ROCSCIENCE

RSWall

Verification Manual

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Introduction

RSWall is a software program that can be used to perform analyses for various types of retaining walls including MSE walls, segmental walls, gravity walls, abutments, and cantilevers. In this verification manual, an overview of the technical base associated with the engineering analysis of retaining walls is presented.

In this verification manual, a variety of examples published in the literature which can be analyzed using RSWall are presented. For each example, the following information is presented:

- A citation to the published work containing the example.
- A description of the example's inputs as they can be entered in RSWall.
- A reference to the .pdf file containing the program outputs for the example.
- A comparison between the results of RSWall and those reported in the cited work(s).
- Explanations for any discrepancies between the program output and literature including any applicable differences in assumptions or errors in the calculations of the cited literature.

1. NCMA Conventional Wall

Verification of the conventional wall example in Appendix A of NCMA (2009), Design Manual for Segmental Retaining Walls, 3rd ed.

1.1. Problem Setup

The conventional segmental wall section in this example consists of five blocks analyzed using the NCMA design standard (version 3).

The wall unit and wall section profile properties are defined as follows:

- Wall unit, type: Modular
- Wall unit, depth: 1.0 ft
- Wall unit, height: 0.667 ft
- Wall unit, center of gravity: 0.5 ft
- Wall unit, unit weight: 120 pcf
- Interlayer shear strength type: Linear
- Minimum shear capacity: 1100 lb/ft
- Maximum shear capacity: 1500 lb/ft
- Wall unit, interlayer friction angle: 35°
- Setback per layer: 1 in
- Number of courses: 5

The geometry defined in the model is as follows:

- Backslope topography: Infinite; slope angle: 0°
- Front face topography: Infinite; slope angle: 0°; embedment depth: 0.5 ft; no passive resistance
- Leveling pad: thickness: 6 in; width: 1.5 ft; setback: 3 in

The soil properties defined in this model are:

- Retained soil: friction angle: 34°; unit weight: 115 pcf
- Foundation soil: friction angle: 30°; unit weight: 115 pcf
- Leveling pad soil: friction angle: 40°; unit weight: 125 pcf

The seismic parameters are:

- A: 0.2
- D (seismic): 0 in

In the advanced settings, the following toggles are applied:

- Ignore some vertical components of resisting forces and moments

1.2. Results

The results of this verification example were compared with the literature. They can be viewed by computing the attached model, "*NCMA Conventional Wall.rswall*" and viewing the results via the main viewport and/or the report generator.

The summarized results are shown in the following tables:

Table 1.1: Static load case results of the NCMA Conventional example

Factor of Safety	Literature	RSWall
Base sliding	1.84	1.84
Overturning	1.88	1.88
Bearing	7.0	7.0
Internal sliding, course 5	226.4	226.4
Internal sliding, course 4	59.3	59.3
Internal sliding, course 3	27.6	27.6
Internal sliding, course 2	16.2	16.2
Internal sliding, course 1	10.8	10.8

Table 1.2: Seismic load case results of the NCMA Conventional example

Factor of Safety	Literature	RSWall
Base sliding	1.27	1.27
Overturning	0.87	1.12 (1)
Bearing	13	11.2 (1)
Internal sliding, course 5	84	84
Internal sliding, course 4	31	31
Internal sliding, course 3	17	17
Internal sliding, course 2	11	11
Internal sliding, course 1	7	7

[1] *In the published text, page 212, M_O appears to be calculated using k_h = 0.2 in Eq. 9-40, which contradicts the reported value of k_h = 0.1; this results in a FS = 0.87 for overturning and FS = 13 in bearing, but correctly substituting k_h = 0.1 gives FS = 1.12 and 11.2 respectively.*

2. NCMA Reinforced Wall

Verification of the reinforced wall example in Appendix B of NCMA (2009), Design Manual for Segmental Retaining Walls, 3rd ed.

2.1. Problem Setup

The reinforced segmental wall section in this example consists of 22 blocks and 8 reinforcement layers analyzed using the NCMA design standard (version 3).

The wall unit and wall section profile properties are defined as follows:

- Wall unit, type: Modular
- Wall unit, depth: 1.0 ft
- Wall unit, height: 0.6667 ft
- Wall unit, width: 0.5 ft
- Wall unit, center of gravity: 0.5 ft
- Wall unit, unit weight: 115 pcf
- Interlayer shear strength type: Linear
- Minimum shear capacity: 1100 lb/ft
- Maximum shear capacity: 5000 lb/ft
- Wall unit, interlayer friction angle: 35°
- Setback per layer: 1 in
- Number of courses: 22

The geometry defined in the model is as follows:

- Backslope topography: Broken, initial run: 0 ft, slope run: 5 ft; slope angle: 25°
- Front face topography: Infinite; slope angle: 0°; embedment depth: 1.33 ft; no passive resistance
- Leveling pad: thickness: 6 in; width: 1.5 ft; setback: 3 in

The soil properties defined in this model are:

- Retained soil: friction angle: 30°; unit weight: 120 pcf
- Infill soil: friction angle: 30°, unit weight: 120 pcf
- Foundation soil: friction angle: 30°; unit weight: 120 pcf
- Leveling pad soil: friction angle: 40°; unit weight: 125 pcf

The applied loads are:

- Live load, uniformly distributed, magnitude: 150 psf; Horizontal distance: 5 ft
- Dead load, uniformly distributed, magnitude: 100 psf: horizontal distance: 5 ft

The seismic parameters are:

- A: 0.2
- D (seismic): 3 in

The reinforcement properties in the model are defined as follows:

- Name: TYPE 1
- Type: Geotextile
- Static design tensile strength: 1918 lb/ft
- Creep reduction factor: 1.58
- Coefficient of interaction: 0.7
- Coefficient of direct sliding: 0.7
- Connection function: Frictional (linear); minimum strength: 991 lb/ft; maximum strength: 1900 lb/ft; friction angle: 25°

The reinforcement layout in the wall is defined as:

- Number of courses below layer: {1, 3, 6, 9, 12, 15, 18, 21}
- Length: 10.5 ft (except for the top layer, which is 11.1 ft)

In the advanced settings:

- Turn OFF: Ignore some vertical components of resisting forces and moments

2.2. Results

The results of this verification example were compared with the literature. They can be viewed by computing the attached model, "*NCMA Reinforced Wall.rswall*" and viewing the results via the main viewport and/or the report generator.

The summarized results are shown in the following tables:

Table 2.1: Static load case results of the NCMA Conventional example

Factor of Safety	Literature	RSWall
Base sliding	2.69	2.69
Overturning	5.13	5.13
Bearing	7.54	7.54
Internal sliding (course 2 governs)	2.28	2.28
Crest toppling	26.3	26.3
Tensile strength, (layer 3 governs)	2.4	2.45
Pullout (layer 8 governs)	2.5	2.58
Connection strength (layer 3 governs)	2.0	1.99

Table 2.2: Seismic load case results of the NCMA Conventional example

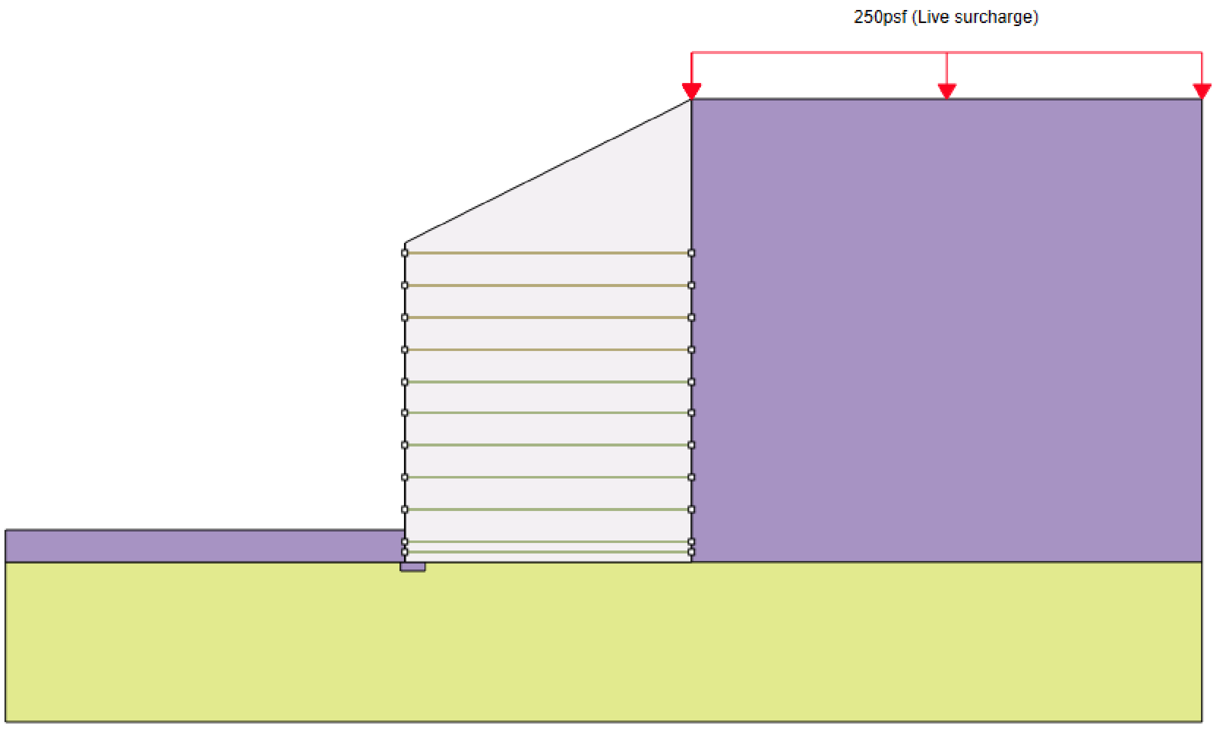
Factor of Safety	Literature	RSWall
Base sliding	2.3	2.30
Overturning	4.23	4.23
Bearing capacity	n/a	7.80
Internal sliding (course 2 governs)	1.94	1.89(1)
Crest toppling	10.93	10.93
Tensile strength, (layer 3 governs)	3.71	3.71

Pullout (layer 8 governs)	2.1	2.20
Connection strength (layer 3 governs)	1.92	1.92

[1] *In the published text, page 247, the writer appears to substitute the value of H instead of H_{ext} for Eqs. 9-95 and 9-96 despite writing the equations with H_{ext}, causing their computed values of internal sliding to differ slightly.*

3. FHWA-NHI-10-025, Example E1

Verification of the Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes – Volume II- FHWA-NHI-10-025, Appendix E, Example E1.



3.1. Problem Setup

This example features a Modular Block Wall (MBW) Faced MSE wall with broken back sloping fill and live load surcharge, reinforced with geogrids.

Methodology:

- Active pressure method: Coulomb method
- Tension in reinforcement: Simplified method

The wall unit and wall section profile properties are defined as follows:

- Wall unit, type: Modular
- Wall unit, depth: 0.001 ft
- Wall unit, height: 20 ft
- Wall unit, width: 1 ft
- Wall unit, center of gravity: 0 ft
- Weight density: 120 pcf
- Number of wall courses: 1
- Layer setback distance: 0 in

The geometry defined in the model is as follows:

- Backslope topography: Broken; slope angle: 26.6°, initial run: 0 ft, slope run: 18ft.
- Front face topography: Infinite; slope angle: 0°; embedment depth: 2 ft; no passive resistance
- Leveling pad: thickness: 6 in; width: 1.5 ft; setback: 3 in

The soil properties defined in this model are:

- Retained soil: friction angle: 30°; soil-structure friction angle: 12.7°; unit weight: 125 pcf
- Foundation soil: friction angle: 30°; soil-structure friction angle: 12.7°; unit weight: 125 pcf
- Reinforced soil: friction angle: 34°; unit weight: 125 pcf
- Base strength:
    - Bearing capacity: User-specified = 16154 psf (note: factored value is 10500 psf = 16154 × 0.65)
    - Contact with soil = Cast on sand

The applied loads are:

- Uniformly distributed load, live surcharge, magnitude = 250 psf, horizontal distance = 18 ft

The reinforcement properties:

- Geotextile reinforcement type
- Coverage = 100%
- Interface sliding friction angle (°): 12.7
- Alpha coefficient = 0.8
- Pullout method = Friction factor, constant value = 0.45
- Connection function = F(depth), minimum = 466.6667 lbs/ft, maximum = 2550 lbs/ft, change per unit depth = 100 psf
- GG1: allowable tensile strength = 1085 lbs/ft
- GG2: allowable tensile strength = 2169 lbs/ft

The reinforcement layout in the wall is defined as:

Table 3.1: Reinforcement layout for FHWA-NHI-10-025 Example E1

Height from bottom (ft)	Type	Length (ft)
0.67	GG2	18
1.33	GG2	18
3.33	GG2	18
5.33	GG2	18
7.33	GG2	18
9.33	GG2	18
11.33	GG2	18
13.33	GG1	18
15.33	GG1	18
17.33	GG1	18

19.33	GG1	18

In the advanced settings:

- Use average depth of adjacent reinforcement layers when calculating Tmax: Yes
- Ignore weight of wall during sliding calculations: Yes

3.2. Results

The results of this verification example were compared with the literature. They can be viewed by computing the attached model, "*FHWA Example E1.rswall*" and viewing the results via the main viewport and/or the report generator.

The summarized results are shown in the following tables:

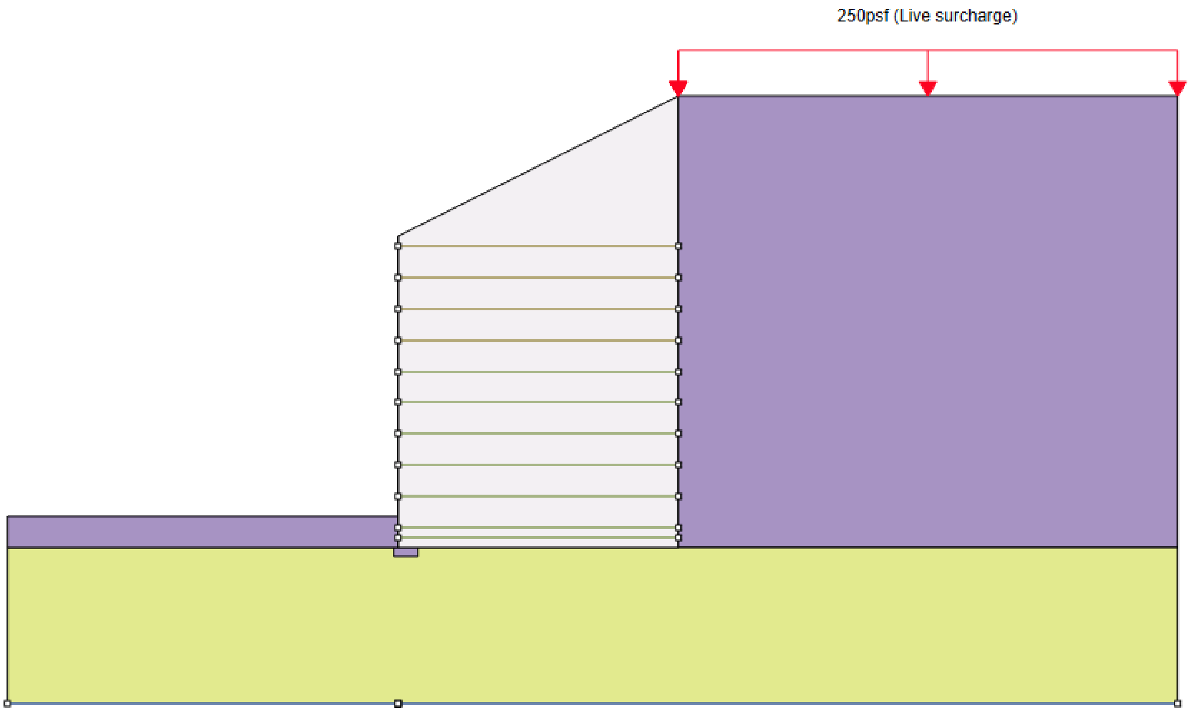
Table 3.2: Static load case results of the FHWA E1

Capacity Demand Ratio (CDR)	Literature	RSWall
Base sliding	1.12	1.12
Bearing	1.60	1.60
Tensile strength (layer 8) [1]	1.00	1.01
Pullout strength (layer 10) [1]	11.4	11.4
Connection strength (layers 3 & 4) [1]	1.00	1.00

[1] In the published text, the layers are numbered from top to bottom, whereas they are numbered bottom to top in RSWall. Hence, the value for Layer 8 reported here is Layer 3 in the text, Layer 10 is Layer 2, etc.

4. FHWA-NHI-10-025, Example E2

Verification of the Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes – Volume II- FHWA-NHI-10-025, Appendix E, Example E2.



4.1. Problem Setup

This example is a variation of Example E1 from the same reference, but with considerations for groundwater effects on the bearing capacity of the structure.

The input parameters of this model are the same as in Example E1, except the following:

- Define Base Strength > Bearing capacity: Based on soil properties
- Load Combinations: Strength, Serviceability
- Advanced > Ignore embedment depth when computing bearing capacity
- Cw and Cwγ method: Interpolate from table

Case 1: No water table

Case 2: Groundwater near surface

- Include water table, constant elevation = -10 ft

4.2. Results

The results of this verification example were compared with the literature. They can be viewed by computing the attached model, "*FHWA Example E2.rswall*" and viewing the results via the main viewport and/or the report generator.

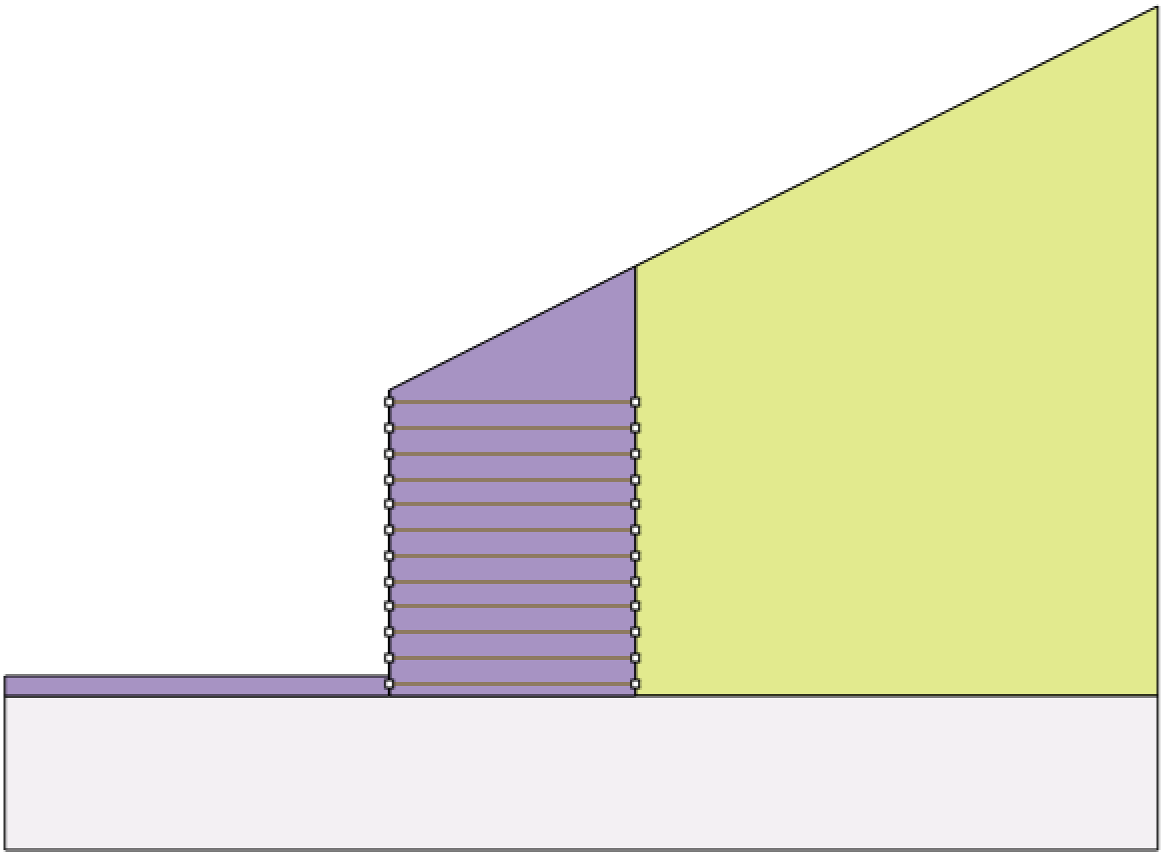
The summarized results are shown in the following tables:

Table 4.1: Comparison of results for the FHWA E2 Example

Capacity Demand Ratio (CDR)	Literature	RSWall
Bearing, Case 1	1.73	1.73
Bearing, Case 2	1.33	1.33

5. FHWA-NHI-10-025, Example E3

Verification of the Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes – Volume II- FHWA-NHI-10-025, Appendix E, Example E3.



5.1. Problem Setup

This example contains a segmental precast panel MSE wall with a sloping backfill surcharge.

Methodology:

- Active pressure method: Coulomb method
- Tension in reinforcement: Simplified method

The wall unit and wall section profile properties are defined as follows:

- Wall unit, type: Modular
- Wall unit, depth: 0.001 ft
- Wall unit, width: 1 ft
- Wall unit, height: 30 ft
- Wall unit, center of gravity: 0 ft
- Number of wall courses: 1

The geometry defined in the model as follows:

- Backslope topography: Infinite; slope angle: 26.6°.
- Front face topography: Infinite; slope angle: 0°; embedment depth: 2 ft; no passive resistance

The soil properties defined in this model are:

- Reinforced soil: friction angle: 34°; soil-structure friction angle: 26.56°; unit weight: 125 pcf
- Retained soil: friction angle: 30°; soil-structure friction angle: 26.56°; unit weight: 125 pcf
- Foundation soil: friction angle: 30°; permanent cohesion: 0 psf; unit weight: 125 pcf
- Base strength:
    - Bearing capacity: User-specified = 16154 psf (note: factored value is 10500 psf = 16154 × 0.65)
    - Contact with soil = Cast on sand

The reinforcement properties are:

- Metallic strip reinforcement type
- In the example, the reinforcement layers consist of 2 or 3 metallic strips spaced every 5 ft, each with nominal allowable tensile strength of 13 kips. Each strip is 1.969" wide. This can be represented by entering the following properties:
    - 2x Metallic Strip:
        - Coverage = 2 × 1.969"/60" × 100% = **6.56%**
        - Allowable tensile strength: 13 kips/ft/strip × 12"/1.969" = **79,228 lb/ft** (per foot width of continuous material)
    - 3x Metallic Strip:
        - Coverage = 3 × 1.969"/60" × 100% = **9.85%**
        - Allowable tensile strength = as above
- Alpha coefficient = 1
- Pullout method = Friction factor, F(depth) function: F* at top = 2, F* at 20 ft = 0.6745
- Connection function = F(depth), minimum = 466.6667 lbs/ft, maximum = 2550 lbs/ft, change per unit depth = 100 psf

The reinforcement layout is as follows:

Table 5.1: Reinforcement layout for FHWA-NHI-10-025 Example E1

Height from bottom (ft)	Type	Length (ft)
1.25	3x Metallic Strip	24
3.75	3x Metallic Strip	24
6.25	3x Metallic Strip	24
8.75	3x Metallic Strip	24
11.25	2x Metallic Strip	24
13.75	2x Metallic Strip	24
16.25	2x Metallic Strip	24
18.75	2x Metallic Strip	24
21.25	2x Metallic Strip	24

23.75	2x Metallic Strip	24
26.25	2x Metallic Strip	24
28.75	2x Metallic Strip	24

In the advanced settings:

- Use average depth of adjacent reinforcement layers when calculating Tmax: Yes
- Ignore weight of wall during sliding calculations: Yes
- F* function depth measured from ground topography: No

5.2. Results

The results of this verification example were compared with the literature. They can be viewed by computing the attached model, "*FHWA Example E3.rswall*" and viewing the results via the main viewport and/or the report generator.

The summarized results are shown in the following tables:

Table 5.2: Comparison of results for Tmax in the FHWA E3 Example

Tmax (kips per 1 ft analysis width)	Literature	RSWall
Layer 1 [1]	24.36 kips / 5 ft = 4.87 k/ft	4.87 k/ft
Layer 2 [1]	22.56/ 5 = 4.51	4.51
Layer 3 [1]	20.77/ 5 = 4.15	4.15
Layer 4 [1]	18.98/ 5 = 3.80	3.79
Layer 5 [1]	17.60/ 5 = 3.52	3.52
Layer 6 [1]	16.59/ 5 = 3.32	3.32
Layer 7 [1]	15.40/ 5 = 3.08	3.07
Layer 8 [1]	13.96/ 5 = 2.79	2.79
Layer 9 [1]	12.35/ 5 = 2.47	2.47
Layer 10 [1]	10.58/ 5 = 2.12	2.12
Layer 11 [1]	8.63/ 5 = 1.73	1.72
Layer 12 [1]	6.46/ 5 = 1.29	1.29

[1] In the published text, the layers are numbered from top to bottom, whereas they are numbered bottom to top in RSWall. Hence, the value for Layer 1 reported here is Layer 12 in the text, Layer 2 is Layer 11, etc.

Table 5.3: Comparison of results for factored pullout strength in the FHWA E3 Example

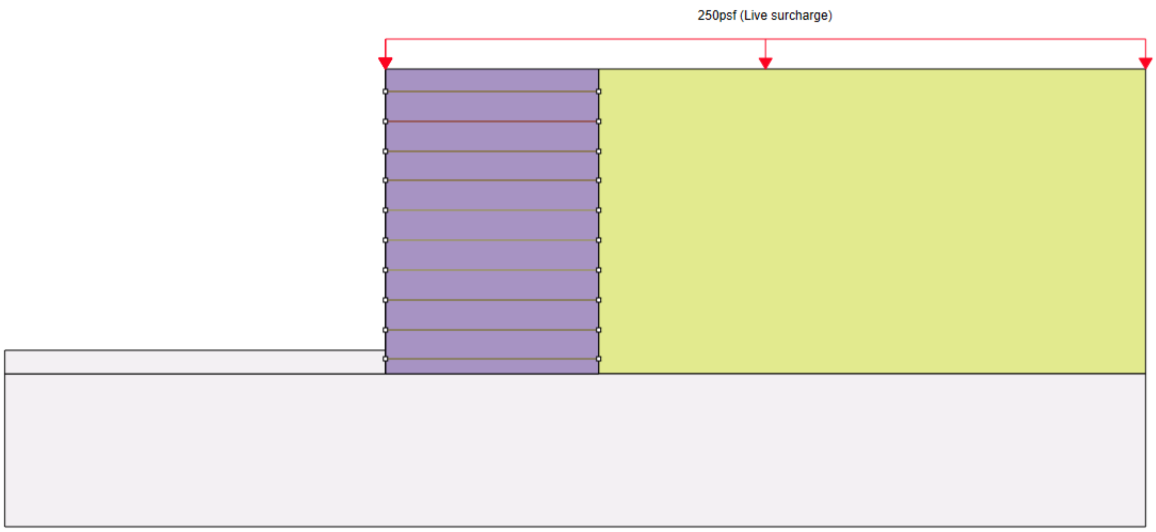
Pr,f (kips per 1 ft analysis width)	Literature	RSWall
Layer 1 [1]	20.24 × 3 strips / 5 ft = 12.14 k/ft	12.14 k/ft
Layer 2 [1]	17.79 × 3/5 = 10.67	10.67
Layer 3 [1]	15.50 × 3/5 = 9.30	9.29
Layer 4 [1]	13.33 × 3/5 = 8.00	8.01
Layer 5 [1]	12.76 × 2/5 = 5.10	5.10

Layer 6 [1]	13.05 × 2/5 = 5.22	5.22
Layer 7 [1]	12.70 × 2/5 = 5.08	5.08
Layer 8 [1]	12.36 × 2/5 = 4.94	4.94
Layer 9 [1]	12.23 × 2/5 = 4.89	4.89
Layer 10 [1]	11.70 × 2/5 = 4.68	4.68
Layer 11 [1]	10.76 × 2/5 = 4.30	4.30
Layer 12 [1]	9.40 × 2/5 = 3.76	3.76

[1] In the published text, the layers are numbered from top to bottom, whereas they are numbered bottom to top in RSWall. Hence, the value for Layer 1 reported here is Layer 12 in the text, Layer 2 is Layer 11, etc.

6. FHWA-NHI-10-025, Example E4

Verification of the Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes – Volume II- FHWA-NHI-10-025, Appendix E, Example E4.



6.1. Problem Setup

This example models a segmental precast panel MSE wall with a level backfill and live load surcharge.

Methodology:

- Active pressure method: Coulomb method
- Tension in reinforcement: Simplified method

The wall unit and wall section profile properties are defined as follows:

- Wall unit, type: Modular
- Wall unit, depth: 0.001 ft
- Wall unit, width: 1 ft
- Wall unit, height: 25.64 ft
- Wall unit, center of gravity: 0
- Number of wall courses: 1

The geometry defined in the model as follows:

- Backslope topography: Infinite, slope angle: 0°.
- Front face topography: Infinite; slope angle: 0°; embedment depth: 2 ft; no passive resistance

The soil properties defined in this model are:

- Reinforced soil: friction angle: 34°; soil-structure friction angle: 0°; unit weight: 125 pcf
- Retained soil: friction angle: 30°; soil-structure friction angle: 0°; unit weight: 125 pcf
- Foundation soil: friction angle: 30°; permanent cohesion: 0 psf; unit weight: 125 pcf
- Base strength:

    - Bearing capacity: User-specified = 16154 psf (note: factored value is 10500 psf = 16154 × 0.65)
    - Contact with soil = Cast on sand

The applied loads are:

- Uniformly distributed load, live surcharge, magnitude = 250 psf, horizontal distance = 0 ft

The reinforcement properties are:

- Metallic grid reinforcement type
- Coverage = **100%**; will specify equivalent strength per 1 ft width of analysis
- Alpha coefficient = 1.0
- In the example, the final design uses 3- and 4-wired grids of various internal spacings:
    - 4W11+W11x0.5’:
        - Allowable tensile strength = 5.17 kip × 4 wires / 5 ft = **4.136 k/ft**
        - Pullout method = Friction factor, F(depth) from 1.247 at top, 0.623 at reference depth of 20 ft
    - 3W11+W11x0.5’:
        - Allowable tensile strength = 5.17 kip × 3 wires / 5 ft = **3.102 k/ft**
        - Pullout method = Friction factor, F(depth) from 1.247 at top, 0.623 at reference depth of 20 ft
    - 4W15+W11x1’:
        - Allowable tensile strength = 7.42 kip × 4 wires / 5 ft = **5.936 k/ft**
        - Pullout method = Friction factor, F(depth) from 0.623 at top, 0.312 at reference depth of 20 ft
    - 4W15+W11x1.5’
        - Allowable tensile strength = 7.42 kip × 4 wires / 5 ft = **5.936 k/ft**
        - Pullout method = Friction factor, F(depth) from 0.416 at top, 0.208 at reference depth of 20 ft

The reinforcement layout in the wall is defined as:

Table 6.1: Reinforcement layout for FHWA-NHI-10-025 Example E4

Height from bottom (ft)	Type	Length (ft)
1.27	4W15+W11x1.5'	18
3.77	4W15+W11x1.5'	18
6.27	4W15+W11x1.5'	18
8.77	4W15+W11x1'	18
11.27	4W15+W11x1'	18
13.77	4W15+W11x1'	18
16.27	4W11+W11x0.5'	18
18.77	4W11+W11x0.5'	18
21.27	3W11+W11x0.5'	18

23.77	4W11+W11x0.5'	18

In the advanced settings:

- Use average depth of adjacent reinforcement layers when calculating Tmax: Yes
- Ignore weight of wall during sliding calculations: Yes
- F* function depth measured from ground topography: No

6.2. Results

The results of this verification example were compared with the literature. They can be viewed by computing the attached model, "*FHWA Example E4.rswall*" and viewing the results via the main viewport and/or the report generator.

The summarized results are shown in the following tables:

Table 6.2: External analysis results of the FHWA E7 Example

Capacity Demand Ratio (CDR)	Literature	RSWall
Bearing	1.57	1.57
Base Sliding	1.37	1.37

[1] *As noted, bearing factor of 0.9 applied in RSWall whereas it is not in the literature*

Table 6.3: Comparison of results for Tmax in the FHWA E4 Example

Tmax (kips per 1 ft analysis width)	Literature	RSWall
Layer 1 [1]	19.05 kip / 5 ft = 3.81 k/ft	3.81
Layer 2 [1]	17.1 / 5 = 3.42	3.42
Layer 3 [1]	16.03 / 5 = 3.21	3.16
Layer 4 [1]	15.71 / 5 = 3.14	3.16
Layer 5 [1]	15.23 / 5 = 3.05	3.06
Layer 6 [1]	14.26 / 5 = 2.85	2.86
Layer 7 [1]	12.77 / 5 = 2.55	2.56
Layer 8 [1]	10.8 / 5 = 2.16	2.17
Layer 9 [1]	8.36 / 5 = 1.67	1.68
Layer 10 [1]	6.25 / 5 = 1.25	1.26

[1] *In the published text, the layers are numbered from top to bottom, whereas they are numbered bottom to top in RSWall. Hence, the value for Layer 1 reported here is Layer 10 in the text, Layer 2 is Layer 9, etc.*

Table 6.4: Comparison of results for factored pullout strength in the FHWA E4 Example

Pr,f (kips per 1 ft analysis width)	Literature	RSWall
Layer 1 [1]	19.66	19.66
Layer 2 [1]	16.12	16.11
Layer 3 [1]	13.27	13.31

Layer 4 [1]	17.41	17.44
Layer 5 [1]	14.5	14.52
Layer 6 [1]	12.06	12.07
Layer 7 [1]	20.75	20.75
Layer 8 [1]	16.47	16.45
Layer 9 [1]	11.25	11.26
Layer 10 [1]	5.16	5.16

[1] In the published text, the layers are numbered from top to bottom, whereas they are numbered bottom to top in RSWall. Hence, the value for Layer 1 reported here is Layer 10 in the text, Layer 2 is Layer 9, etc.

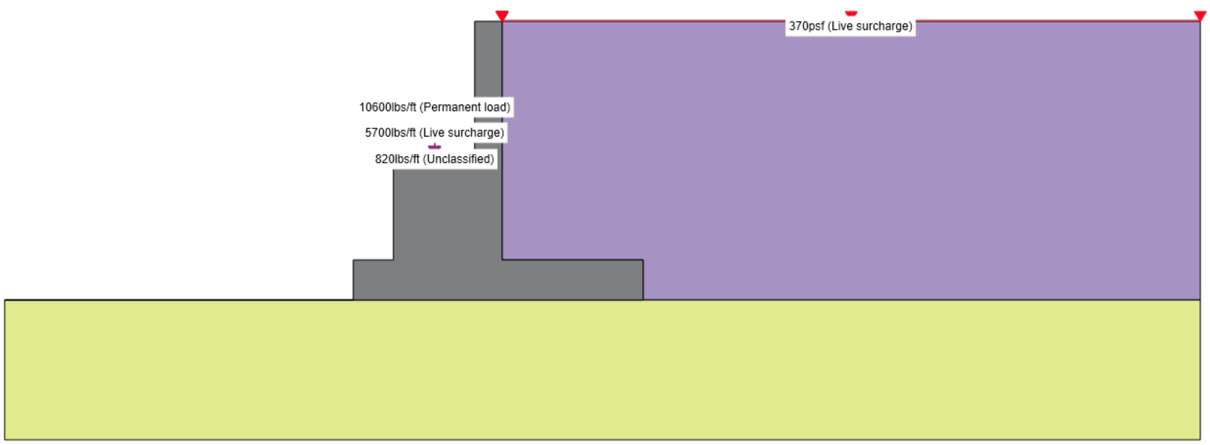
7. FHWA-NHI-10-025, Example E5

Verification of the Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes – Volume II- FHWA-NHI-10-025, Appendix E, Example E5.

7.1. Overview

This is a two-part example that involves evaluating the stability of a bridge abutment and its supporting MSE wall with segmental precast panel facing.

7.2. Abutment Analysis – Setup



Methodology:

- Active pressure method: Coulomb method

The wall section profile is defined as follows:

- Unit weight: 150 pcf

Table 7.1: Abutment wall geometry for the FHWA E5 Example

Dimension	Quantity (ft)
b1	1.5
b2	3
b3	1
b4	5.25
h1	1.5
h2	3.85
h3	5

Topography:

- Backslope topography: Infinite, slope angle: 0°.
- Front face topography: Infinite; slope angle: 0°; embedment depth: 0 ft; no passive resistance

The soil properties defined in this model are:

- Retained soil: friction angle: 34°; soil-structure friction angle: 0°; unit weight: 125 pcf
- Foundation soil: friction angle: 34°; permanent cohesion: 0 psf; unit weight: 125 pcf
- Base strength:
    - Bearing capacity: User-specified = 12757 psf (note: factored value is 7000 psf = 12757 × 0.65)
    - Contact with soil = Cast on sand

The applied loads are:

- Load 1: Live load, Uniformly distributed, Magnitude = 370 psf, horizontal distance = 0 ft
- Load 2: Dead load, Line load, Vertical direction, Magnitude = 10.6 k/ft, horizontal distance = 2.5 ft, applied on top of the wall
- Load 3: Live load, Line load, Vertical direction, Magnitude = 5.7 k/ft, horizontal distance = 2.5 ft, applied on top of the wall
- Load 4: Unclassified load, Line load, Horizontal direction, Magnitude = 0.82 k/ft, horizontal distance = 2.5 ft, applied on top of the wall

7.3. Abutment Analysis - Results

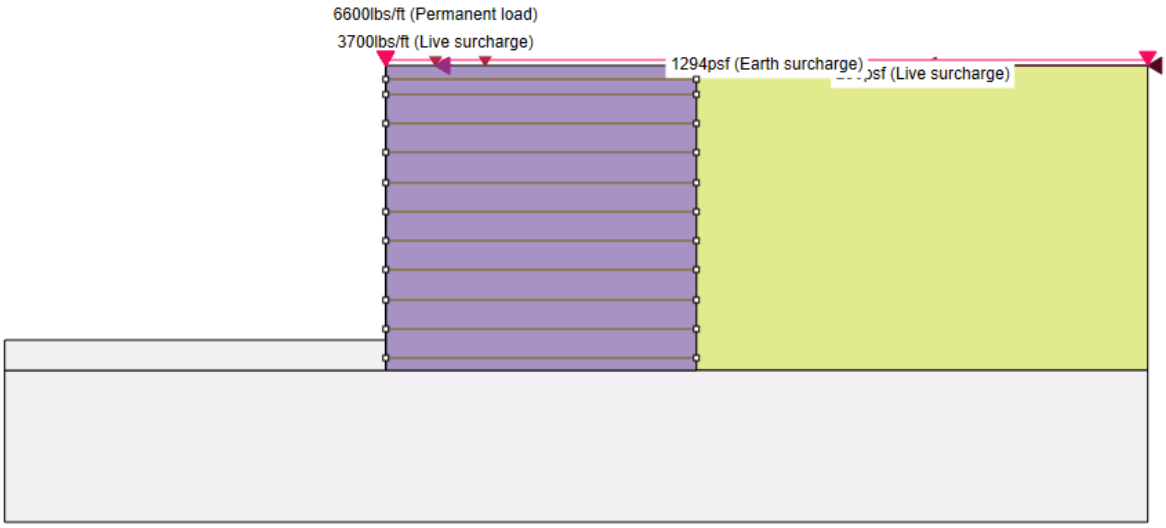
The results of this verification example were compared with the literature. They can be viewed by computing the attached model, "*FHWA Example E5a.rswall*" and viewing the results via the main viewport and/or the report generator.

Table 7.2: Static load case results of the FHWA E5, Cantilever Part

Capacity Demand Ratio (CDR)	**Literature**	**RSWall**
Bearing	1.36	1.38
Base Sliding	1.97	2.46[1]

[1] The FHWA assumes a sliding resistance factor of 0.8 which is specified in AASHTO 2020 to be 1.0, accounting for the difference (2.46 × 0.8 = 1.97).

7.4. MSE Wall Analysis – Setup



Methodology:

- Active pressure method: Coulomb method
- Tension in reinforcement: Simplified method

The wall unit and wall section profile properties are defined as follows:

- Wall unit, type: Modular
- Wall unit, depth: 0.001 ft
- Wall unit, width: 1 ft
- Wall unit, height: 25.5 ft
- Wall unit, center of gravity: 0 ft
- Wall unit, unit weight = 125 pcf
- Number of wall courses: 1
- Bottom elevation: -25.5 ft

The geometry defined in the model as follows:

- Backslope topography: Infinite, slope angle: 0°.
- Front face topography: Infinite; slope angle: 0°; embedment depth: 2.5 ft; no passive resistance

The soil properties defined in this model are:

- Reinforced soil: friction angle: 34°; soil-structure friction angle: 0°; unit weight: 125 pcf
- Retained soil: friction angle: 30°; soil-structure friction angle: 0°; unit weight: 125 pcf
- Foundation soil: friction angle: 30°; permanent cohesion: 0 psf; unit weight: 120 pcf
- Base strength:
    - Bearing capacity: User-specified = 23077 psf (note: factored value is 15000 psf = 23077 × 0.65)
    - Contact with soil = Cast on sand

The loading is complicated for this part of the example, because it is a coupled analysis involving the results from the first part.

- Load 1 [(1)]: Dead load, Line load, Vertical direction, Magnitude = 6.6 k/ft, horizontal distance = 4.13 ft, bearing width = 8.26 ft
- Load 2 [(1)]: Live load, Line load, Vertical direction, Magnitude = 3.85 k/ft, horizontal distance = 4.13 ft, bearing width = 8.26 ft
- Load 3 [(1)]: Live load, Earth load, Horizontal direction, Magnitude = 3.7 k/ft, horizontal distance = 4.13 ft
- Load 4: Live load, uniformly distributed, Magnitude = 250 psf, horizontal distance = 26 ft, to simulate the effect of FS2 in Figure E5-2 in the literature
- Load 5: Earth load, uniformly distributed, Magnitude = 1294 psf, horizontal distance = 0 ft, to simulate the effect of force V5 as it is presented in the literature, to simulate the effect of forces F3 and V5 as they are presented in the literature.[(2)]

[(1)] *An approximate distance of 4.13 ft was selected for this resultant force transferred from the abutment on top; in reality, it depends on the actual resultant location which varies depending on the load combination. This uncertainly is assumed not to significantly affect the results of the analysis*.

[(2)] *V5 is actually an EV-type load whereas F3 is EH. The combined UDL is assumed to be EH for this demonstration, resulting in an approximation.*

The reinforcement properties are:

- Metallic strip reinforcement type
- Coverage = 1.969”/12” × 100% = 16.41%
- Allowable tensile strength = 10 k/ft × 12”/1.969” = 60.94 k/ft per 1 ft analysis width
- Alpha coefficient = 1.0
- Pullout method = Friction factor, F* = F(Depth), F* = 2 at the top, F* = 0.6745 at depth 20 ft

The reinforcement layout in the wall is defined as:

Table 7.3: Reinforcement layout for FHWA-NHI-10-025 Example E5

Elevation (ft)	Type	Length (ft)
-1.12	Metallic strip	26
-2.35	Metallic strip	26
-4.81	Metallic strip	26
-7.27	Metallic strip	26
-9.73	Metallic strip	26
-12.19	Metallic strip	26
-14.65	Metallic strip	26
-17.11	Metallic strip	26

-19.57	Metallic strip	26
-22.04	Metallic strip	26
-24.49	Metallic strip	26

Note that the top of the MSE wall is assumed to be at elevation zero, and the bottom of the wall was specified to be at elevation -25.5 ft.

In the advanced settings:

- Horizontal extent of pullout zone (ratio of wall height) = (0.5 + 10.75) / 25.5 = 0.441
- Use average depth of adjacent reinforcement layers when calculating Tmax: Yes
- Ignore weight of wall during sliding calculations: Yes
- F* function depth measured from ground topography: No

7.5. MSE Wall Analysis - Results

The results of this verification example were compared with the literature. They can be viewed by computing the attached model, "*FHWA Example E5b.rswall*" and viewing the results via the main viewport and/or the report generator.

The summarized results are shown in the following tables. Owing to the following reasons, the results of the literature do not exactly match the output from RSWall.

- RSWall doesn't currently support load factors for EV, EH, etc. so the most similar ones have been used where necessary (this results in approximate analysis)
- The literature employs a sliding resistance factor = 0.8 for the cantilever wall but Table 11.5.6-1 says it should be 1.0
- In computing overturning moments about Point B on Table E5-7.1, the literature result seems to be incorrect, which introduces inaccuracies when calculating eccentricity and bearing
- An approximate analysis is done to amalgamate all the loads from the abutment and their locations into a single case
- Due to the extra layer of surcharge above the MSE wall, F* and Ka differs in the literature in since it measures the depth based on the actual depth of soil, rather than as a surcharge.
- The literature assumes an internal zone width of $0.3H_1$ when calculating the pullout length, but it should be the expanded distance to the point load (about $0.44H_1$)
- Combining forces F3 and V5 into a single UDL results in an approximation.

Owing to the numerous differences between the assumptions of these analyses, the results do not exactly match but are within the same orders of magnitude.

Table 7.4: Static load case results of the FHWA E5, Cantilever Part

Capacity Demand Ratio (CDR)	Literature	RSWall

Bearing	1.53	1.50
Base Sliding	1.55	1.71

Table 7.5: Comparison of results for Tmax in the FHWA E5 MSE Wall Example

Tmax (kips per 1 ft analysis width)	Literature	RSWall
Layer 1 [1]	53.22 kip / 10 ft = 5.32 k/ft	5.00
Layer 2 [1]	55.54 / 10 = 5.55	5.21
Layer 3 [1]	52.55 / 10 = 5.26	4.96
Layer 4 [1]	49.63 / 10 = 4.96	4.89
Layer 5 [1]	48.52 / 10 = 4.85	4.81
Layer 6 [1]	48.39 / 10 = 4.84	4.70
Layer 7 [1]	48.87 / 10 = 4.88	4.59
Layer 8 [1]	50.46 / 10 = 5.05	4.93
Layer 9 [1]	52.65 / 10 = 5.27	5.97
Layer 10 [1]	41.00 / 10 = 4.10	5.35
Layer 11 [1]	39.86 / 10 = 3.99	5.30

[1] In the published text, the layers are numbered from top to bottom, whereas they are numbered bottom to top in RSWall. Hence, the value for Layer 1 reported here is Layer 10 in the text, Layer 2 is Layer 9, etc.

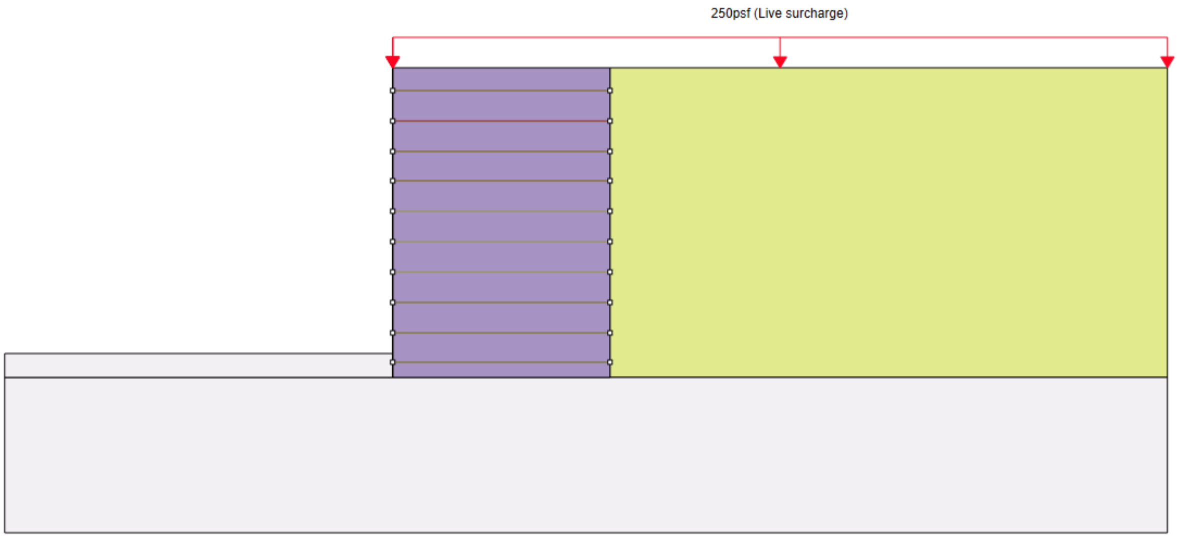
Table 7.6: Comparison of results for factored pullout strength in the FHWA E5 MSE Wall Example

Pr,f (kips per 1 ft analysis width)	Literature	RSWall
Layer 1 [1]	22.04	21.79
Layer 2 [1]	19.29	18.51
Layer 3 [1]	16.73	16.13
Layer 4 [1]	14.34	16.33
Layer 5 [1]	12.14	15.61
Layer 6 [1]	10.12	14.64
Layer 7 [1]	8.27	14.83
Layer 8 [1]	8.15	14.57
Layer 9 [1]	8.21	13.89
Layer 10 [1]	8.01	12.76
Layer 11 [1]	7.74	12.04

[1] In the published text, the layers are numbered from top to bottom, whereas they are numbered bottom to top in RSWall. Hence, the value for Layer 1 reported here is Layer 10 in the text, Layer 2 is Layer 9, etc.

8. FHWA-NHI-10-025, Example E7

Verification of the Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes – Volume II- FHWA-NHI-10-025, Appendix E, Example E7.



8.1. Problem Setup

This example is similar to Example E4 of the same reference but includes seismic loading. The input for this example is the same as that presented for Example E4, except the following.

- Reinforced and retained soils: soil-structure friction angle = 30°
- Extreme limit state: ON
- Seismic loading:
  - Kh = 0.211
  - Kv = 0
  - Use different Kh for external analysis = 0.206
- To simulate the seismic load factors for FHWA, the following custom load factors are specified for the Extreme limit state:
  - Maximum vertical earth pressure = 1.35
  - Minimum vertical earth pressure = 1.0
  - Horizontal earth pressure = 1.0(1)
  - Earthquake loads = 0.5

(1) Example shows 1.5 but that is not the case during the presented calculations.

In the advanced settings:

- Use average depth of adjacent reinforcement layers when calculating Tmax: Yes
- Ignore weight of wall during sliding calculations: Yes
- F* function depth measured from ground topography: No
- Use FHWA method when computing seismic inertial force: Yes
- Assume seismic active force acts horizontally: Yes

- Normalized height of seismic active force: 0.5
- Toggle off the strength limit state; only the extreme limit state will be evaluated for this example

8.2. Results

The results of this verification example were compared with the literature. They can be viewed by computing the attached model, "*FHWA Example E7.rswall*" and viewing the results via the main viewport and/or the report generator.

The summarized results for the extreme limit state are shown in the following tables. However, there are many differences between the methodology of FHWA and AASHTO, which results in differences between the literature results and those computed in RSWall. They are summarized as follows:

- FHWA uses K_{AE} to calculate F_2 during the seismic case, rather than K_A
- FHWA assumes that F_2 acts horizontally during seismic calculations.
- It seems like there is a mistake in the calculation of T_{HF} on page 7; the load factor gamma_EQ is taken as 0.5 when applied to the live load surcharge, as opposed to 1.0 in the table. The rest of the example seems to use 0.5, so the value of 0.5 was chosen in RSWall.
- In FHWA, only during sliding assessment there are no load factors applied.
- FHWA tries to apply load variable load factors even during the seismic case. But even in doing so, it inconsistently applies some of the factors in Table E7-4 of the literature.
- A bearing resistance factor of 0.9 is prescribed in AASHTO (11.5.8, 2020) but 1.0 is used in the FHWA literature.
- In FHWA, when calculating $T_{totalf} = T_{max} + T_{md}$, T_{max} is factored by γ_{EV}. But AASHTO explicitly factors both by $\gamma_{seis} = 1.0$.

Table 8.1: External analysis results of the FHWA E7 Example

Capacity Demand Ratio (CDR)	Literature	RSWall
Bearing	16.15 / 7.29 = 2.22	2.09
Base Sliding	1.58	1.58

Table 8.1: Comparison of results for tensile strength in the FHWA E7 Example

CDR (Tensile strength)	Literature	RSWall
Layer 1 [1]	1.20	1.20
Layer 2 [1]	1.32	1.33
Layer 3 [1]	1.40	1.42
Layer 4 [1]	1.43	1.42
Layer 5 [1]	1.47	1.46
Layer 6 [1]	1.56	1.55
Layer 7 [1]	1.19	1.19
Layer 8 [1]	1.36	1.37
Layer 9 [1]	1.28	1.27

Layer 10 [1]	2.14	2.13

[1] In the published text, the layers are numbered from top to bottom, whereas they are numbered bottom to top in RSWall. Hence, the value for Layer 1 reported here is Layer 10 in the text, Layer 2 is Layer 9, etc.

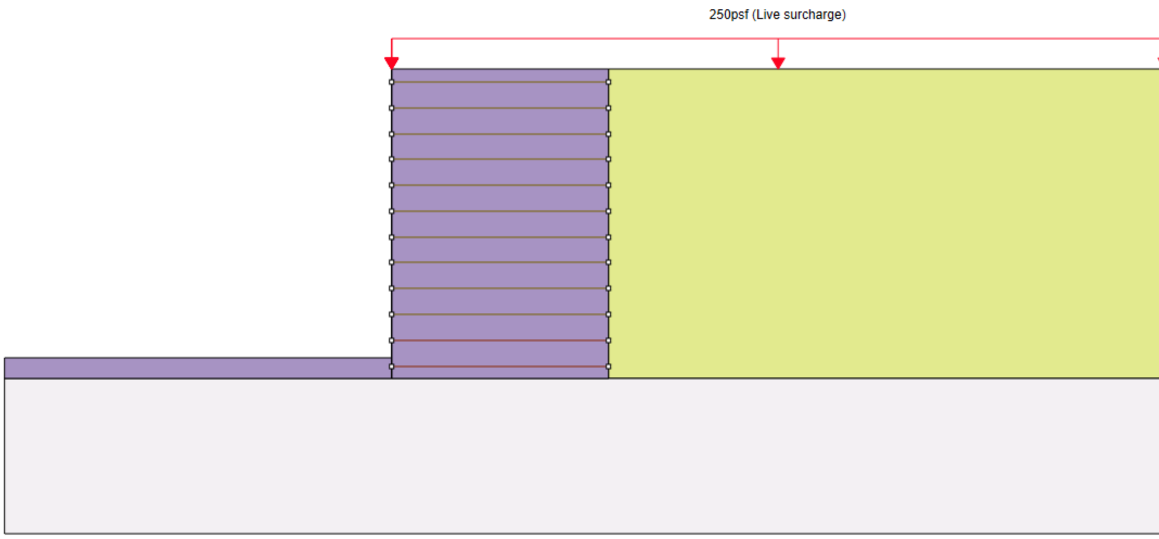
Table 6.3: Comparison of results for pullout strength in the FHWA E7 Example

CDR (Pullout strength)	Literature	RSWall
Layer 1 [1]	4.99	5.00
Layer 2 [1]	4.51	4.51
Layer 3 [1]	3.94	4.00
Layer 4 [1]	5.26	5.24
Layer 5 [1]	4.50	4.49
Layer 6 [1]	3.97	3.96
Layer 7 [1]	7.52	7.49
Layer 8 [1]	6.89	6.85
Layer 9 [1]	5.82	5.79
Layer 10 [1]	3.36	3.33

[1] In the published text, the layers are numbered from top to bottom, whereas they are numbered bottom to top in RSWall. Hence, the value for Layer 1 reported here is Layer 10 in the text, Layer 2 is Layer 9, etc.

9. FHWA-HIF-24-002, Example C1

Verification of the Design and Construction of Mechanically Stabilized Earth (MSE) Walls - FHWA-HIF-024-002, Appendix C, Example C1.



9.1. Problem Setup

This example models a segmental precast panel MSE wall with a level backfill and live load surcharge. Two alternatives for the design are considered: (i) geogrids using the stiffness method and (b) steel strips using the coherent gravity method.

Methodology:

- Active pressure method: Coulomb method
- Tension in reinforcement: Stiffness method (with geogrids) and coherent gravity method (with steel strips)

The wall unit and wall section profile properties are defined as follows:

- Wall unit, type: Modular
- Wall unit, depth: 0.001 ft
- Wall unit, width: 1 ft
- Wall unit, height: 30 ft
- Wall unit, center of gravity: 0 ft
- Number of wall courses: 1

The geometry defined in the model as follows:

- Backslope topography: Infinite, slope angle: 0°.
- Front face topography: Infinite; slope angle: 0°; embedment depth: 2 ft; no passive resistance
- Base strength: Contact with soil = Cast on sand

The soil properties defined in this model are:

- Reinforced soil: friction angle: 34°; soil-structure friction angle: 20°; unit weight: 125 pcf

- Retained soil: friction angle: 30°; soil-structure friction angle: 20°; unit weight: 120 pcf
- Foundation soil: friction angle: 30°; permanent cohesion: 0 psf; unit weight: 120 pcf

The applied loads are:

- Uniformly distributed load, live surcharge, magnitude = 250 psf, horizontal distance = 0 ft

The reinforcement properties (steel strips) are:

- Metallic strip reinforcement type
- Alpha coefficient = 1.0
- Pullout method = Friction factor, F(depth) from 2 at top, 0.6745 at reference depth of 20 ft
- There are multiple ways to specify the values of coverage in combination with the allowable tensile strength. For this example, the tensile strength is the strength of the strip if it were 1 ft wide, and then the coverage is calculated based on the actual width of the strip. If there are multiple strips, the coverage is multiplied by the number of strips.
    - 2x Steel Strips:
        - Nominal strength = 9.07 k/ft ÷ 0.75 = 12.093 k/ft (the already factored value was given in the literature)
        - Allowable tensile strength = 12.093 k/ft × 12”/2” = **72.56 k/ft per foot width of material**
        - Coverage = 2 strips × 2”/12” ÷ 5 ft spacing × 100% = 6.67%
    - 3x Steel Strips:
        - Allowable tensile strength = as above
        - Coverage = 3 strips × 2”/12” ÷ 5 ft spacing × 100% = 10%

The reinforcement layout (steel strips) is defined as:

Table 9.1: Reinforcement layout for FHWA-HIF-24-002 Example C1 for the case of steel strips

Height from bottom (ft)	Type	Length (ft)
1.25	3x Steel Strip	21
3.75	3x Steel Strip	21
6.25	2x Steel Strip	21
8.75	2x Steel Strip	21
11.25	2x Steel Strip	21
13.75	2x Steel Strip	21
16.25	2x Steel Strip	21
18.75	2x Steel Strip	21
21.25	2x Steel Strip	21
23.75	2x Steel Strip	21
26.25	2x Steel Strip	21
27.75	2x Steel Strip	21

The reinforcement properties (geogrids) are:

- Geogrid reinforcement type
- Alpha coefficient = 1.0
- Coverage = 80%
- Pullout method = Coefficient of interaction
- Coefficient of interaction = 0.8
- Creep factor = 2.6
- Allowable tensile strength = 12.5 k/ft ÷ (1.1 × 2.6 × 1.1) = 3.973 k/ft (with reduction coefficients applied)
- Secant stiffness = 73530 lb/ft

The reinforcement layout (geogrids) is defined as:

Table 9.2: Reinforcement layout for FHWA-HIF-24-002 Example C1 for the case of geogrids

Height from bottom (ft)	Type	Length (ft)
1.25	Geogrid	21
3.75	Geogrid	21
6.25	Geogrid	21
8.75	Geogrid	21
11.25	Geogrid	21
13.75	Geogrid	21
16.25	Geogrid	21
18.75	Geogrid	21
21.25	Geogrid	21
23.75	Geogrid	21
26.25	Geogrid	21
27.75	Geogrid	21

In the advanced settings:

- Use average depth of adjacent reinforcement layers when calculating Tmax: Yes
- Ignore weight of wall during sliding calculations: Yes
- F* function depth measured from ground topography: Yes
- Stiffness Method: Facing coefficient = 1; Soil cohesion coefficient = 1

9.2. Results

The results of this verification example were compared with the literature. They can be viewed by computing the attached models, "*FHWA Example C1 - CGM.rswall*" and "*FHWA Example C1 - SM.rswall*" and viewing the results via the main viewport and/or the report generator.

The external stability results were compared as follows:

Table 9.3: External analysis results for Example C1 of FHWA-HIF-24-002

Output	Literature	RSWall
Maximum bearing stress (ksf)	6.91	6.91
Base Sliding CDR	1.94	1.94

Note that the methodology presented in the literature for this example differs slightly from the AASHTO standard in the following points, which results in differences between the results of RSWall and the literature:

- The literature factors all the loads contributing to Tmax separately, whereas AASHTO recommends using unfactored loads to determine Tmax, and then factoring Tmax by γ_{EV} later. The latter approach is adopted in RSWall.
- In the Coherent Gravity Method, the literature includes live loads when calculating Tmax in the pullout case despite stating that it does not

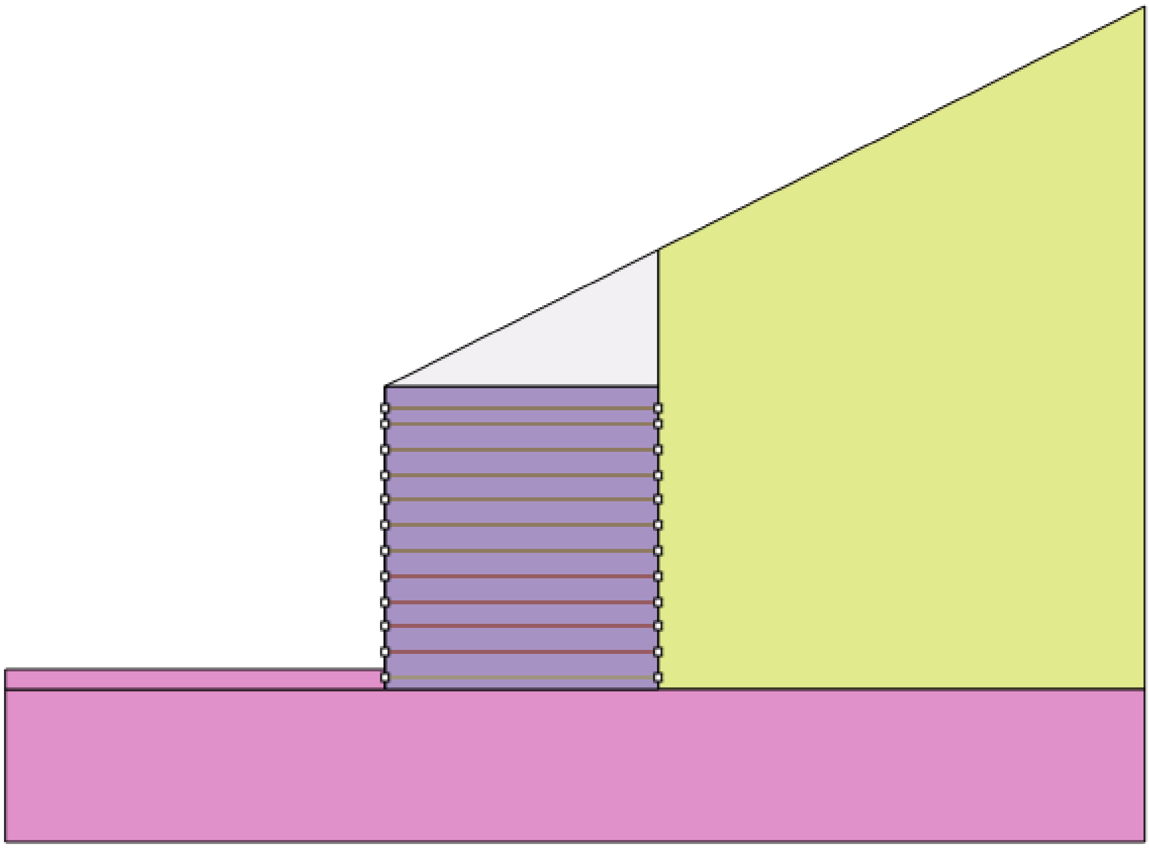
Reinforcement stability calculations were compared as follows.

Table 9.4: Reinforcement stability results for Example C1 of FHWA-HIF-24-002

Capacity Demand Ratio (CDR)	Literature	RSWall
Tensile strength (steel strips; coherent gravity)	1.01	0.96
Pullout strength (steel strips; coherent gravity)	1.20	1.22
Tensile strength (geogrids; stiffness method)	2.18	2.22
Pullout strength (geogrids; stiffness method)	4.03	4.00

10. FHWA-HIF-24-002, Example C2

Verification of the Design and Construction of Mechanically Stabilized Earth (MSE) Walls - FHWA-HIF-024-002, Appendix C, Example C2.



10.1. Problem Setup

This example contains a segmental precast panel MSE wall with a sloping backfill surcharge. Two alternatives for the design are considered: (i) geogrids using the stiffness method and (b) steel strips using the coherent gravity method.

Methodology:

- Active pressure method: Coulomb method
- Tension in reinforcement: Stiffness method (with geogrids) and coherent gravity method (with steel strips)

The wall unit and wall section profile properties are defined as follows:

- Wall unit, type: Modular
- Wall unit, depth: 0.001 ft
- Wall unit, width: 1 ft
- Wall unit, height: 30 ft

- Wall unit, center of gravity: 0 ft
- Number of wall courses: 1

The geometry defined in the model as follows:

- Backslope topography: Infinite; slope angle: 26.6°.
- Front face topography: Infinite; slope angle: 0°; embedment depth: 2 ft; no passive resistance
- Base strength: Contact with soil = Cast on sand

The soil properties defined in this model are:

- Reinforced soil: friction angle: 34°; soil-structure friction angle: 20°; unit weight: 125 pcf
- Retained soil: friction angle: 30°; soil-structure friction angle: 20°; unit weight: 120 pcf
- Backslope soil: friction angle: 30°; unit weight: 120 pcf
- Foundation soil: friction angle: 30°; permanent cohesion: 0 psf; unit weight: 120 pcf

The reinforcement properties (steel strips) are defined as:

- Metallic strip reinforcement type
- Alpha coefficient = 1.0
- Pullout method = Friction factor, F(depth) from 2 at top, 0.6745 at reference depth of 20 ft
- There are multiple ways to specify the values of coverage in combination with the allowable tensile strength. For this example, the tensile strength is the strength of the strip if it were 1 ft wide, and then the coverage is calculated based on the actual width of the strip. If there are multiple strips, the coverage is multiplied by the number of strips.
    - 2x Steel Strips:
        - Nominal strength = 9.07 k/ft ÷ 0.75 = 12.093 k/ft (the already factored value was given in the literature)
        - Allowable tensile strength = 12.093 k/ft × 12”/2” = **72.56 k/ft per foot width of material**
        - Coverage = 2 strips × 2”/12” ÷ 5 ft spacing × 100% = 6.67%
    - 3x Steel Strips:
        - Allowable tensile strength = as above
        - Coverage = 3 strips × 2”/12” ÷ 5 ft spacing × 100% = 10%
    - 4x Steel Strips:
        - Allowable tensile strength = as above
        - Coverage = 4 strips × 2”/12” ÷ 5 ft spacing × 100% = 13.33%

The reinforcement layout (steel strips) is defined as:

Table 10.1: Steel strlip layout for FHWA-HIF-24-002 Example C2

Height from bottom (ft)	Type	Length (ft)
1.25	4x Steel Strip	27
3.75	3x Steel Strip	27
6.25	3x Steel Strip	27
8.75	3x Steel Strip	27
11.25	3x Steel Strip	27

13.75	2x Steel Strip	27
16.25	2x Steel Strip	27
18.75	2x Steel Strip	27
21.25	2x Steel Strip	27
23.75	2x Steel Strip	27
26.25	2x Steel Strip	27
27.75	2x Steel Strip	27

The reinforcement properties (geogrids) are defined as:

- Geogrid reinforcement type
- Alpha coefficient = 1.0
- Coverage = 80%
- Pullout method = Coefficient of interaction
- Coefficient of interaction = 0.8
- Creep factor = 2.6
- Allowable tensile strength (with reduction coefficients applied):
    - T1: 4.80 k/ft ÷ (1.1 × 2.6 × 1.05) = 1.598 k/ft
    - T2: 9.87 k/ft ÷ (1.1 × 2.6 × 1.05) = 3.287 k/ft
    - T3: 11.99 k/ft ÷ (1.1 × 2.6 × 1.05) = 3.993 k/ft
- Secant stiffness:
    - T1: 23830 lb/ft
    - T2: 57940 lb/ft
    - T3: 69570 lb/ft

The reinforcement layout (geogrids) is defined as:

Table 10.2: Geogrid layout for FHWA-HIF-24-002 Example C2

Height from bottom (ft)	Type	Length (ft)
1.25	T3	27
3.75	T3	27
6.25	T3	27
8.75	T3	27
11.25	T3	27
13.75	T2	27
16.25	T2	27
18.75	T2	27
21.25	T2[1]	27
23.75	T1	27

26.25	T1	27
27.75	T1	27

In the advanced settings:

- Use average depth of adjacent reinforcement layers when calculating Tmax: Yes
- Ignore weight of wall during sliding calculations: Yes
- F* function depth measured from ground topography: Yes
- Stiffness Method: Facing coefficient = 1; Soil cohesion coefficient = 1

10.2. Results

The results of this verification example were compared with the literature. They can be viewed by computing the attached models, "*FHWA Example C2 - CGM.rswall*" and "*FHWA Example C2 - SM.rswall*", and viewing the results via the main viewport and/or the report generator.

The external stability results were compared as follows:

Table 10.3: External analysis results for Example C2 of FHWA-HIF-24-002

Output	Literature	RSWall
Maximum bearing stress (ksf)	9.76	9.77
Base Sliding CDR	1.06	1.06

Note that the methodology presented in the literature for this example differs slightly from the AASHTO standard in the following points, which results in differences between the results of RSWall and the literature:

- For an unknown reason, the literature example presents differing values of Tmax for the coherent gravity method between the tensile and pullout caes, even though they should be consistent (no live loads exist in the example).
- AASHTO specifies a coefficient for pullout strength of 0.7, but the literature appears to use 0.9
- AASHTO specifies a coefficient for tensile strength of 0.8, but the literature does not adopt it in this example
- The literature example's calculation of Tmax cannot be reproduced with the provided hand calculations and is off by about 20% at the bottom of the wall. The error increases as the analysis proceeds up the wall.
- See additional note in the footnote section of the table below.

Reinforcement stability calculations were compared as follows.

Table 10.4: Reinforcement stability results for Example C2 of FHWA-HIF-24-002

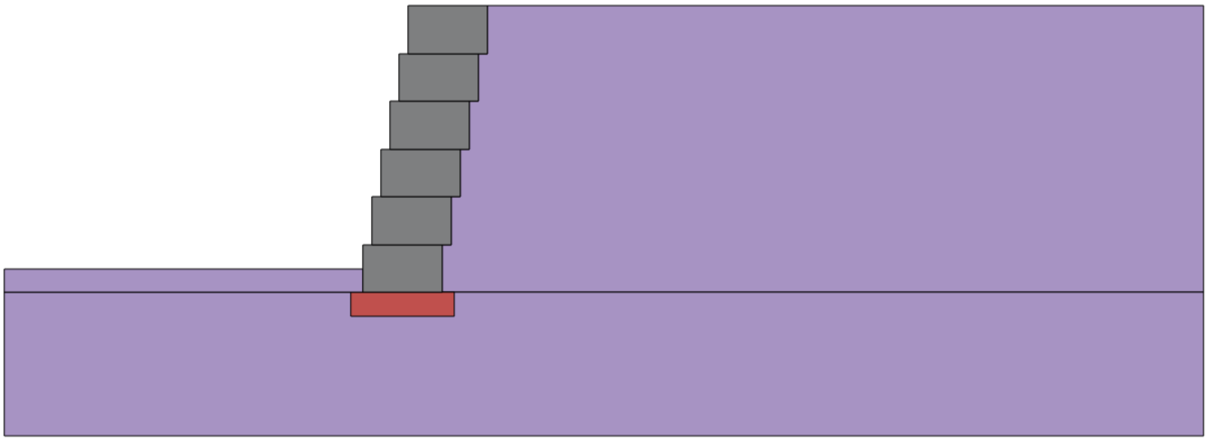
Capacity Demand Ratio (CDR)	Literature	RSWall

Tensile strength (steel strips; coherent gravity)	1.00	1.00
Pullout strength (steel strips; coherent gravity)	1.49	1.50
Tensile strength (geogrids; stiffness method)	1.66[1]	2.02
Pullout strength (geogrids; stiffness method)	33.05	32.8

[1] The literature example appears to switch periodically between assuming three and four layers of the T1 geogrid type, resulting in the fourth layer from the bottom varying between T1 and T2 assignments.

11. Redi-Rock Manual, Example 1

Verification of Example 1 from Johnson et al. (2022). Precast Modular Block Design Manual Volume 1: Gravity Walls. Aster Brands: Charlevoix, MI.



11.1. Problem Setup

This example contains an unreinforced segmental wall with uniform facing blocks, evaluated using the AASHTO (2020) design standard.

Methodology:

- Active pressure method: Coulomb method

The wall unit and wall section profile properties are defined as follows:

- Wall unit, type: Modular
- Wall unit, depth: 1.667 ft
- Wall unit, height: 1 ft
- Wall unit, center of gravity: 0.875 ft
- Wall unit, unit weight: 134 pcf
- Interlayer shear strength function: Linear; friction angle = 37°; min. strength = 320 lb/ft; max. Strength = 5000 lb/ft
- Number of wall courses: 6
- Layer setback distance: 2.25 in

The geometry defined in the model as follows:

- Backslope topography: Infinite; slope angle: 0°.
- Front face topography: Infinite; slope angle: 0°; embedment depth: 0.5 ft; no passive resistance
- Leveling pad included:
    - Thickness: 6 in
    - Width: 2.167 ft
    - Setback: 3 in

The soil properties defined in this model are:

- Retained & foundation soil (“SM-1”): friction angle: 30°; soil-structure friction angle: 20°; unit weight: 120 pcf
- Leveling pad soil (“GP”): friction angle: 40°; soil-structure friction angle: 26.67°; unit weight: 125 pcf

Other settings:

- Assess only the Serviceability limit state

11.2. Results

The results of this verification example were compared with the literature. They can be viewed by computing the attached model, “*Redi-Rock Example 1.rswall*” and viewing the results via the main viewport and/or the report generator.

Note that the results differ slightly between the literature and RSWall due to the following reason:

- The true batter angle of the wall is measured 8.8° and adopted in RSWall, but the literature assumes the block-to-block batter angle of 10.6°

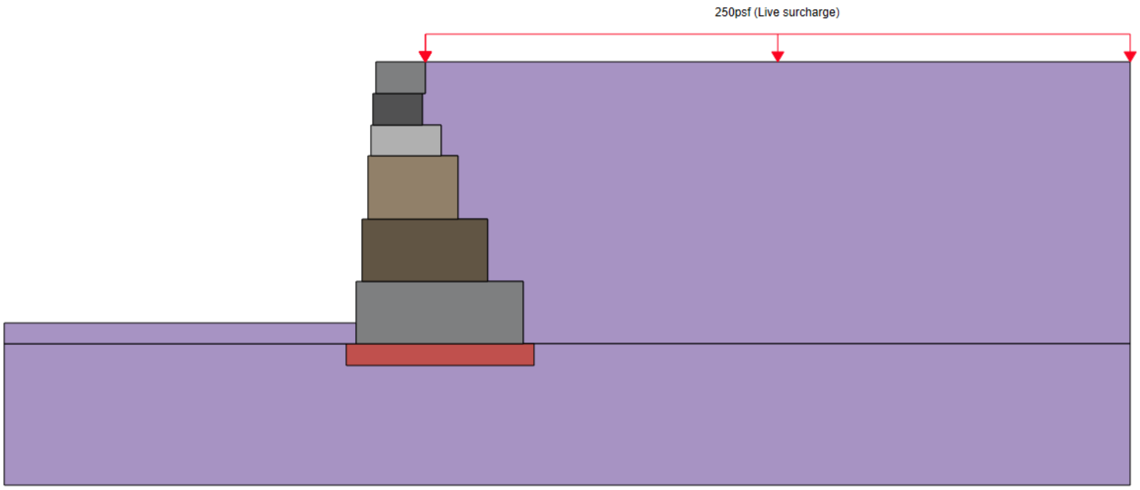
The summarized results are shown in the following tables:

Table 11.1: Strength load case result for Redi-Rock Example 1

Capacity Demand Ratio (CDR)	Literature	RSWall
Base sliding (above leveling pad)	1.96	1.91
Base sliding (below leveling pad)	1.57	1.53
Overturning	2.02	1.98
Bearing	5.94	6.14
Internal sliding (course 1)	3.57	3.43
Toppling (course 1)	2.68	2.59

12. Redi-Rock Manual, Example 2

Verification of Example 2 from Johnson et al. (2022). Precast Modular Block Design Manual Volume 1: Gravity Walls. Aster Brands: Charlevoix, MI.



12.1. Problem Setup

This example contains an unreinforced segmental wall with non-uniform facing blocks, evaluated using the AASHTO (2020) design standard.

Methodology:

- Active pressure method: Coulomb method

The wall unit and wall section profile properties are defined as follows:

- Wall unit, type: Modular
- Layer 6 (top of wall): R-28T
  - Depth: 28 in
  - Height: 18 in
  - Center of gravity: 15.1 in
  - Unit weight: 112 pcf
  - Interlayer shear strength function: Linear; friction angle = 44°; min. strength = 6061 lb/ft; max. Strength = 11276 lb/ft
- Layer 5: R-28PCM
  - Depth: 28 in
  - Height: 18 in
  - Center of gravity: 14.4 in
  - Unit weight: 120 pcf
  - Interlayer shear strength function: Linear; friction angle = 44°; min. strength = 6061 lb/ft; max. Strength = 11276 lb/ft
- Layer 4: R-41PCM
  - Depth: 40.5 in
  - Height: 18 in

  - Center of gravity: 20.7 in
  - Unit weight: 123 pcf
  - Interlayer shear strength function: Linear; friction angle = 44°; min. strength = 6061 lb/ft; max. Strength = 11276 lb/ft
- Layer 3: R-5236HC
  - Depth: 52 in
  - Height: 36 in
  - Center of gravity: 26.7 in
  - Unit weight: 123 pcf
  - Interlayer shear strength function: Bilinear; friction angle 1 = 44°; friction angle 2 = 22° min. strength = 4547 lb/ft; tangent strength = 8488 lb/ft; max. Strength = 15000 lb/ft
- Layer 2: R-7236HC
  - Depth: 72 in
  - Height: 36 in
  - Center of gravity: 36.7 in
  - Unit weight: 113 pcf
  - Interlayer shear strength function: Bilinear; friction angle 1 = 44°; friction angle 2 = 22° min. strength = 4547 lb/ft; tangent strength = 8488 lb/ft; max. Strength = 15000 lb/ft
- Layer 1 (bottom of wall): R-9636HC
  - Depth: 96 in
  - Height: 36 in
  - Center of gravity: 48.4 in
  - Unit weight: 112 pcf
  - Interlayer shear strength function: Bilinear; friction angle 1 = 44°; friction angle 2 = 22° min. strength = 4547 lb/ft; tangent strength = 8488 lb/ft; max. Strength = 15000 lb/ft
- Number of wall courses: 6
- Layer setback angle: 5.16°

The geometry defined in the model as follows:

- Backslope topography: Infinite; slope angle: 0°.
- Front face topography: Infinite; slope angle: 0°; embedment depth: 1 ft; no passive resistance
- Leveling pad included:
  - Thickness: 12 in
  - Width: 96 + 12 = 108 in
  - Setback: 6 in

The soil properties defined in this model are:

- Retained & foundation soil (“SM-2”): friction angle: 30°; soil-structure friction angle: 22.5°; unit weight: 120 pcf
- Leveling pad soil (“GP”): friction angle: 40°; soil-structure friction angle: 26.67°; unit weight: 125 pcf

The applied loads are:

- Live load, 250 psf, horizontal distance = 0 ft

Other settings:

- Assess only the Serviceability limit state

12.2. Results

The results of this verification example were compared with the literature. They can be viewed by computing the attached model, "*Redi-Rock Example 2.rswall*" and viewing the results via the main viewport and/or the report generator.

Note that the results differ slightly between the literature and RSWall due to the following reasons:

- The facing batter is assumed to be uniform in the current version of RSWall at the time of writing, whilst it is not uniform in the literature example; this results in a minor deviation of the top backslope point relative to the toe of the wall.
- An additional sliver of internal soil is considered in the literature to reconcile the approximation of a straight linear interface between the soil and back of wall, resulting in minor differences in the vertical forces and resisting moments.

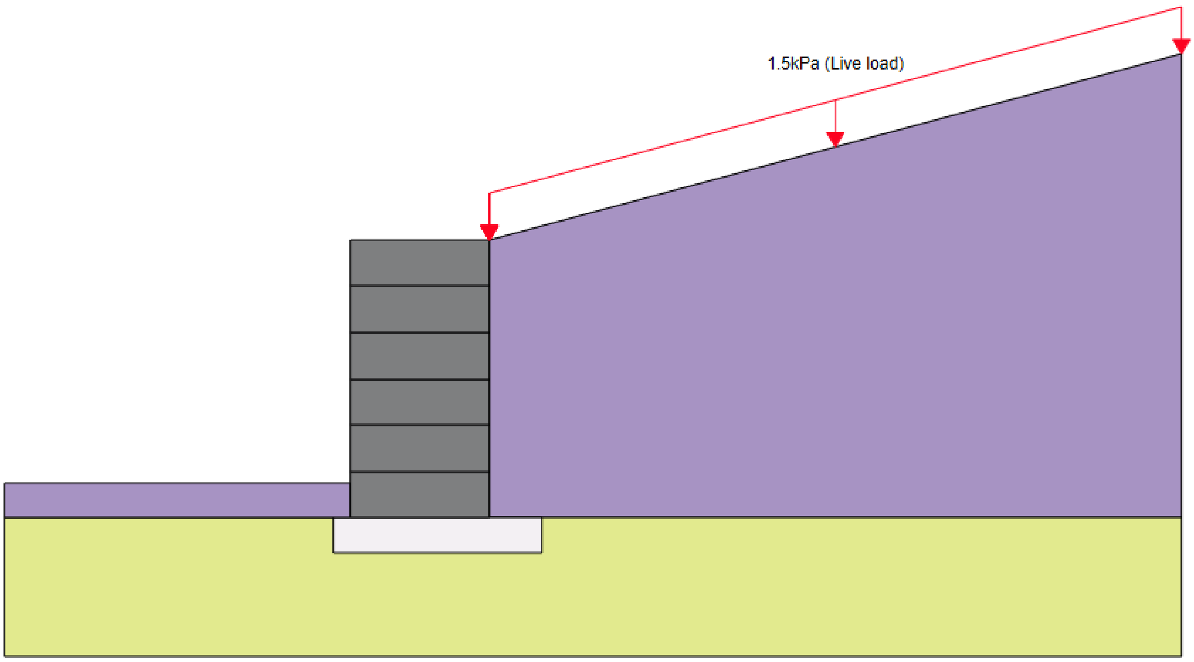
The summarized results are shown in the following tables:

Table 12.1: Strength load case result for Redi-Rock Example 1

Capacity Demand Ratio (CDR)	**Literature**	**RSWall**
Base sliding (above leveling pad)	1.77	1.63
Base sliding (below leveling pad)	1.51	1.40
Overturning	2.02	2.10
Bearing	5.61	5.40
Internal sliding (course 1)	3.74	4.01
Toppling (course 1)	2.20	2.12

13. Concrete Masonry Gravity Retaining Wall

Verification of a conventional wall design example from Appendix A of the Concrete Masonry Association of Australia's RW03 Manual (2014): Concrete Masonry Gravity Retaining Walls.



13.1. Problem Setup

This example contains an unreinforced segmental wall with uniform facing blocks, evaluated using the Australian AS 4678 design standard.

Methodology:

- Active pressure method = Coulomb method

The wall unit and wall section profile properties are defined as follows:

- Wall unit, type: Modular
- Wall unit, depth: 0.6 m
- Wall unit, height: 0.2 m
- Wall unit, center of gravity: 0.3 m
- Wall unit, unit weight: 18.7 kN/m^3
- Number of wall courses: 6
- Layer setback distance: 0 m

The geometry defined in the model as follows:

- Backslope topography: Infinite; slope angle: 15°.
- Front face topography: Infinite; slope angle: 0°; embedment depth: 0.15 m; no passive resistance

- Leveling pad included:
    - Thickness: 0.15 m
    - Width: 0.6 + 0.15 × 2 = 0.9 m
    - Setback: 0.075 m

The soil properties defined in this model are:

- Retained soil: friction angle: 29°; soil-structure friction angle: 19.33°; unit weight: 19.6 kN/m^3, In situ condition, permanent cohesion = 0 kPa
- Foundation soil: friction angle: 35°; soil-structure friction angle: 35°; unit weight = 18.6 kN/m^3, Class 2 condition, permanent cohesion = 3 kPa
- Leveling pad soil: friction angle: 40°; soil-structure friction angle: 40°; unit weight: 20 kN/m^3, Class 1 condition, permanent cohesion = 0 kPa

The applied loads are:

- Live load, 1.5 kPa, horizontal distance = 0 m

Other settings:

- Structure classification design factor = 1.1
- This example focuses on Load Case B

13.2. Results

The results of this verification example were compared with the literature. They can be viewed by computing the attached model, "*CMAA Example.rswall*" and viewing the results via the main viewport and/or the report generator.

Note that due to the following differences between assumptions, the literature result is different from the RSWall result:

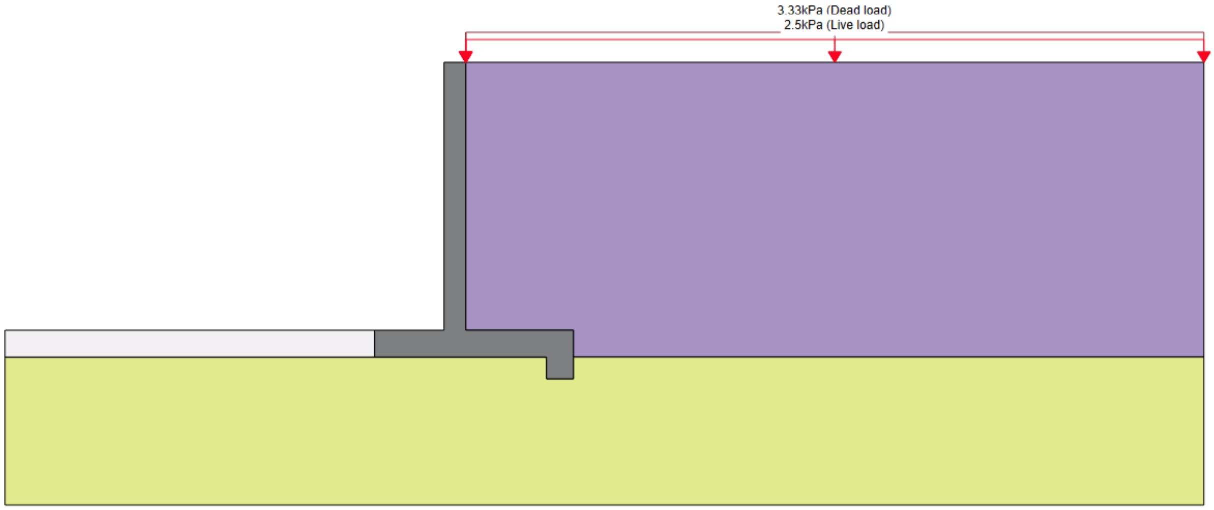
- The literature example utilizes the factored sum of resisting moments (factored by ×1.1) when calculating eccentricity, but the bearing resistance is further multiplied by the same factor, which is unconservative. RSWall only applies the factor once during the bearing analysis.
- The literature calculates the resisting moments about a different pivot point, which results in a different CDR for overturning
- Dispersion of stresses through the leveling pad is assumed to occur over a 1:1 distribution in the literature whereas RSWall assumes 1:2.

Table 13.1: Strength load case result for the CMAA Appendix A example

Capacity Demand Ratio (CDR)	**Literature**	**RSWall**
Base sliding	11.8 / 9.0 = 1.31	1.31
Overturning	3.86 / 3.85 = 1.00	1.39
Bearing	19.2 / 13.5 = 1.42	0.81

14. MBIE Cantilever Wall Example

Verification of a cantilever wall example from MBIE (2014), Design of concrete cantilever retaining walls to resist earthquake loading for residential sites, Worked Example 2 (Version 1): MBIE Guidance on the seismic design of retaining structures for residential sites in Greater Christchurch (Version 2).



14.1. Problem Setup

This example contains a cantilever wall evaluated using the Australian AS 4678 design standard. Note that since the methodology in the literature is based on the New Zealand standard, the results differ.

Methodology:

- Active pressure method = Coulomb method
- Passive pressure method = Caquot-Kerisel method

The wall section profile is defined as follows:

- Unit weight = 24.5 kN/m^3

Table 14.1: Cantilever wall section profile for the MBIE example

Dimension	Quantity (m)
b1	0.65
b2	0.00
b3	0.20
b4	1.00
b5	0.25
b6	0.00
h1	0.20
h2	0.25

h3	2.50

The geometry defined in the model as follows:

- Backslope topography: Infinite; slope angle: 0°.
- Front face topography: Infinite; slope angle: 0°; embedment depth: 0.25 m; include passive resistance

The soil properties defined in this model are:

- Fill soil: friction angle and soil-structure friction angle: 31.3°; unit weight: 18 kN/m^3, Class 1 condition, permanent cohesion = 0 kPa
- Foundation soil: friction angle: 31.3°; soil-structure friction angle: 20.67°; unit weight: 18 kN/m^3, Class 1 condition, permanent cohesion = 0 kPa
- Passive soil: friction angle: 31.3°; soil-structure friction = 20.67°; unit weight: 18 kN/m^3, Class 1 condition, permanent cohesion = 0 kPa

The applied loads are:

- Live load, 2.5 kPa, horizontal distance = 0 m
- Dead load, 3.33 kPa, horizontal distance = 0 m

Other settings:

- To simulate the New Zealand-based factors in the example, assess Load Case B and define the following factors:
    - Strength case:
        - Dead load, maximum factor, strength case = 1.2
        - Dead load, minimum factor, strength case = 0.9
        - Live load, strength case = 0.4

14.2. Results

The results of this verification example were compared with the literature. They can be viewed by computing the attached model, "*MBIE Example.rswall*" and viewing the results via the main viewport and/or the report generator.

Note that due to the following differences between assumptions, the literature result is different from the RSWall result:

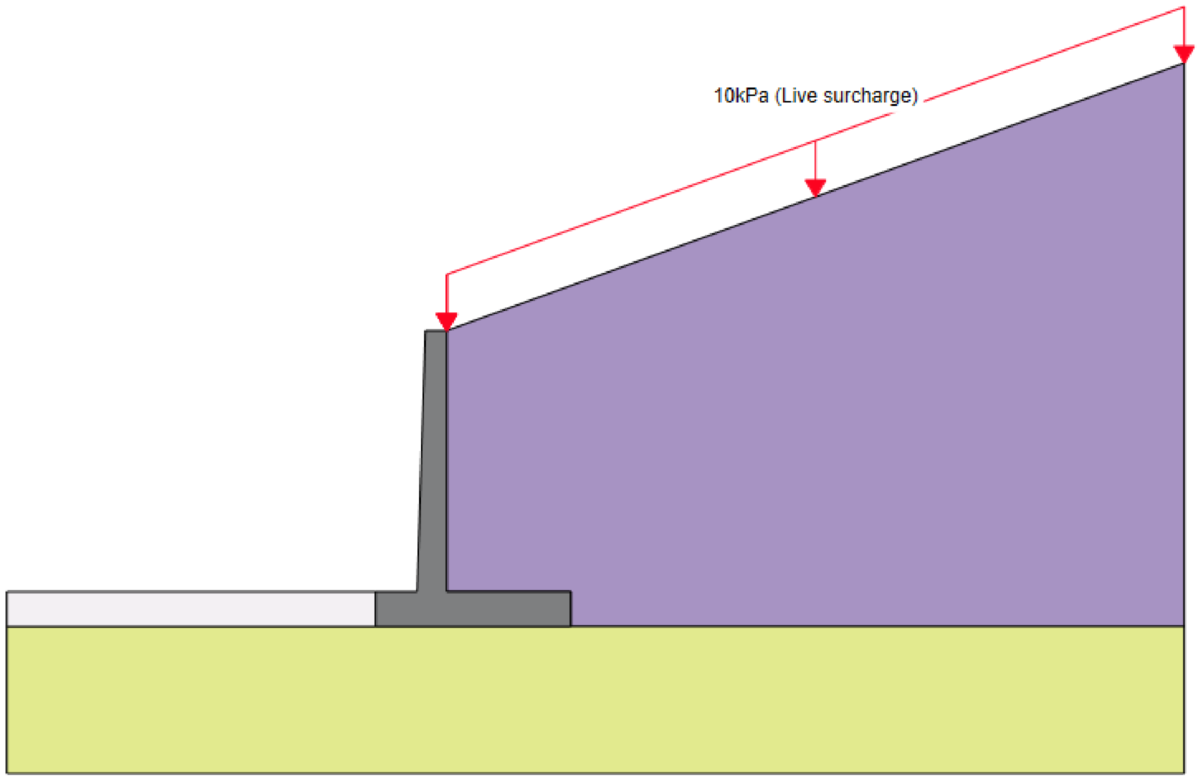
- The literature uses a separate factor of 1.5 for the driving forces, which causes differences in the base sliding and overturning results (their analysis is more conservative)
- During bearing capacity calculations, the example methodology is different from that recommended in the Australian standard
- The example adopts separate reduction factors for passive and sliding resistance which are not present in AS 4678
- The literature includes the weight of soil at the level of the shear key in the resisting weight for sliding, whereas it is ignored in RSWall

Table 14.1: Static load case result for the MBIE Cantilever example

Capacity Demand Ratio (CDR)	Literature	RSWall
Base sliding	42.372 / 36.271 = 1.17	1.32
Overturning	(25.828 + 74.306 + 4.05) / 31.239 = 3.34	4.54
Bearing	84.082 / 79.787 = 1.05	3.17

15. Eurocode Designers' Guide – Example 9.1

Verification of a cantilever wall analysis presented in the Frank et al. (2013). Designer's Guide to Eurocode 7: Geotechnical Design. ICE Publishing: London, UK. It is listed as Example 9.1 in the literature.



15.1. Problem Setup

This example contains a cantilever wall evaluated using the Eurocode design standard. The results for Design Approaches 2 and 3 are presented here.

Methodology:

- Active pressure method = Kerisel-Absi
- Passive pressure method = Kerisel-Absi

The wall section profile is defined as follows:

- Wall Type = Cantilever
- Unit weight = 24 kN/m^3

Table 14.1: Cantilever wall section profile for the Eurocode Designer's Guide example

Dimension	Quantity (m)

b1	0.95
b2	0.20
b3	0.50
b4[1]	2.86 or 3.87
b5	0.00
b6	0.00
h1	0.00
h2	0.80
h3	6.00

[1] The values of b4 used in the calculations for this example are 2.86 m (Design approach 2) and 3.87 m (Design approach 3).

The topography defined in the model as follows:

- Backslope topography: Infinite; slope angle: 20°.
- Front face topography: Infinite; slope angle: 0°; embedment depth: 0.8 m; include passive resistance

The soil properties defined in this model are:

- Retained soil: unit weight = 20 kN/m^3, friction angle = 32°, soil-structure friction angle = 20°, permanent cohesion = 0 kPa
- Foundation soil: unit weight = 20 kN/m^3, friction angle = 32°, soil-structure friction angle = 32°, permanent cohesion = 0 kPa
- Passive soil: unit weight = 20 kN/m^3, friction angle = 32°, soil-structure friction angle = 20°, permanent cohesion = 0 kPa

The applied loads are:

- Live load, 10 kPa, horizontal distance = 0 m

Other settings:

- Use backslope angle as soil-structure friction angle = Yes

15.2. Results

The results of this verification example were compared with the literature. They can be viewed by computing the attached model, "*Eurocode Guide Example.rswall*" and viewing the results via the main viewport and/or the report generator.

Note that due to the following differences between assumptions, the literature result is different from the RSWall result:

- For earth pressures, the author of the literature approximates Ka and Kp by visual inspection
- The literature reports the total vertical force in a way that excludes the variable surcharge, resulting in smaller eccentricity and subsequently a different result for the bearing stress

- In the literature, the correct values of iq and ig (load inclination factors) for DA-2 combination appear to be the ones identified under the DA-2* combination rather than the values reported for DA-2.

Table 15.1: Design Approach 2 (DA2) results for the Eurocode Design Guide example

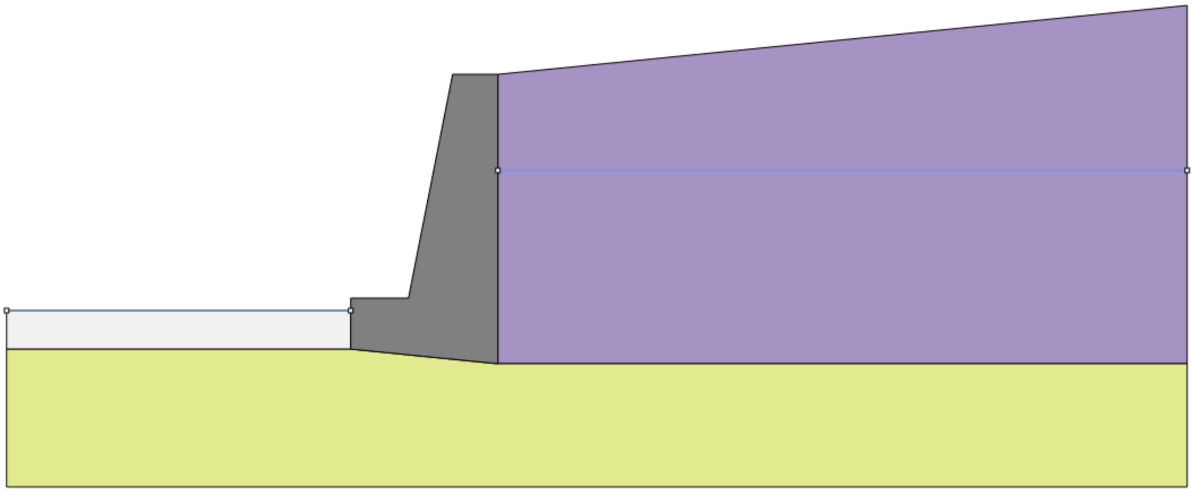
Capacity Demand Ratio (CDR)	Literature	RSWall
Base sliding	1.20	1.19
Bearing	1.00	0.70

Table 15.2: Design Approach 3 (DA3) results for the Eurocode Design Guide example

Capacity Demand Ratio (CDR)	Literature	RSWall
Base sliding	1.19	1.19
Bearing	1.00	0.87

16. Gravity Wall from Geo5

Verification of a gravity wall presented in the Geo5 Verification Manual no. 1 (Update 02/2016); Demo_vm_en_01.gtz



16.1. Problem Setup

This example contains a gravity wall evaluated using the Eurocode design standard which presented as part of Geo5's verification files.

Methodology:

- Active pressure method = Colomb method
- Passive pressure method = Use at-rest pressure

The wall section profile is defined as follows:

- Unit weight = 24 kN/m^3
- Elevation at toe = 0 m

Table 14.1: Gravity wall section profile for the Geo5 example

Dimension	Quantity (m)
b1	0.90
b2	0.70
b3	0.70
b4	0.00
b5	0.00
h1	0.23
h2	0.80
h3	3.50

The topography defined in the model as follows:

- Backslope topography: Infinite; slope angle: 5.71°.
- Front face topography: Infinite; slope angle: 0°; embedment depth: 0.6 m; include passive resistance

The soil properties defined in this model are:

- Retained soil [1]: unit weight = 18 kN/m^3, saturated unit weight = 20.5 kN/m^3, friction angle = 26.8°, soil-structure friction angle = 15°, permanent cohesion = 9 kPa
- Foundation soil: unit weight = 18.5 kN/m^3, saturated unit weight = 20.5 kN/m^3, friction angle = 27°, soil-structure friction angle = 27°, permanent cohesion = 8 kPa
- Passive soil: unit weight = 18.5 kN/m^3, saturated unit weight = 20.5 kN/m^3, friction angle = 27°, soil-structure friction angle = 15°, permanent cohesion = 8 kPa

Base strength:

- User defined bearing capacity: 100 kPa

Groundwater:

- Elevation at front: 0.6 m
- Elevation at back: 2.8 m

Other settings:

- Wall base porewater pressure based on: Front of wall
- Custom design factors
  - Friction angle, M2: 1.1
  - Cohesion, M2: 1.4
- Evaluate Design Approach 1, Combination 2 only (it is the one most similar to the computations presented in the literature)

[1] At the time of writing, RSWall does not yet support multiple strata in the backfill, so an amalgamation of the two soil regions defined in the literature is assumed here.

16.2. Results

The results of this verification example were compared with the literature. They can be viewed by computing the attached model, "*Gravity Wall Geo5.rswall*" and viewing the results via the main viewport and/or the report generator.

Due to the flexibility of Eurocode 7, there are many differences between the assumptions in Geo5 and those made in RSWall, resulting in different results of the analysis:

- Geo5 adopts a different assumption for the hydrostatic forces near the bottom of the analysis depth
- Geo5 adopts a γ_s factor for external stability that is not explicitly present in the EN1997-1:2004

- Geo5 uses a different assumption when considering the cohesion component in the base sliding resistance
- The methodology for computing passive force is different
- The methodology for computing Kac and the cohesion-related portion of lateral earth pressure is different

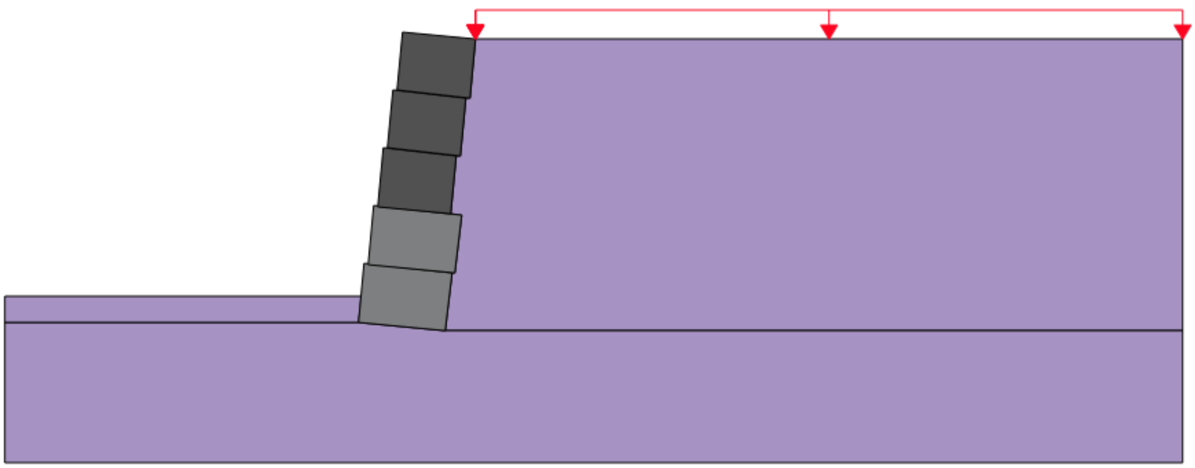
Table 16.2: Result for the Geo5 gravity wall example

Output	**Literature**	**RSWall** [1]
Base sliding ODR	65.98 / 61.79 = 1.07	1.20
Overturning ODR	190.74 / 73.99 = 2.58	4.89
Design bearing pressure (kPa)	65.577	54.9

[1] *see above reasoning which accounts for the differences*

17. A.N. Beal Gabion Wall

Verification of the gabion wall presented in Beal, A.N. (n.d.). Worked examples of retaining wall design to BS8002. Accessed 2024 June 20, <https://anbeal.co.uk/bs8002earthretainingworkedexamples.html>



17.1. Problem Setup

In this example a five-layer gabion wall is analyzed for external stability. The inputs are provided as follows.

The example does not explicitly reference the Eurocode, and no design factors are considered. To most closely replicate the unfactored results in the literature, evaluate Design Approach 1, Combination 2 of Eurocode only, and set all the material factors (M2) to 1.0.

Methodology:

- Active pressure method = Colomb method

The wall section profile is defined as follows:

- Unit weight = 13.8 kN/m^3
- Lower baskets:
  - Height = 1 m
  - Depth = 1.5 m
  - Width = 1 m
- Upper baskets:
  - Height = 1 m
  - Depth = 1.25 m
  - Width = 1 m
- Courses: 2x Lower + 3x Upper
- Setback per layer [1] = 0.0625 m (62.5 mm)
- Basket tilt angle = 6°

The topography defined in the model as follows:

- Backslope topography: Infinite; slope angle: 0°.
- Front face topography: Infinite; slope angle: 0°; embedment depth: 0.443 m; do not consider passive resistance

The soil properties defined in this model are homogenous:

- Friction angle = 40°, soil-structure interface angle = 40°, unit weight = 17 kN/m^3, permanent cohesion = 0 kPa

The applied loads are:

- Unclassified load, 10 kPa UDL, horizontal distance = 0 m

17.2. Results

The results of this verification example were compared with the literature. They can be viewed by computing the attached model, "*ANB Gabion.rswall*" and viewing the results via the main viewport and/or the report generator.

Table 17.1: Force summations for the A.N. Beal gabion wall example

Output	Literature	RSWall[1]
Sum of active horizontal forces (kN/m)	36.2	36.0
Sum of vertical forces (kN/m)	117.7	117.4

[1] *At the time of writing, RSWall does not have an option to vary the setback between each layer. To best simulate the results of the literature, the total setback is averaged over the courses, resulting in minor deviations.*

Note: The presented example in the literature differs in methodology when computing bearing stresses and capacity.

18. A.N. Beal Mass Concrete Wall

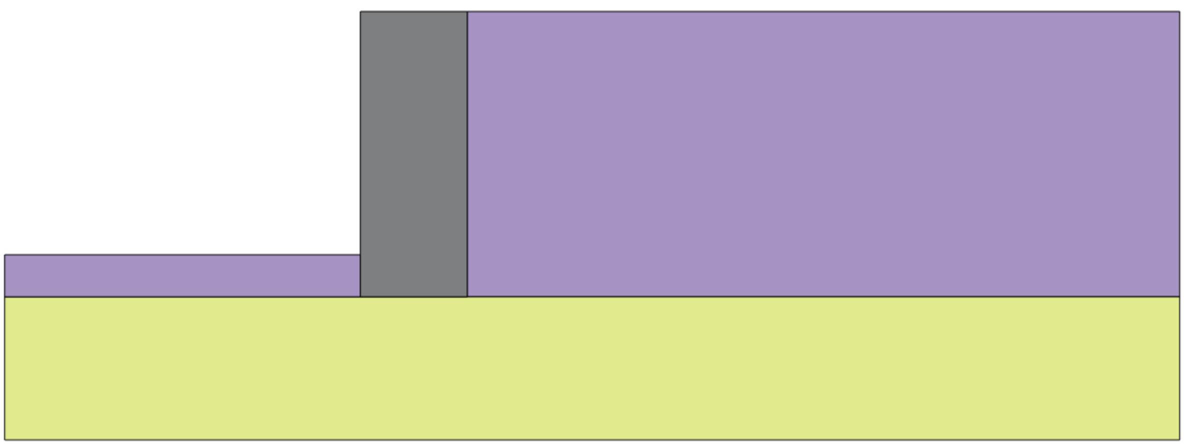
Verification of the mass concrete wall presented in Beal, A.N. (n.d.). Worked examples of retaining wall design to BS8002. Accessed 2024 June 20, <https://anbeal.co.uk/bs8002earthretainingworkedexamples.html>

18.1. Problem Setup – Part 1

In this example mass concrete gravity wall is analyzed for external stability. The inputs are provided as follows.

The example does not explicitly reference AASHTO, and no design factors are considered. To most closely replicate the unfactored results in the literature, evaluate the AASHTO serviceability limit state with all design factors set to 1.

There are three scenarios analyzed in this example: (i) without groundwater nor surcharge, (ii) with surcharge only; (ii) with groundwater and no surcharge.



Methodology:

- Active pressure method = Colomb method

The wall section profile is defined as follows:

- Wall type = Gravity wall
- Unit weight = 23 kN/m^3
- Gravity wall profile:
    - b3 = 1.5 m for dry case
    - h2 = 4 m
    - All other dimensions zero

The topography defined in the model as follows:

- Backslope topography: Infinite; slope angle: 0°.

- Front face topography: Infinite; slope angle: 0°; embedment depth: 0.6 m; no passive resistance

The soil properties defined in this model are:

- Retained & passive soils: friction angle 35°, soil-structure friction angle = 20°, unit weight = 19 kN/m^3
- Foundation soil: friction angle 35°, soil-structure friction angle = 20°, unit weight = 18.5 kN/m^3

Other settings:

- Wall base porewater pressure based on: Averaged
- Base strength = Cast on Sand

18.2. Results - Part 1

The results of this verification example were compared with the literature. They can be viewed by computing the attached model, *"ANB Gravity Dry.rswall"* and viewing the results via the main viewport and/or the report generator.

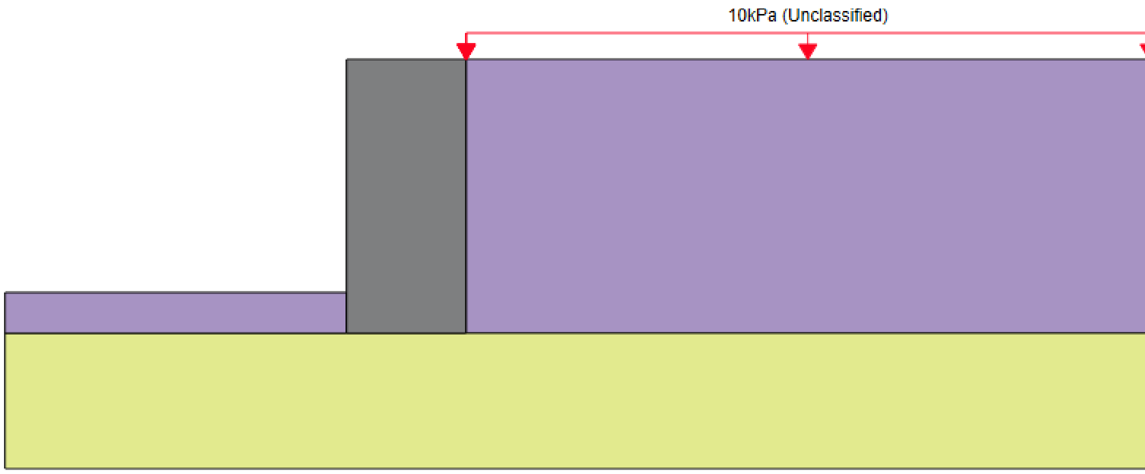
Table 18.1: Result for the A.N. Beal gravity wall example, dry case

Output	Literature	RSWall
Active force, horizontal component (kN/m)	35.0	35.0
Active force, vertical component (kN/m)	12.7	12.7
Eccentricity (m)	0.247	0.246
Sliding resistance (kN/m)	105.5	105.5
Bearing stress (kPa)	150	150

18.3. Problem Setup – Part 2

Apply the following modifications to the model:

- Add an unclassified load, 10 kPa UDL, horizontal distance = 0 m
- Change the b3 dimension to 1.75 m



18.4. Results - Part 2

The results of this verification example were compared with the literature. They can be viewed by computing the attached model, *"ANB Gravity Surcharge.rswall"* and viewing the results via the main viewport and/or the report generator.

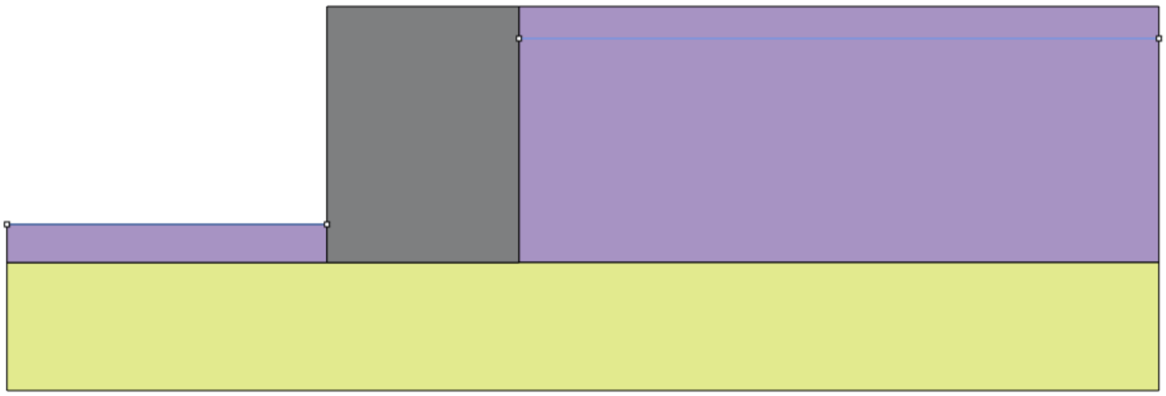
Table 18.2: Result for the A.N. Beal gravity wall example, surcharge case

Output	Literature	RSWall
Active force, surcharge horizontal component (kN/m)	9.2	9.21
Active force, surcharge vertical component (kN/m)	3.3	3.35
Eccentricity (m)	0.288	0.288

18.5. Problem Setup – Part 3

Apply the following modifications to the model:

- Enable passive resistance
- Change the b3 dimension to 3.0 m
- Enable groundwater table:
  - Front face elevation: 0.6 m
  - Elevation behind wall: 3.5 m
- Disable the surcharge
- Retained & passive soils: saturated unit weight = 20.81 kN/m^3
- Foundation soil: saturated unit weight = 20.5 kN/m^3



18.6. Results - Part 3

The results of this verification example were compared with the literature. They can be viewed by computing the attached model, *"ANB Gravity Wet.rswall"* and viewing the results via the main viewport and/or the report generator.

Table 18.3: Result for the A.N. Beal gravity wall example, wet case

Output	Literature	RSWall
Active force, horizontal component (kN/m)	23.7	23.7
Active force, vertical component (kN/m)	8.6	8.6
Hydrostatic water force (kN/m)	60.0	60.1
Base water force (kN/m)	60.4	60.3
Passive force (kN/m)	14.7	14.7

References

1. Beal, A.N. (n.d.). *Worked examples of retaining wall design to BS8002.* Accessed 2024 June 20, <https://anbeal.co.uk/bs8002earthretainingworkedexamples.html>

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