Analysis of Retaining Walls Under Vertical & Lateral Loads

Notes for Using
RetWall

An Excel Template for the Analysis of Retaining-Walls by

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Introduction

RetWall is essentially an analysis tool. It can be used for the design of reinforced concrete, masonry and gabion retaining walls.

RetWall is not meant to predict the real retaining wall behaviour. It is a tool that helps save time when designing such structures by conventional methods and producing documentation for records and presentation.

Influence of water table within the retained material can be included. However no allowance is made for buoyancy of the base when it is submerged.

The stability checks are based on unfactored loads. When calculating the required shear & moment resistance at base of the wall, factored loads are used. If required for permissible stress design, the load factor values can be made equal to unity.

Where it is necessary to improve the sliding resistance, a retaining wall can have a nib beneath its base. This nib is considered effective when the wall slides. It is assumed to play no part in the prevention of overturning or influencing ground pressures. The total resistance against sliding of the wall is taken as the frictional resistance plus the passive earth resistance against the nib face.

Method of Use

The use of the spreadsheet is self explanatory. Input data cells are shaded green. The data input for wall design is via the change in contents of these green cells.

The design data can be stored in the worksheet “Store” for more than say 3000 walls, as required. Two buttons in the header of worksheet "Store" allow the addition and deletion of data rows.

Starting from a minimum of 200 walls, data rows are added and or deleted in multiples of 10 and up to 1000 rows at a time. To add more than 1000 rows, the add row step can be repeated.

The worksheet “Retaining_Wall” has buttons to allow retrieval of the stored data. Relevant buttons at the top of this worksheet can be clicked to store, retrieve, display-next or display-previous wall data.

A data reference number starting from 1001 upwards is used for each wall data. This data can be recalled, amended and or re-stored later for any wall by the use of this reference number.

The data store facility can also be used for analysing as many loading cases as required. To do so, save wall data for each load case. Click relevant buttons at top of the spreadsheet to store, retrieve, display-next or display-previous retaining wall data.

When familiarity has been gained, data in the worksheet "Store" can be modified directly for ease and Auto Analysis of all walls. This worksheet includes columns which summarize the usage levels and status for each member. Overstressed members can be identified at a glance.

Wall & Induced Pressures Diagram

A wall diagram is included in the screen display and printed output. Using the data input by the user, this diagram shows shape of the wall and levels of back fill, front fill and water. In addition, the induced ground pressures in the vertical and horizontal directions are also shown.

The diagram permits instant check of input data for wall geometry and various material levels being used in the analysis. It also enables comprehension of design results at a glance.

Auto Analysis and or Paper Printing of Results

A facility via worksheet "Store" provides an option to analyse and or print the analyses of all wall by a single click of the “Auto Analyse/Print” Button.

To use this facility, there are two rightmost columns (coloured yellow) in the worksheet “Store”. One column is headed “Analyse Y?” and the other “Print Y?”. An “Auto Analyse/Print” Button is also located at the top of these two columns.

Entering “Y” in these two columns signifies that the wall analysis in the row needs analysing and or its results printing. Leaving the cells blank signifies that the respective wall is not to be analysed and or printed.

This auto facility is useful when all or a selected few walls are to be analysed and or printed after corrections to the design data e.g. changes in height, thicknesses, fill height, etc.

These changes can be made directly in the worksheet “STORE”; this however requires a good understanding of the stored data. Caution is therefore necessary for obtaining valid results and to avoid fouling of the stored data.

Load Summary

RetWall involves application of various loads in its analysis. To help ensure that all intended loads have been applied, a load summary table is included in the screen display and printed output. In a design check processes this table shows all loads included in the analysis at a glance.

Stability Check

Stability checks comprise calculations for safety factors against overturning and sliding. No load factors are used in these checks. Instead, the calculated and required factors are compared to indicate the extent of wall stability.

The fill on the external face of the wall is ignored for its vertical loading.

The presence of surcharge, point and line loads may enhance wall stability against overturning. To ensure that a critical case is not missed, two overturning checks are carried out. One with earth loads only and the other including surcharge, point and line loads that may have been applied.

The influence of nib is ignored when checking overturning. This is a conservative assumption as passive pressure on the rear nib face resists overturning and is ignored.

Lateral Loads

The influence of Surcharge, Earth, Water, Line & Point Loads is to exert lateral pressure on the wall. When these loads are not present, their values are input as zero.

The formulae used for calculating the magnitude of these loads are shown below via sketches.

Active, Passive & At-rest Pressures

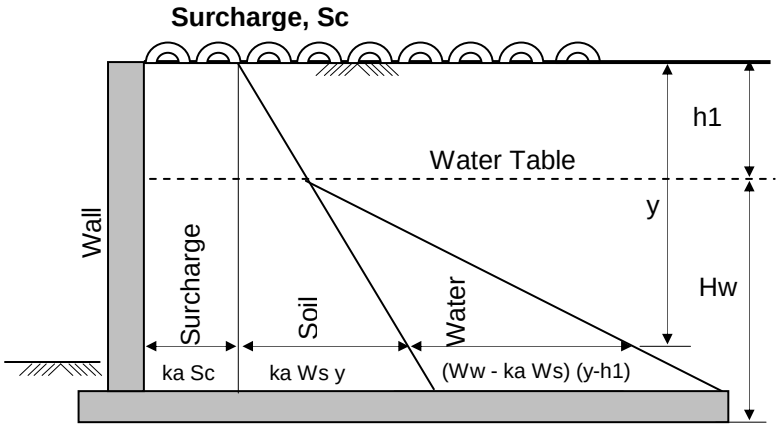
Active pressure is associated with lateral expansion of the soil and is a minimum value.

Passive pressure is associated with lateral compression of the soil and is a maximum value.

When the lateral strain in the soil is zero, the lateral pressure is known as pressure at-rest. This pressure has not been used in this template. It is generally used in the design of basement walls, culverts, etc.

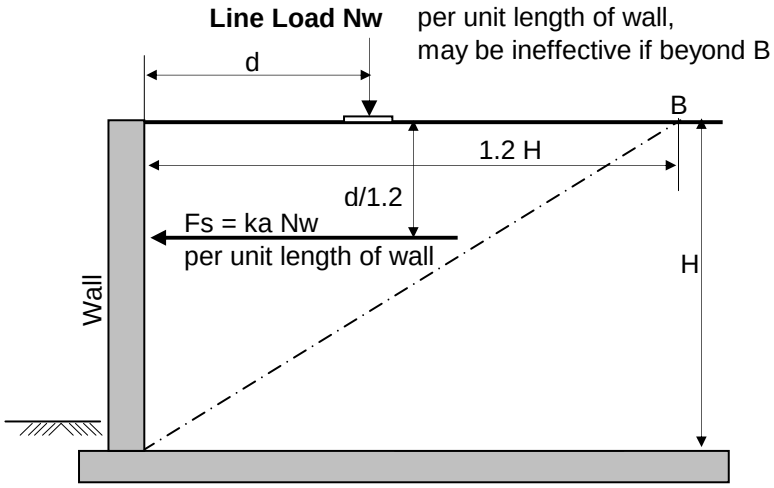
The equations for the earth pressure coefficients ka for active and kb for passive are shown in the screen display & the printed output.

Analysis Formulae Source:
Table 20, "Pressure due to Surcharge", RC Designer's Handbook, 10th Edition, Charles E Reynolds and James C Steedman, 1988

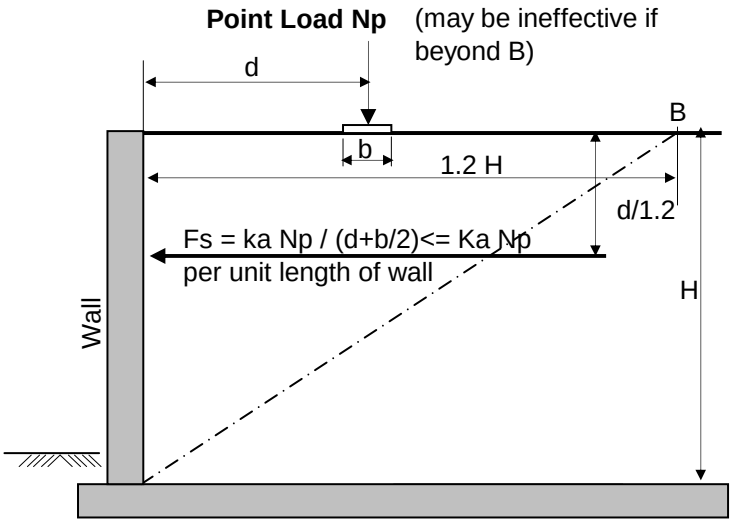


Pressures due to Surcharge, Earth & Water

Wheel Load distance:
The design N kN wheel load acts at a closest distance to wall face given by:
d = kerb width + load-width b/2 For example:
d = 600 + 200/2 = 700 mm



Lateral Force due to a Line Load, Np



Lateral Force due to a Point Load, Np

Centroid of Wall Section

The wall can have its front face vertical or tapered. Its sectional area is given by:

Area = (H + Hp) * (T1+T2) / 2

The location of its centroid from the earth vertical face is given by:

Wall cg = [$T1^2$ + T1 * T2 + $T2^2$] / [3*(T1 + T2)]

In masonry and gabion walls, the wall front face could be stepped. This can be represented in the template by a wall taper producing matching area and centroid.

Passive Earth Pressure - Sliding Check

Passive earth pressure is assumed to act only when the wall slides. In all other calculations, this pressure is ignored.

A nib provided below the base slab assists when the retaining wall slides. The height of passive pressure that may exist above the nib can be selected from the following pull-down option list:

Nib Only, Nib+Toe, Nib+Toe+Fill

In practice, the passive pressure should only be considered if it can be guaranteed that there will be no future excavation in front of the wall.

Reinforcement in Retaining Walls

Any reinforcement that may be required in the retaining wall is not calculated. In fact a wall can be mass concrete or masonry.

Lateral shear and moment values at base of the retaining wall are however calculated. These are factored values using load factors input by the user. They can be used to calculate the reinforcement required at junction of the wall and its base.

To calculate reinforcement required in the base and at other locations of the retaining wall, further calculations may be necessary. To this end, the calculated ground pressure values are available for use. These ground pressure value are however not factored. In a limit state design, these pressure values can be multiplied by appropriate load factors.

Effective Height of Retaining Walls for Deflection Checks

RetWall does not check deflection. Subtle aspects of using of BS8110-1: 1997 are however discussed for guidance when the wall construction is reinforced concrete.

Considering the wall as a cantilever subjected to lateral loads, the basic span to effective depth ratio is 7 as per clause 3.4.6.3 and Table 3.9 of the code.

This basic ratio can be enhanced for the influence of reinforcement provided in the wall using clauses 3.4.6.5 and 3.4.6.6 of BS8110-1 noted as below.

The use of clause 3.4.6.3 may appear onerous to some designers. Hence, they may instead consider using Clause 3.9.3.3 of the code.

As per Clause 3.9.3.7.2, the slenderness ratio le/h should not exceed that given in Table 3.23. Considering that the wall is unbraced and that a minimum reinforcement of 0.13% to Clause 3.12.5 has been provided, the maximum permitted value of le/h can be up to 30.

Care needs to be exercised in the choice of wall effective height in the range 7 to 30 times its depth. The effective height implied in the code is actual height when using Clause3.4.6.3 for a cantilever wall and 2 times the actual height when using Clause 3.9.3.3 for an unbraced wall.

Assumptions & Limitations

- Wall friction is zero. This could be significant for walls exceeding 3.5 m in height.
- Backfill soil is a granular cohesionless material.
- Rotational slide or slope failure is not investigated.
- Effect of ground water seepage beneath the wall is not checked.
- Deflection of the wall due to lateral pressure is not checked.
- All loads are considered to be static. Dynamic loads and vibrations are not covered.
- Sliding check assumes that passive pressure acts without movement.
- Self weight of fill on external face of the wall is ignored.
- When calculating bearing pressures, "No Tension" equilibrium check using triangular stress block is not carried out. When resultant is outside the middle third, the base may have tension i.e. negative pressure. Base Tension is flagged by a Note in red in the display & out.

Stability & Sliding Ratios for Design

When designing retaining walls, minimum stability ratios are specified and used for checks against Stability and Sliding. As a guide and example, the stability ratios used in one project are noted below for reference purposes.

Design Conditions	Stability Ratios	Sliding Ratios
Erection	1.6	1.6
Test	1.6	1.6
Operating	1.75	1.6
Shutdown	1.75	1.6

References

1) Reinforced Concrete Designer's Handbook, 10th Edition, Charles E Reynolds & James C Steedman, 1988