: one on a rigid foundation and one on a flexible foundation. The study aimed to keep construction costs to a minimum while ensuring the wall was strong and stable (using "penalty functions" for non-linear optimization).the costs were quite similar.

Menon et.al.(2016) , applied reliability analysis methods such as FORM,SORM, and Monte Carlo the like hood of fails due to sliding in a cantilever retaining wall.

Mishra et al.(2018), used computer AI, specifically emnn (EMOTINOAL NEURALNETWORK),mars(MULTIVARIATE ADAPTIVE REGRESSION SPLINE), and sos(SUPORT VECTOR MACHINE), to design retaining wall. Their approach predicts how safely a wall holds back soil. Specifically against sliding, by analyzing data .

Sun and yuefei(2019), used a computer simulation technique called the particle discrete element method to study how both partial size and the spaces between partials work together in rock and soil material. The main goal of their study was to create more accurate computer models that better represents the complex to real world characteristics of soil and rock.

Tamaher Abood et.al (2023), the retaining structure holds the back soil or other loose material that change in ground elevation is occurs. The back fill of the structure is exerts to push soil and change the structure against over turn and sliding. The most commonly adopted height of 3m to 6m height. In this method include the fos against sliding, overturning and bearing are calculated.

U c Sari et al.(2019),according to research by us sari et al.steep slopes are usually created by wind and river erosion. These slopes are made even more unstable by heavy construction or traffic, which can trigger dangerous landslide. When a retaining wall fails. It causes significant damage to the surrounding environment making proper design essential.

Yang and ching(2016), introduced a new and simplified method for geotechnical reliability analysis. In their study they applied first and second order reliability methods.(FORM and SORM), along with simulation based as like Monte Carlo simulation to determine the reliability index.

3. OBJECTIVES OF THE STUDY

The main objectives of this study are:

The following are objectives are to be followed.

- To analyze and design of cantilever and counter fort retaining wall using ETAB software.
- To model the cantilever and counter fort retaining wall using MATLAB.
- To design reinforcement for stem, base slab, heel and toe by conventional method.
- To check the stability against sliding overturning by conventional method.
- To compare the result from ETABS and MATLAB.

4. METHODOLOGY

The methodology adopted in this study includes conventional design calculations, ETABS modeling, and MATLAB programming.

4.1 Conventional Design

The retaining wall dimensions are initially selected based on standard design criteria. Stability checks are performed for: Sliding, Overturning, Bearing pressure. The active earth pressure coefficient is calculated using Rankin's theory. The maximum bending moment acting on the wall stem is calculated using. The factor of safety against sliding is calculated as:

4.2 ETABS Modeling

The retaining wall geometry was modeled in ETABS using shell elements. Material properties, load combinations, soil pressure distribution, and seismic loads were assigned according to design standards. The Obtaining shear force and bending moment results.



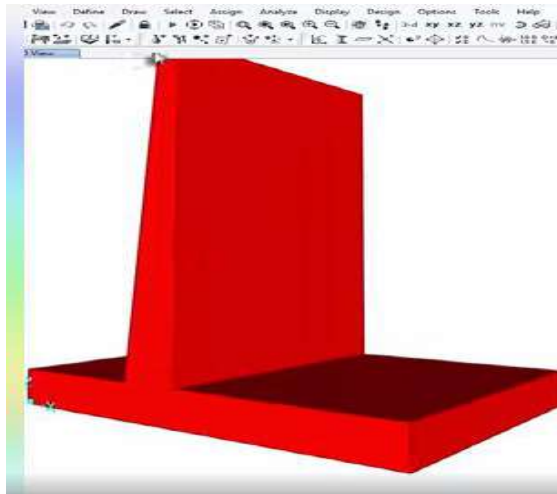


Fig.4.2.1 cantilever retaining wall

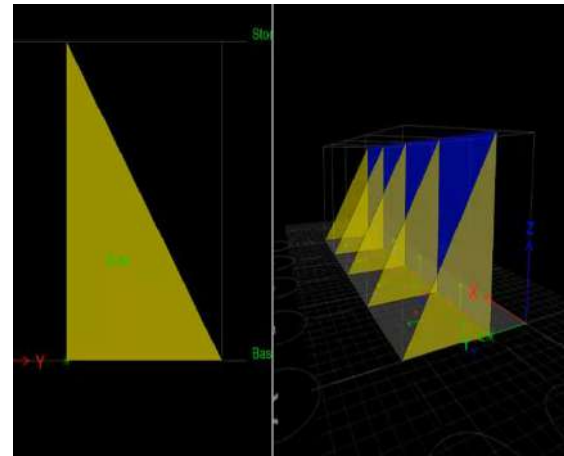


Fig.4.2.2 counter fort retaining wall

4.3 MATLAB Programming

MATLAB code was developed to automate the retaining wall analysis. The program calculates:

- Earth pressure coefficients
- Static and seismic earth pressures
- Sliding and overturning safety factors
- Base pressure distribution
- Response spectrum curves

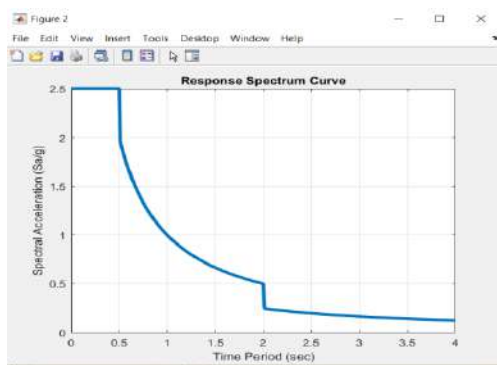


Fig. 4.3 Response spectrum curves for cantilever retaining wall

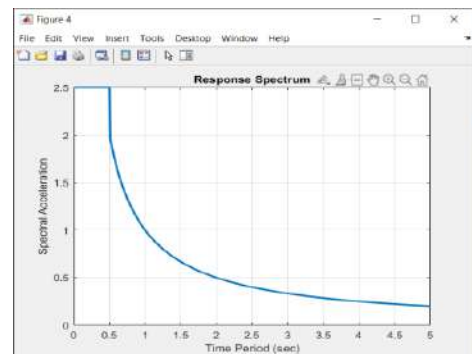


Fig.4.5. Response spectrum curves for counter fort retaining wall

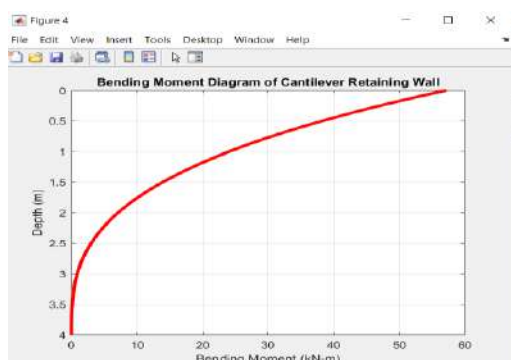


Fig.4.4 bending moment diagrams

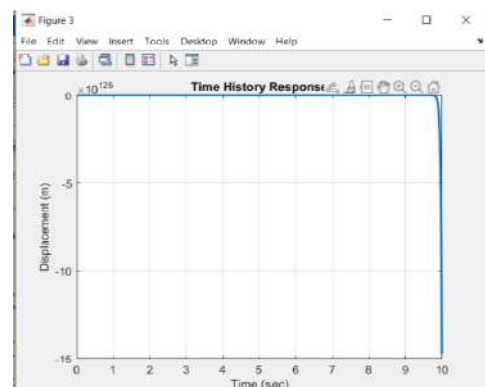


Fig.4.6 Time history Response for counter fort retaining wall

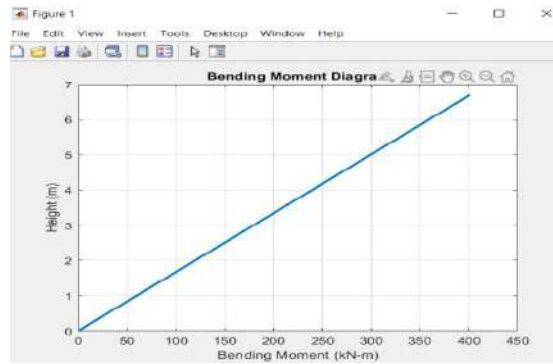


Fig.4.7 Bending moment for counter fort retaining wall

The MATLAB code also includes Mononobe–Okabe seismic earth pressure calculations.

5. RESULTS AND DISCUSSION

The cantilever retaining wall and counterfort retaining wall were analyzed under static and seismic conditions.

For the cantilever retaining wall:

- Factor of safety against sliding = 1.51
- Factor of safety against overturning = 2.57
- Maximum base pressure = 68.53 kN/m²

5.1 Result analysis of cantilever retaining

Descriptions	Retaining wall result
Active earth pressure	71.49kN
FOS against over turning	2.57
FOS against sliding	1.79
Eccentricity from TOE	0.06m
P _{max} pressure intensity @ toe	68.53 kN/m ³
P _{min} pressure intensity @ Heel	53.84 kN/m ³
Area of reinforcement	
a) Toe slab	
❖ Longitudinal reinforcement	253.01mm ²
❖ Distribution reinforcement	540 mm ²
b) Heel slab	
❖ Longitudinal reinforcement	361 mm ²
❖ Distribution reinforcement	540 mm ²
c) Stem	
❖ Longitudinal reinforcement	938.38 mm ²
❖ Distribution reinforcement	540 mm ²

Result analysis of cantilever retaining wall by mat lab

$k_v = 0.0750$

Active Earth Pressure Coefficient $K_a = 0.333$

Static Earth Pressure $P_a = 42.67$ kN/m

Seismic Earth Pressure Coefficient $K_{ae} = 0.335$

Seismic Earth Pressure $P_{ae} = 42.87$ kN/m

Total Vertical Load = 201.75 kN

FOS against Sliding = 2.59

Overturning Moment = 57.17 kN-m

Resisting Moment = 405.82 kN-m

FOS Against Overturning = 7.10

Eccentricity $e = 0.228$ m

Maximum Base Pressure $q_{max} = 97.94$ kN/m²

Minimum Base Pressure $q_{min} = 36.56 \text{ kN/m}^2$

FS Overturning = 7.10

Bearing pressure is SAFE

$q_{max} = 97.94 \text{ kN/m}^2$

$K_a = 0.333$

$q_{min} = 36.56 \text{ kN/m}^2$

$K_{ae} = 0.335$

SHEAR AND MOMENT RESULTS

Static Earth Pressure = 42.67 kN/m

Maximum Shear Force = 42.87 kN

Seismic Earth Pressure = 42.87 kN/m

Maximum Bending Moment = 57.17 kN-m

FS Sliding = 2.59

Table 5.2 Result analysis of counter fort retaining wall

Descriptions	Retaining wall results
Active earth pressure	88.14 kN
FOS against over turning	2.3
FOS against sliding	1.6
Eccentricity from TOE	0.8
P_{max} pressure intensity @ toe	85.18 kN/m ²
P_{min} pressure intensity @ Heel	76.90 kN/m ²
Area of reinforcement	
d) Toe slab	
❖ Longitudinal reinforcement	865.87mm ²
❖ Distribution reinforcement	480 mm ²
e) Heel slab	
❖ Longitudinal reinforcement	307.49 mm ²
❖ Distribution reinforcement	716.86 mm ²
f) Stem	
❖ Longitudinal reinforcement	967.45 mm ²
❖ Distribution reinforcement	350mm ²
g) Counter fort	
❖ Longitudinal reinforcement	819.01 mm ²
❖ Distribution reinforcement	450 mm ²

Result analysis of counter fort retaining wall by mat lab

Base Width = 4.36 m

Resisting Moment = 1298.99 kN-m

Toe Width = 1.5 m

Overturning Moment = 267.34 kN-m

Heel Width = 3.05 m

FACTOR OF SAFETY

STATIC EARTH PRESSURE

FS Overturning = 4.86

$K_a = 0.333$

FS Sliding = 2.11

$P_a = 119.71 \text{ kN/m}$

ECCENTRICITY

SEISMIC EARTH PRESSURE

Eccentricity = -0.069 m

$K_{ae} = 0.383$

BEARING PRESSURE

$P_{ae} = 137.66 \text{ kN/m}$

$P_{max} = 95.33 \text{ kN/m}^2$

SELF WEIGHT

$P_{min} = 115.52 \text{ kN/m}^2$

Total Weight = 459.12 kN

TIME HISTORY ANALYSIS

MOMENTS

The seismic analysis showed that lateral earth pressure increases significantly during earthquake loading. Response spectrum analysis was carried out using spectral acceleration values corresponding to different time periods.

The MATLAB-generated response spectrum curve demonstrated variation of spectral acceleration with time period. For the counterfort retaining wall, the wall showed better stability for higher heights. Counterforts reduced bending moment and shear force in the stem. The wall required less reinforcement compared to an equivalent cantilever wall for larger heights.

The comparison between ETABS and MATLAB results indicated good agreement between both methods. ETABS provided detailed structural visualization, whereas MATLAB offered fast computational analysis and automated calculations.

Comparison Result analysis of cantilever retaining wall conventional method, ETABS analysis, and MATLAB analysis

Parameter	Conventional method	ETABS	MATLAB analysis
Wall height (m)	5.0	5.0	5.0
Active earth pressure (kN/m)	66.70	68.25	67.10
Maximum base pressure(kN/m ²)	68.53	70.15	69.42
Minimum base pressure(kN/m ²)	53.84	55.62	54.90
FOS against sliding	1.51	1.64	1.58
FOS against overturning	2.57	2.72	2.63
Maximum shear force(kN)	53.4	55.8	54.6
Maximum bending moment(kN-m)	71.2	74.6	72.8
Maximum displacement(mm)	-	2.85	2.92
Response spectrum peak sa/g	-	2.50	2.50

Table.5.3 comparison Result analysis of cantilever retaining wall

Comparison Result analysis of counterfort retaining wall conventional method, ETABS analysis, and MATLAB analysis

Parameter	Conventional method	ETABS	MATLAB analysis
Wall height (m)	6.7	6.7	6.7
Active earth pressure (kN/m)	119.62	122.45	120.80
Seismic earth pressure pae(kN/m)	137.56	140.28	138.95
Maximum base pressure(kN/m ²)	85.18	87.92	86.75
Minimum base pressure(kN/m ²)	76.90	79.35	78.10
FOS against sliding	1.68	1.82	1.75
FOS against overturning	2.84	3.02	2.91
Maximum shear force (kN)	138.5	145.2	141.8
Maximum bending moment(kN-m)	666.79	702.35	684.60
Maximum lateral displacement(mm)	-	3.45	3.58
Maximum base reaction (kN/m)	381.90	389.25	384.80
Fundamental time period (sec)	-	0.72	0.75
Response spectrum peak sa/g	2.50	2.50	2.50

Table.5.4 comparison Result analysis of counterfort retaining wall

6. CONCLUSION

This study focused on the analysis and design of cantilever and counter fort retaining walls using conventional methods, ETABS software, and MATLAB programming. Based on the analysis, the following conclusions are drawn: Cantilever retaining walls are suitable and economical for moderate heights up to about 6–8 m. Counterfort retaining walls are more efficient for greater wall heights because they reduce bending moments and shear forces. MATLAB programming successfully automated retaining wall calculations and reduced manual effort. ETABS software provided accurate structural analysis and visualization of load distribution. Seismic loading significantly increases earth pressure and affects retaining wall stability. Response spectrum analysis is effective in studying retaining wall behavior during earthquakes. The comparison between ETABS and MATLAB results showed satisfactory agreement. The study concludes that integrating conventional design methods with software tools improves the accuracy, safety, and efficiency of retaining wall analysis and design.

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