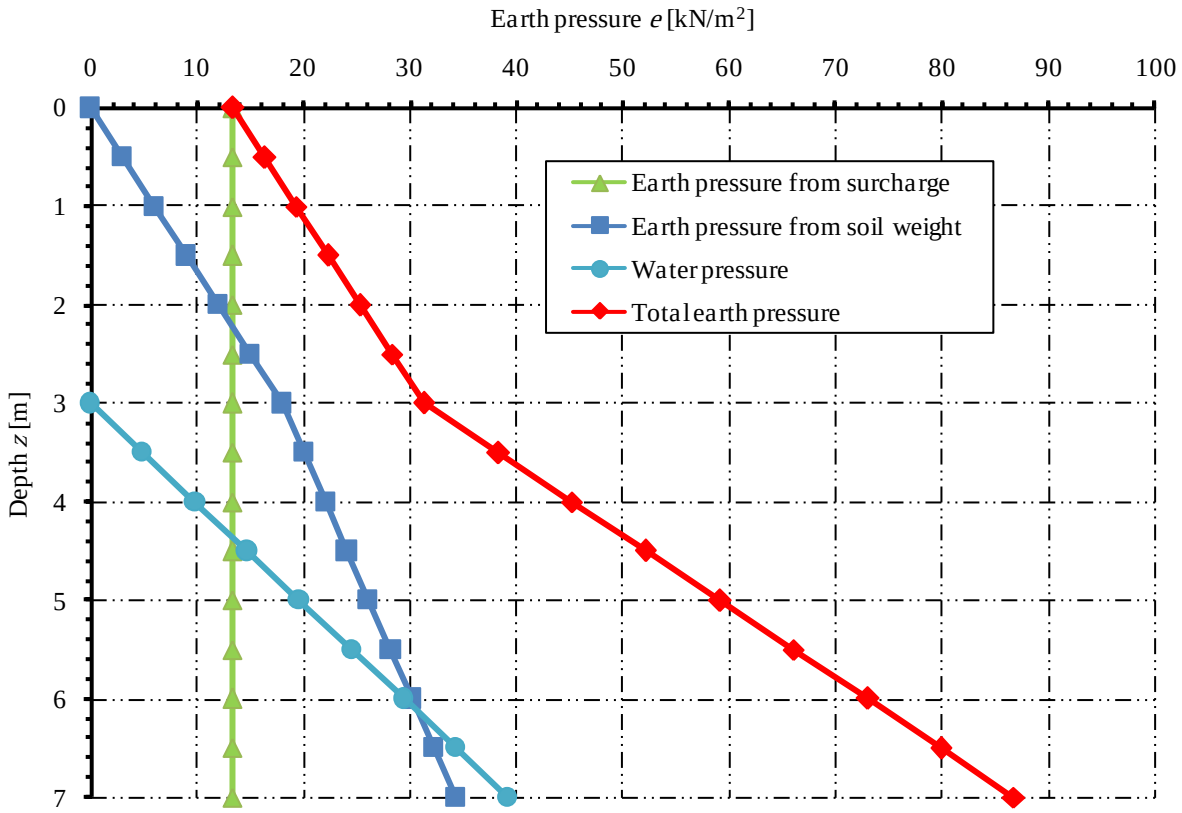
Lateral Earth Pressure
by the Program
GEO Tools



Mahmoud El Gendy

Mohamed El Gendy

GEOTEC Software Inc.

PO Box 14001 Richmond Road PO, Calgary AB, Canada T3E 7Y7

Tele.:+1(587) 332-3323

geotec@geotecsoftware.com

www.geotecsoftware.com

2023

Table of Contents Page

Preface

Various problems in Geotechnical Engineering can be investigated by the program *GEO Tools*. The original version of the program *GEO Tools* in the *GEOTEC Office* package was developed by Prof. M. Kany, Prof. M. El Gendy and Dr. A. El Gendy. After the death of Prof. Kany, Prof. M. El Gendy and Dr. A. El Gendy further developed the program to meet the needs of practice.

This book describes the essential equations used in *GEO Tools* to obtain the lateral earth pressure on the retaining structures with some verification examples. *GEO Tools* is a simple user interface program and needs little information to define a problem.

1 Lateral Earth Pressure

1.1 Lateral Active Earth Pressure

Lateral earth pressure is the pressure that soil exerts in the horizontal direction. Lateral active earth pressure at point *A* in the soil is equal to the effective vertical stress σ'_v multiplied by a coefficient, $\sigma_h = k_a \sigma'_v$. If a water table exists, horizontal hydrostatic water pressure is considered. Lateral water pressure at point *A* in the soil is the weight of the water column above that point $w = \gamma_w z$.

1.2 Defining the project data

1.2.1 Firm Header

When printing the results, the main data (firm name) are displayed on each page at the top in two lines. The firm name can be defined, modified, and saved using the "Firm Header" option from the setting tab (see Figure 1).

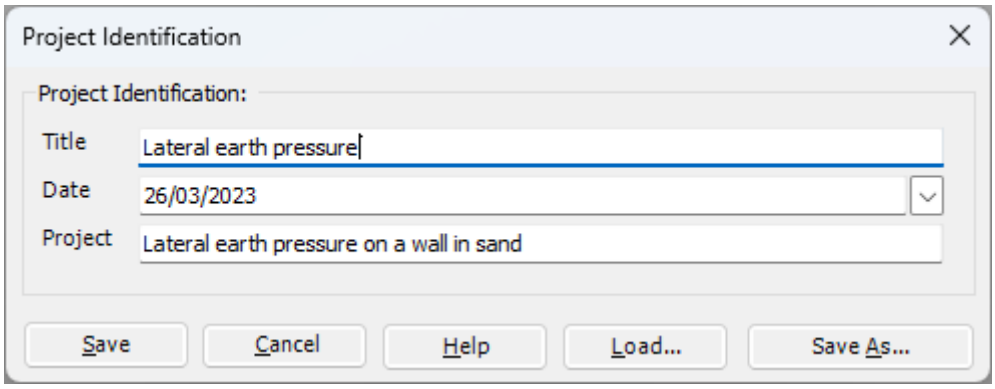


Figure 1 Firm Header

1.2.2 Task of the program *GEO Tools* (Analysis Type)

The *GEO Tools* program can be used to analyze various problems in Geotechnical Engineering for shallow and deep foundations, Figure 2.

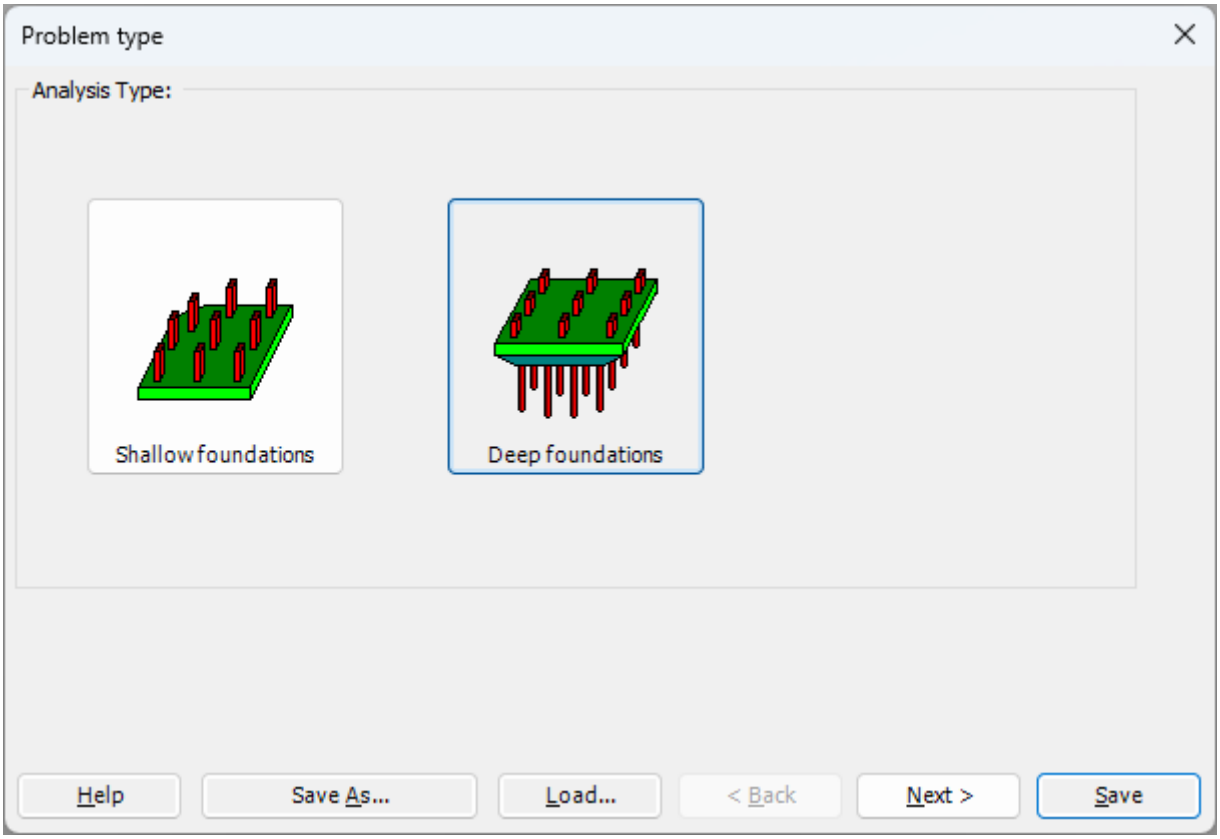


Figure 2 Problem type

According to the main menu (Figure 3), the following geotechnical problems can be analyzed for shallow foundations:

1. Analysis of an axially and laterally loaded single pile (Mindlin's solution)
2. Analysis of laterally loaded single pile by p-y curve
3. Analysis of laterally loaded single pile (elastic embedded pile)
4. Bearing capacity and settlement of single pile or pile wall
5. Analysis of a combined piled raft
6. Stress coefficients according to GEDDES
7. Sheet pile wall
8. Analysis of single barrette
9. Analysis of a barrette raft
10. Lateral earth pressure
11. Effective vertical stress
12. Analysis of a monopole

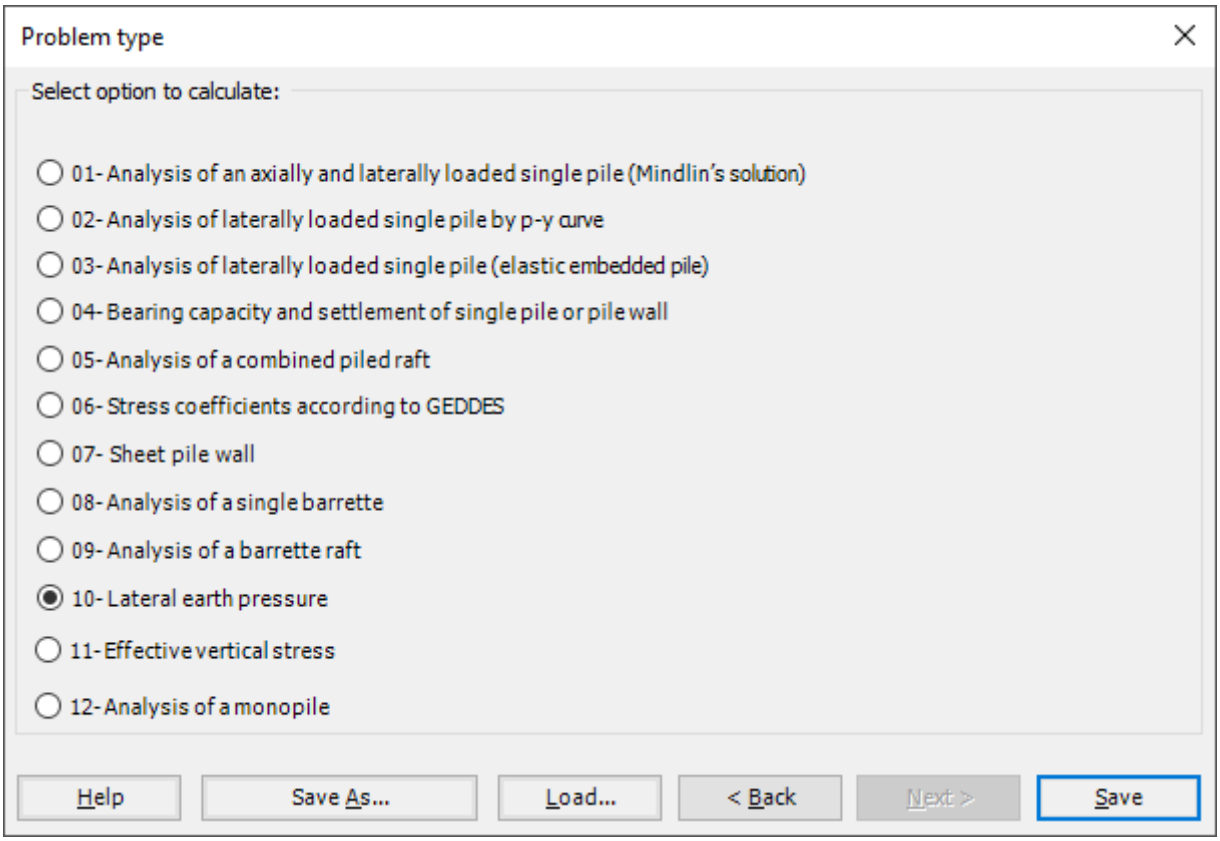


Figure 3 Problem type for shallow foundation

In the menu of Figure 3, select the option:

10-Lateral earth pressure

The following paragraph describes how to determine the lateral earth pressure by using the program *GEO-Tools*. The input data are the geometry of the wall, load intensity, and soil properties.

1.2.3 Project Identification

In the program, it must be distinguished between the following two data groups:

1 System data (For identification of the project that is created and information to the output for the printer).

2 Soil data (Soil properties and so on).

The defining input data for these data groups is carried out as follows:

After clicking on the "Project Identification" option, the following general project data are defined (Figure 4):

Title: Title label

Date: Date

Project: Project label

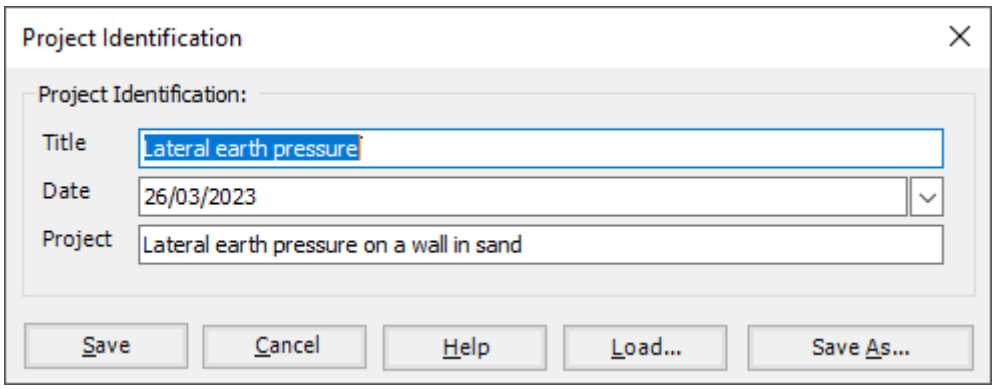


Figure 4 Project Identification

1.2.4 Lateral earth pressure

After clicking on the "Lateral earth pressure" option, the following data for determining the lateral earth pressure are defined (Figure 5):

Load intensity and water:

q Distributed load [kN]

Gw Ground water depth [m]

Element/Width of Working Area:

Dz Depth increment in z-direction [m]

Bw Width of working area [m]

Soil data:

Layer:

c	Cohesion of the soil, [kN/m^2]
φ	Angle of internal friction of the soil, [°]
γ_d	Dry unit weight of the soil, [kN/m^3]
γ_{sat}	Saturated unit weight of the soil, [kN/m^3]
h	Layer thickness [m]

Soil type

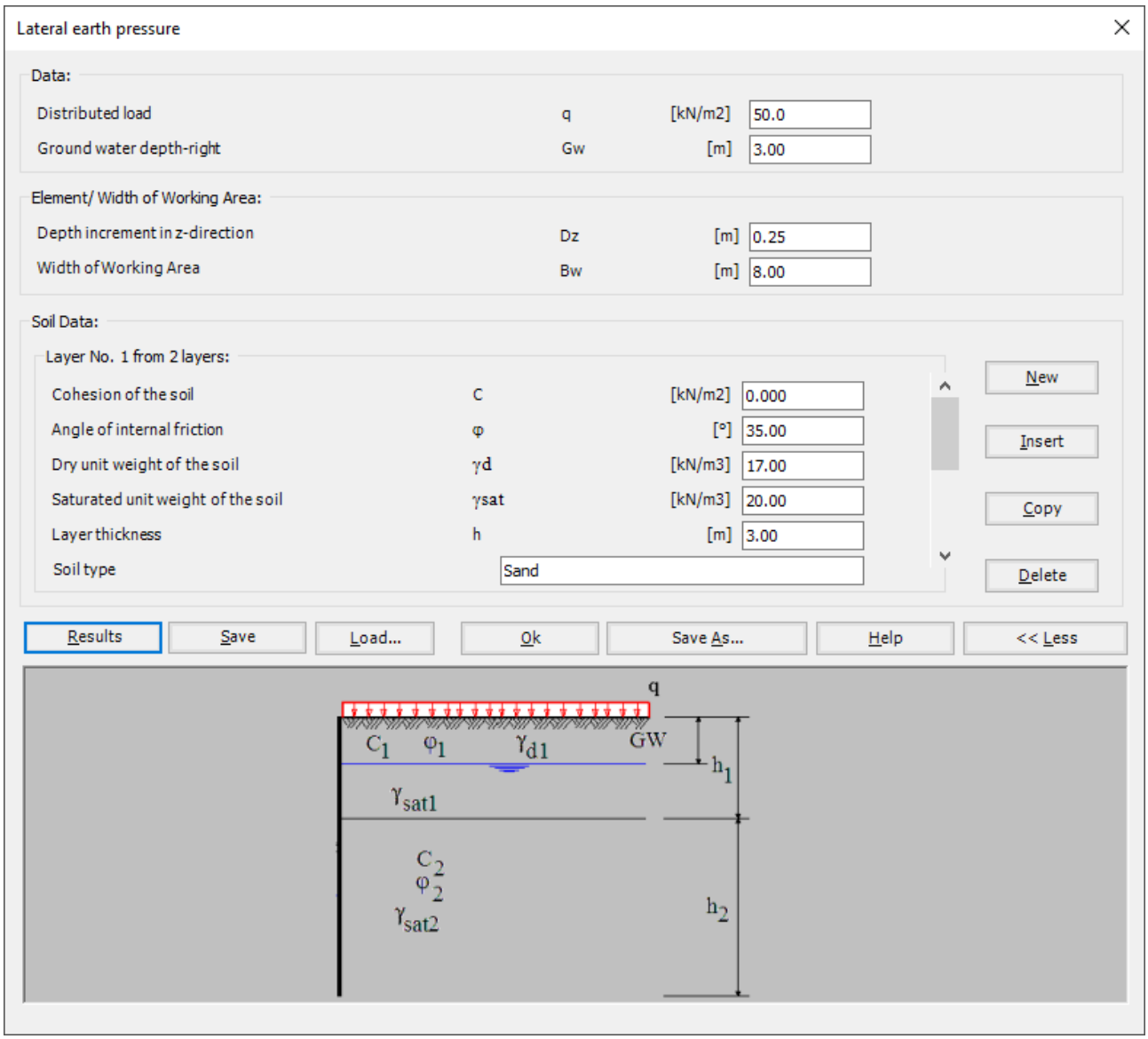


Figure 5 Lateral earth pressure

1.3 Examples to verify Lateral Earth Pressure

1.3.1 Introduction

The application possibilities of the program *GEO Tools* to obtain the lateral earth pressure on the retaining structures are presented below in some numerical examples. Examples were carried out to verify and test the application of the analytical and numerical proposed procedures outlined in this book.

1.3.2 Example 1: Lateral earth pressure on a wall in sand

1.3.2.1 Description of the problem

For the given wall in sand Figure 6, determine per meter the following:

- Lateral earth pressure on the wall
- Lateral water pressure on the wall
- Lateral earth pressure on the wall due to a surface surcharge load
- Total horizontal force on the wall.

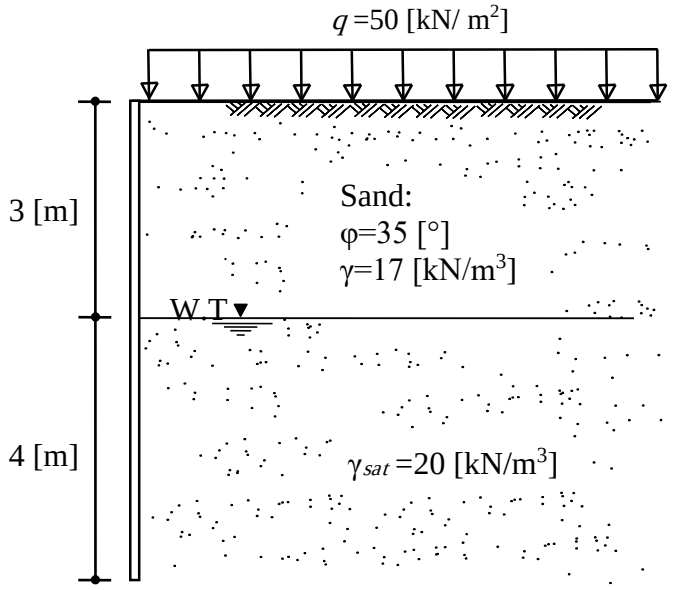


Figure 6 Wall in Sand

1.3.2.2 Lateral Active Earth Pressure

Lateral active earth pressure at point *A* in the soil is equal to the effective vertical stress σ'_v multiplied by a coefficient, $\sigma_h = k_a \sigma'_v$. If a water table exists, horizontal hydrostatic water pressure is considered. Lateral water pressure at point *A* in the soil is the weight of the water column above that point $w=\gamma_w z$.

Coefficient of lateral active earth pressure is given by:

$$k_a = \frac{1-\sin 35}{1+\sin 35} = 0.27$$

The determination of the lateral active earth pressure σ_a is tabulated in 0 and plotted in Figure 7 and Figure 8, while the total lateral earth pressure forces are plotted in Figure 9 and Figure 10.

Table 1 Determination of lateral active earth pressure with depth

Depth z [m]	lateral active earth pressure $\sigma_a = k_a \sigma'_v$ [kN/m^2]	Hydrostatic water pressure $w = \gamma_w z$ [kN/m^2]	Total lateral active earth pressure $E = \sigma_a + w$ [kN/m^2]
3	$\sigma_{a1} = k_a \sigma'_{v1} = 0.27 \times 51 = 13.77$	0	13.77
7	$\sigma_{a2} = k_a \sigma'_{v2} = 0.27 \times 91.76 = 24.78$	$w = \gamma_w h_2 = 9.81 \times 4 = 39.24$	64.02

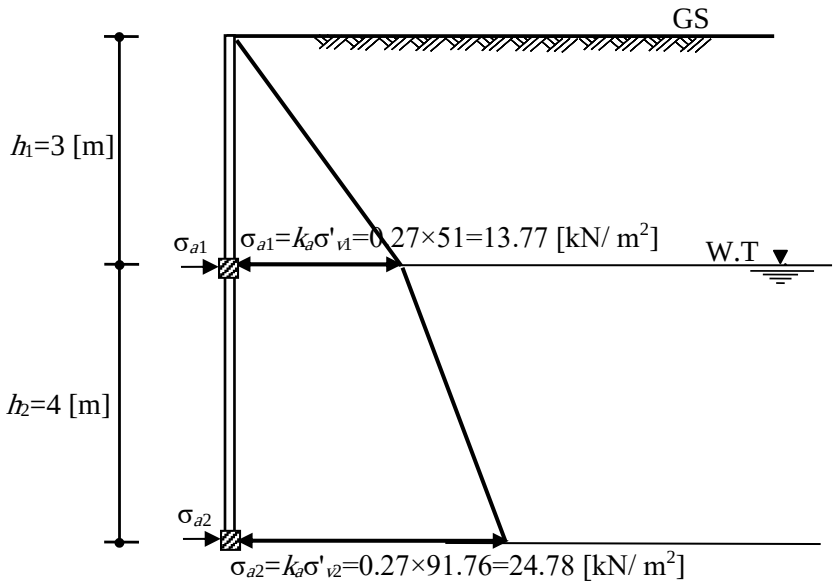


Figure 7 Lateral active earth pressure σ_a

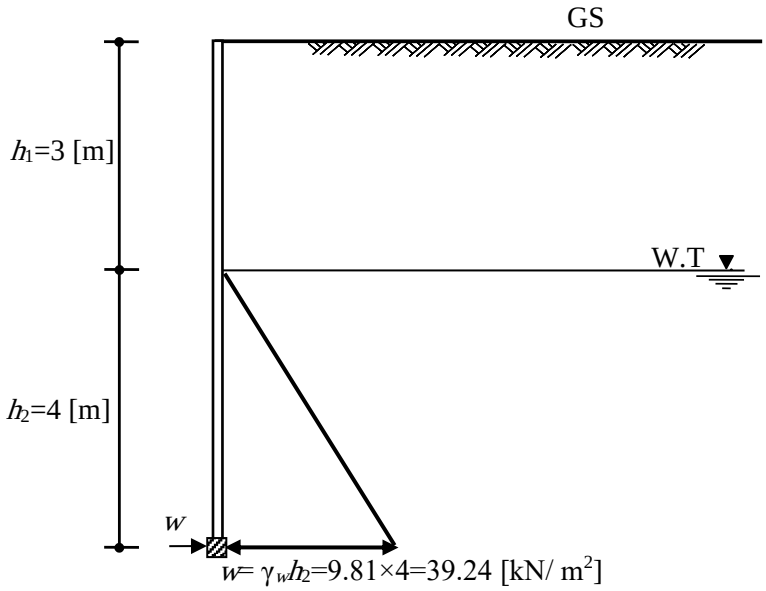


Figure 8 Hydrostatic pressure w

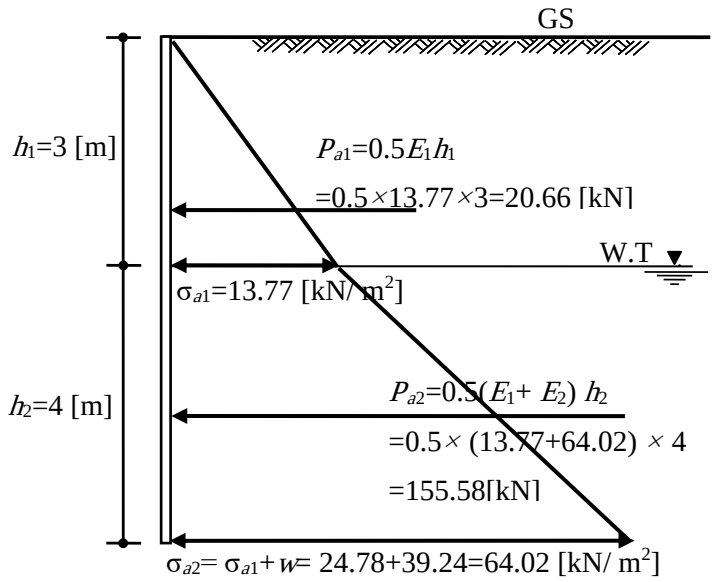


Figure 9 Total lateral earth pressure σ_a and active forces P_a

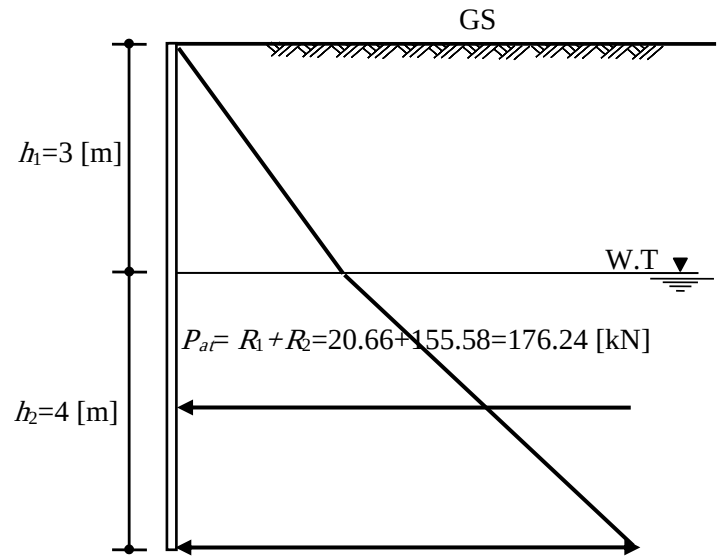


Figure 10 Total horizontal force on the wall P_{at}

1.3.2.3 Lateral earth pressure with a surface surcharge load (fill)

Since the surcharge load (fill) covers an extensive area on the surface, the lateral earth pressure at any point *A* in the soil increases by $k_a\ q$= 0.27×50=13.5 [kN/m^2] due to the weight of the fill, Table 2 and Figure 11.

Table 2 Determination of lateral active earth pressure with depth

Depth z [m]	Layer thickness h [m]	lateral active earth pressure $\sigma_a = k_a\ q + E$ [kN/m^2]
3	3	$\sigma_{a1}= k_a\ q + k_a\ \sigma'_{v1}$ = 0.27×50+13.77=27.27
7	4	$\sigma_{a2}= k_a\ q + k_a\ \sigma'_{v2}$ = 0.27×50+64.02=77.52

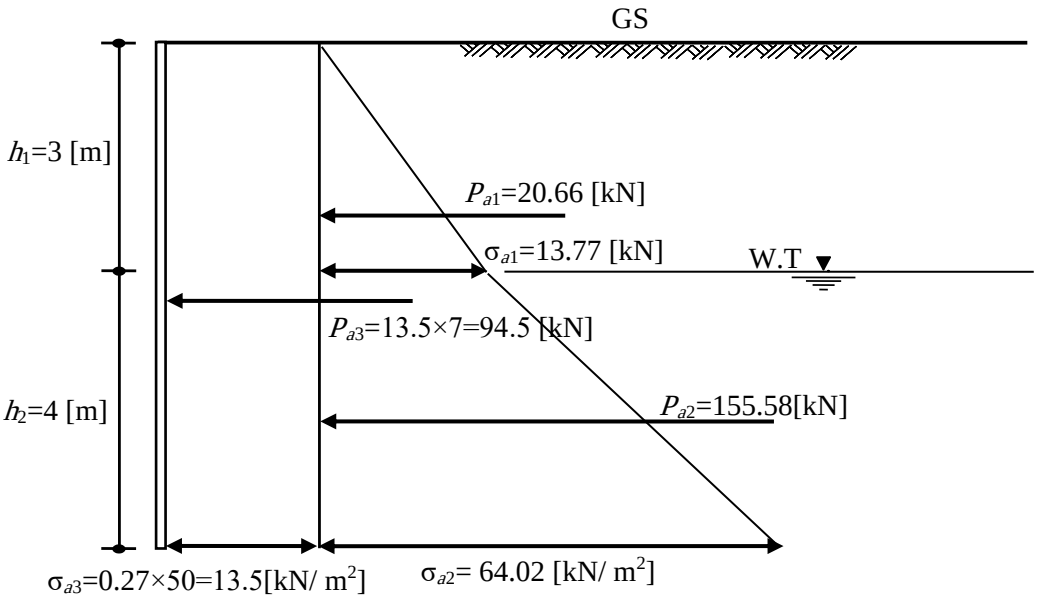


Figure 11 Total lateral earth pressure σ$_a$ and active forces P_a

Figure 12 shows the earth pressures and water presser in a single view

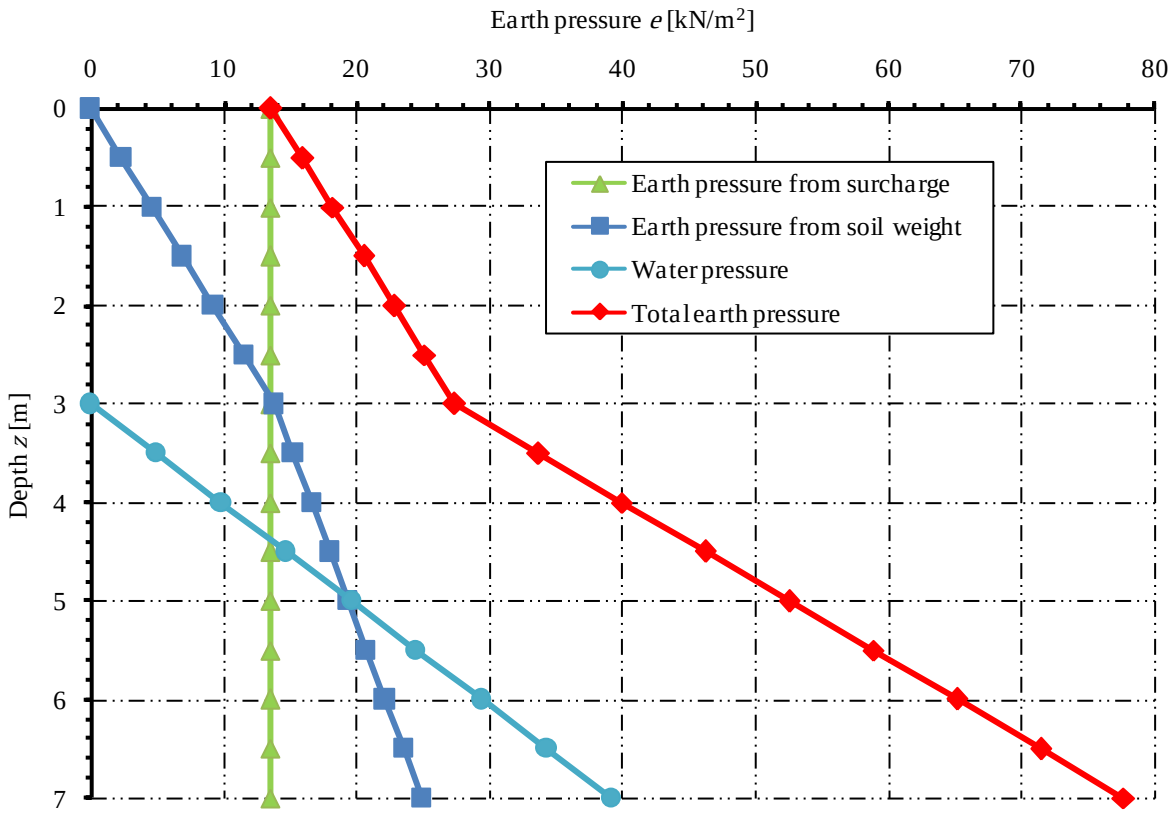


Figure 12 Earth pressure from the soil weight and surcharge and water pressure

1.3.2.1 Lateral earth pressure on a wall in sand by GEO Tools

The lateral earth pressure on a wall in sand obtained by *GEO Tools* is equal to that obtained by hand calculation. Also, the input data and results of GEO Tools for this example are presented on the next pages.

```
************************************************************
                        GEO Tools
                       Version 13
          Program authors M. El Gendy/ A. El Gendy
************************************************************
Title: Lateral earth pressure
Date: 26/03/2023
Project: Lateral earth pressure on a wall in sand
File: Ex1

------------------------------------------------------------
Lateral earth pressure
------------------------------------------------------------

Data:
Distributed load                          q    [kN/m2] = 50.0
Total thickness of soil layers            Ht   [m]     = 7.00

Element size/ Width of Working Area:
Element size                              Dz   [m]     = 0.25
Width of Working Area                     Bw   [m]     = 8.00

Soil Data:
Ground water depth                        Gwl  [m]     = 3.00

Layer No.: 1
Cohesion of the soil                      C    [kN/m2] = 0.000
Angle of internal friction                φ    [°]     = 35.00
Dry unit weight of the soil               γd   [kN/m3] = 17.00
Saturated unit weight of the soil         γsat [kN/m3] = 20.00
Layer thickness                           h    [m]     = 3.00
Soil type                                 BOD  [-]     = Sand

Layer No.: 2
Cohesion of the soil                      C    [kN/m2] = 0.000
Angle of internal friction                φ    [°]     = 35.00
Dry unit weight of the soil               γd   [kN/m3] = 17.00
Saturated unit weight of the soil         γsat [kN/m3] = 20.00
Layer thickness                           h    [m]     = 4.00
Soil type                                 BOD  [-]     = Sand
```

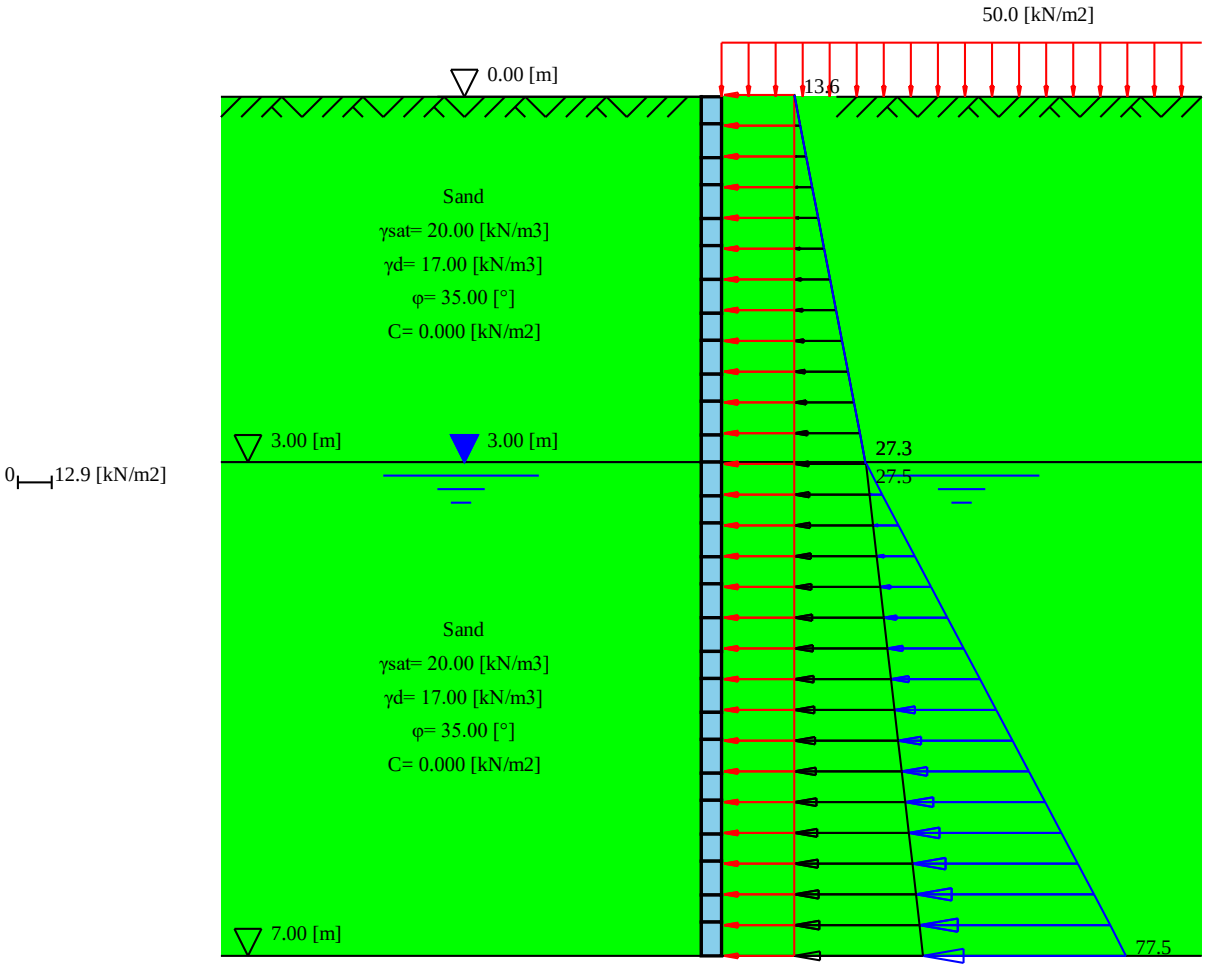
Result:
Resultant R [kN] = 271.8
Location of the resultant from the wall base Y [m] = 2.50

Earth pressures on the sheet pile:

No. I [-]	Depth z1 [m]	Depth z2 [m]	Active earth pressure from surcharge q1 [kN/m2]	Active earth pressure from surcharge q2 [kN/m2]	Active earth pressure from soil weight σz1 [kN/m2]	Active earth pressure from soil weight σz2 [kN/m2]	Water pressure u1 [kN/m2]	Water pressure u2 [kN/m2]	Total lateral earth pressure σ'1 [kN/m2]	Total lateral earth pressure σ'2 [kN/m2]
1	0.00	0.25	13.5	13.5	0.0	1.2	0.0	0.0	13.6	14.7
2	0.25	0.50	13.5	13.5	1.2	2.3	0.0	0.0	14.7	15.9
3	0.50	0.75	13.5	13.5	2.3	3.5	0.0	0.0	15.9	17.0
4	0.75	1.00	13.5	13.5	3.5	4.6	0.0	0.0	17.0	18.2
5	1.00	1.25	13.5	13.5	4.6	5.8	0.0	0.0	18.2	19.3
6	1.25	1.50	13.5	13.5	5.8	6.9	0.0	0.0	19.3	20.5
7	1.50	1.75	13.5	13.5	6.9	8.1	0.0	0.0	20.5	21.6
8	1.75	2.00	13.5	13.5	8.1	9.2	0.0	0.0	21.6	22.8
9	2.00	2.25	13.5	13.5	9.2	10.4	0.0	0.0	22.8	23.9
10	2.25	2.50	13.5	13.5	10.4	11.5	0.0	0.0	23.9	25.1
11	2.50	2.75	13.5	13.5	11.5	12.7	0.0	0.0	25.1	26.2
12	2.75	3.00	13.5	13.5	12.7	13.8	0.0	0.0	26.2	27.3
13	3.00	3.25	13.5	13.5	13.8	14.5	0.1	2.5	27.5	30.5
14	3.25	3.50	13.5	13.5	14.5	15.2	2.5	4.9	30.5	33.7
15	3.50	3.75	13.5	13.5	15.2	15.9	4.9	7.4	33.7	36.8
16	3.75	4.00	13.5	13.5	15.9	16.6	7.4	9.8	36.8	39.9
17	4.00	4.25	13.5	13.5	16.6	17.3	9.8	12.3	39.9	43.1
18	4.25	4.50	13.5	13.5	17.3	18.0	12.3	14.7	43.1	46.2
19	4.50	4.75	13.5	13.5	18.0	18.7	14.7	17.2	46.2	49.4
20	4.75	5.00	13.5	13.5	18.7	19.3	17.2	19.6	49.4	52.5
21	5.00	5.25	13.5	13.5	19.3	20.0	19.6	22.1	52.5	55.7
22	5.25	5.50	13.5	13.5	20.0	20.7	22.1	24.5	55.7	58.8
23	5.50	5.75	13.5	13.5	20.7	21.4	24.5	27.0	58.8	61.9
24	5.75	6.00	13.5	13.5	21.4	22.1	27.0	29.4	61.9	65.1
25	6.00	6.25	13.5	13.5	22.1	22.8	29.4	31.9	65.1	68.2
26	6.25	6.50	13.5	13.5	22.8	23.5	31.9	34.3	68.2	71.4
27	6.50	6.75	13.5	13.5	23.5	24.2	34.3	36.8	71.4	74.5
28	6.75	7.00	13.5	13.5	24.2	24.8	36.8	39.1	74.5	77.5

Lateral earth pressure

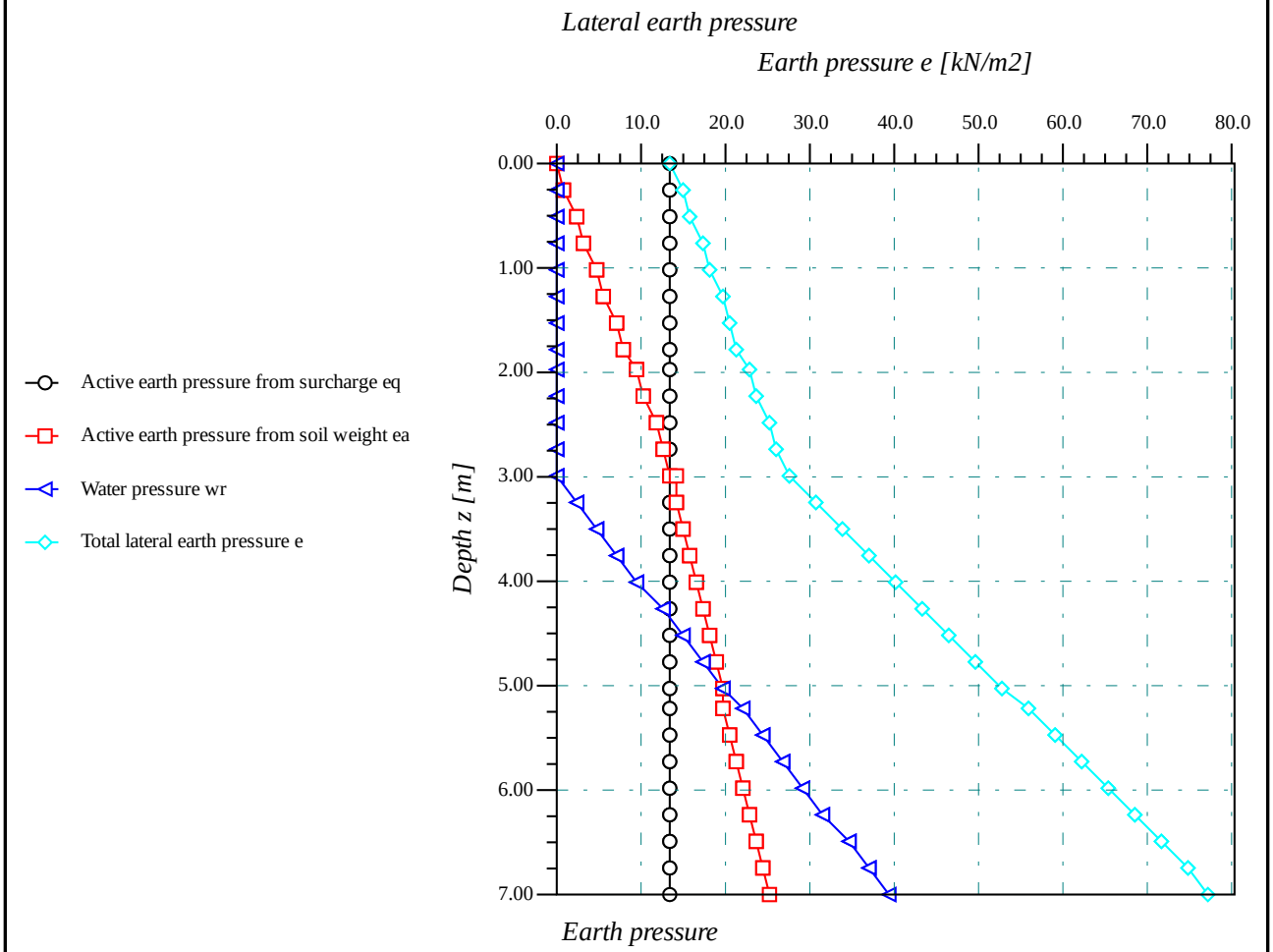
Earth pressure



Earth pressure e [kN/m2]

Max. e = 77.5 at z = 7.00 [m], Min. e = 13.6 at z = 0.00 [m]

GEOTEC Software Inc PO Box 14001 Richmond Road PO, Calgary AB, Canada T3E 7Y7	
Scale: 55	**Title: Lateral earth pressure**
File: Ex1	**Date: 26/03/2023**
Page No.:	**Project: Lateral earth pressure on a wall in sand**



GEOTEC Software Inc **PO Box 14001 Richmond Road PO, Calgary AB, Canada T3E 7Y7**	
Scale: 788	**Title: Lateral earth pressure**
File: Ex1	**Date: 26/03/2023**
Page No.:	**Project: Lateral earth pressure on a wall in sand**

1.3.3 Example 2: Lateral earth pressure for layered soil (with cohesion)

1.3.3.1 Description of the problem

For the given soil profile of three layers in Figure 13, determine the lateral earth pressure on the wall.

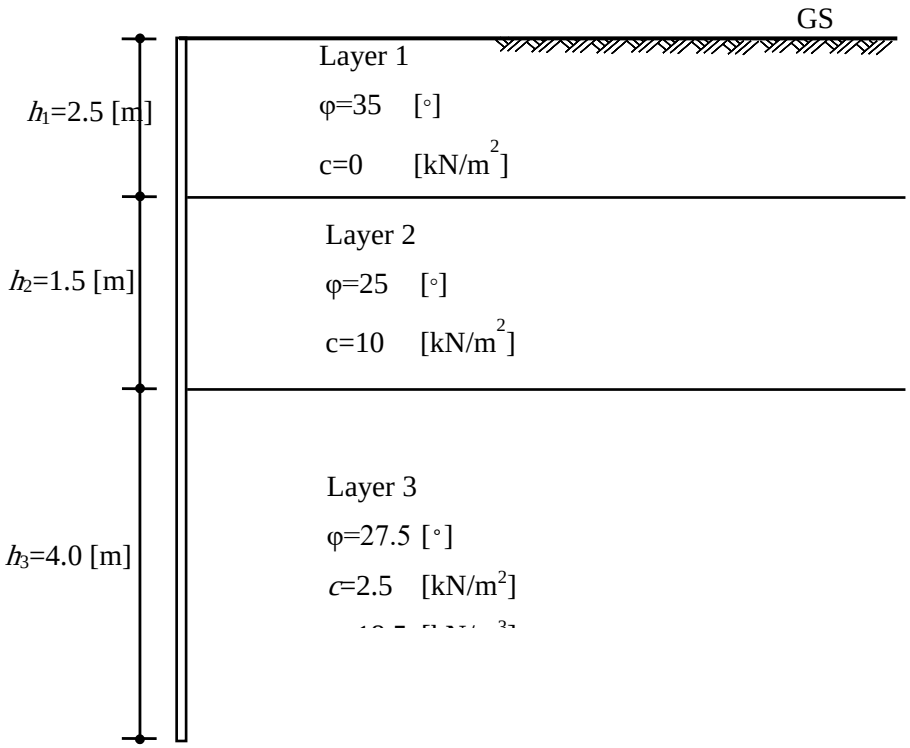


Figure 13 Soil profile

1.3.3.2 Lateral earth pressure on a wall in sand by GEO Tools

The lateral earth pressure on a wall for the three layers obtained by *GEO Tools* for this example are presented on the next pages.

```
************************************************************
                        GEO Tools
                       Version 13
          Program authors M. El Gendy/ A. El Gendy
************************************************************
Title: Lateral earth pressure
Date: 26/03/2023
Project: Lateral earth pressure for layered soil (with cohesion)
File: Ex2

------------------------------------------------------------
Lateral earth pressure
------------------------------------------------------------

Data:
Distributed load                          q    [kN/m2] = 0.0
Total thickness of soil layers            Ht   [m]     = 8.00

Element size/ Width of Working Area:
Element size                              Dz   [m]     = 0.25
Width of Working Area                     Bw   [m]     = 8.00

Soil Data:
Ground water depth                        Gwl  [m]     = 8.00

Layer No.: 1
Cohesion of the soil                      C    [kN/m2] = 0.000
Angle of internal friction                φ    [°]     = 35.00
Dry unit weight of the soil               γd   [kN/m3] = 19.00
Saturated unit weight of the soil         γsat [kN/m3] = 18.81
Layer thickness                           h    [m]     = 2.50
Soil type                                 BOD  [-]     = Sand

Layer No.: 2
Cohesion of the soil                      C    [kN/m2] = 10.000
Angle of internal friction                φ    [°]     = 25.00
Dry unit weight of the soil               γd   [kN/m3] = 17.00
Saturated unit weight of the soil         γsat [kN/m3] = 16.61
Layer thickness                           h    [m]     = 1.50
Soil type                                 BOD  [-]     = Sand

Layer No.: 3
Cohesion of the soil                      C    [kN/m2] = 2.500
Angle of internal friction                φ    [°]     = 27.50
Dry unit weight of the soil               γd   [kN/m3] = 18.50
Saturated unit weight of the soil         γsat [kN/m3] = 18.31
Layer thickness                           h    [m]     = 4.00
Soil type                                 BOD  [-]     = Sand
```

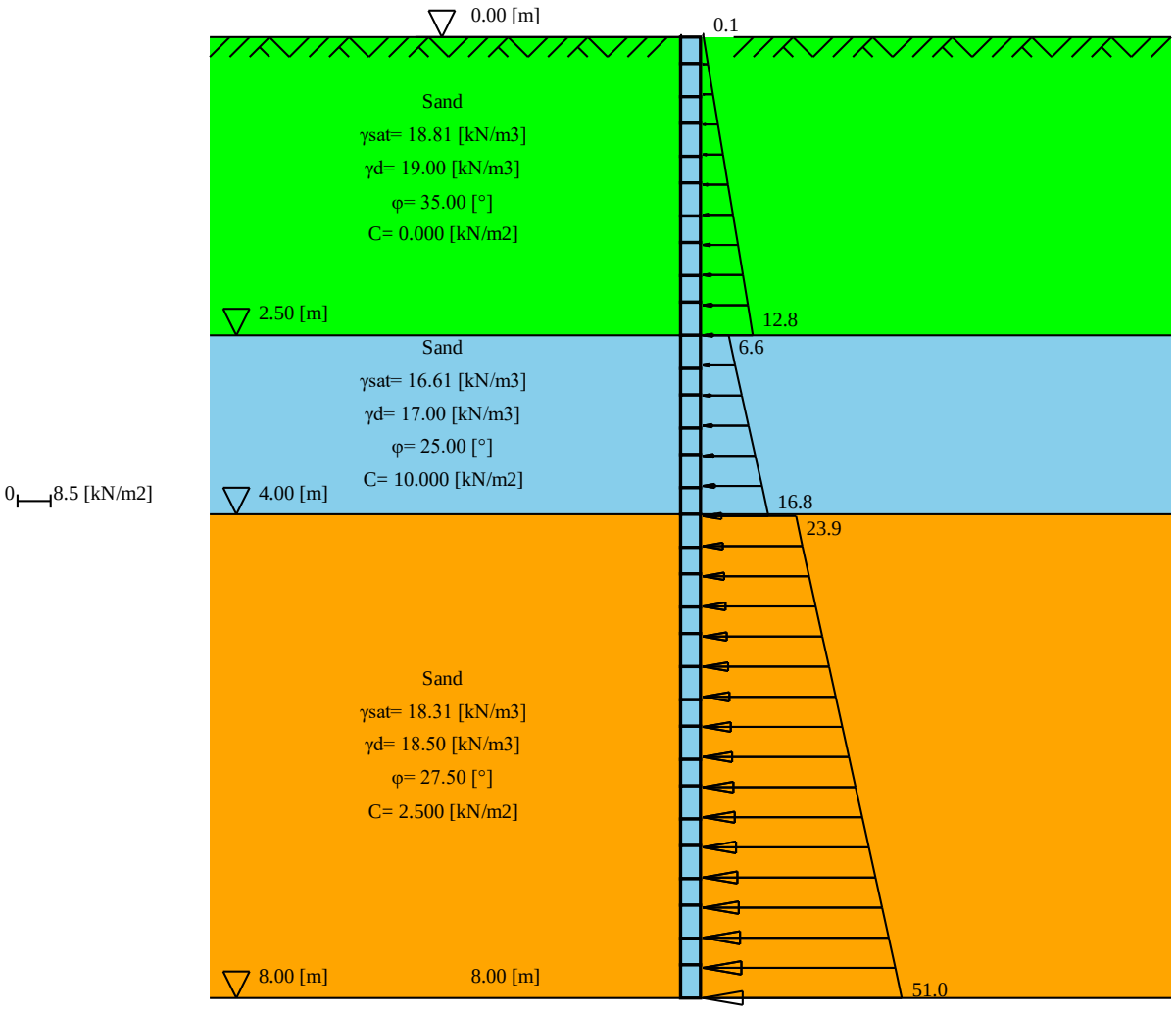
Result:
Resultant R [kN] = 183.8
Location of the resultant from the wall base Y [m] = 2.43

Earth pressures on the sheet pile:

No. I	Depth z1 [m]	Depth z2 [m]	Active earth pressure from soil weight σz1 [kN/m2]	Active earth pressure from soil weight σz2 [kN/m2]	Total lateral earth pressure σ'1 [kN/m2]	Total lateral earth pressure σ'2 [kN/m2]
1	0.00	0.25	0.1	1.3	0.1	1.3
2	0.25	0.50	1.3	2.6	1.3	2.6
3	0.50	0.75	2.6	3.9	2.6	3.9
4	0.75	1.00	3.9	5.1	3.9	5.1
5	1.00	1.25	5.1	6.4	5.1	6.4
6	1.25	1.50	6.4	7.7	6.4	7.7
7	1.50	1.75	7.7	9.0	7.7	9.0
8	1.75	2.00	9.0	10.3	9.0	10.3
9	2.00	2.25	10.3	11.6	10.3	11.6
10	2.25	2.50	11.6	12.8	11.6	12.8
11	2.50	2.75	6.6	8.3	6.6	8.3
12	2.75	3.00	8.3	10.0	8.3	10.0
13	3.00	3.25	10.0	11.7	10.0	11.7
14	3.25	3.50	11.7	13.4	11.7	13.4
15	3.50	3.75	13.4	15.2	13.4	15.2
16	3.75	4.00	15.2	16.8	15.2	16.8
17	4.00	4.25	23.9	25.5	23.9	25.5
18	4.25	4.50	25.5	27.3	25.5	27.3
19	4.50	4.75	27.3	29.0	27.3	29.0
20	4.75	5.00	29.0	30.7	29.0	30.7
21	5.00	5.25	30.7	32.4	30.7	32.4
22	5.25	5.50	32.4	34.1	32.4	34.1
23	5.50	5.75	34.1	35.8	34.1	35.8
24	5.75	6.00	35.8	37.5	35.8	37.5
25	6.00	6.25	37.5	39.2	37.5	39.2
26	6.25	6.50	39.2	40.9	39.2	40.9
27	6.50	6.75	40.9	42.6	40.9	42.6
28	6.75	7.00	42.6	44.3	42.6	44.3
29	7.00	7.25	44.3	46.0	44.3	46.0
30	7.25	7.50	46.0	47.7	46.0	47.7
31	7.50	7.75	47.7	49.4	47.7	49.4
32	7.75	8.00	49.4	51.0	49.4	51.0

Lateral earth pressure

Earth pressure



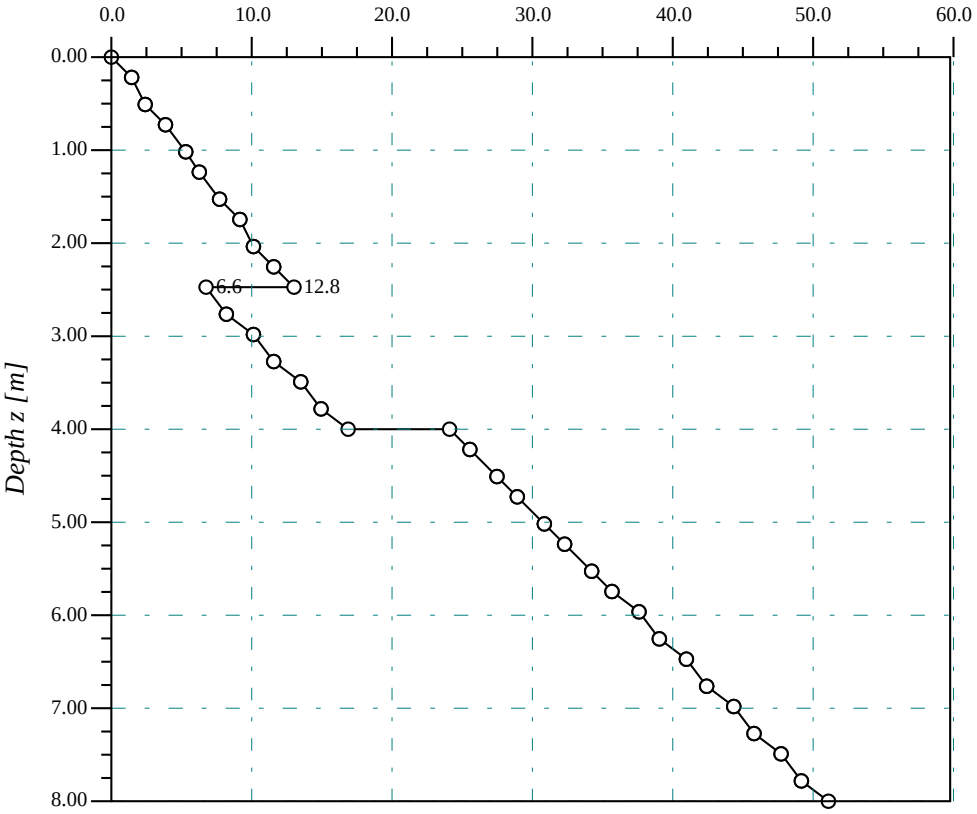
Earth pressure e [kN/m2]

Max. e = 51.0 at z = 8.00 [m], Min. e = 0.1 at z = 0.00 [m]

GEOTEC Software Inc PO Box 14001 Richmond Road PO, Calgary AB, Canada T3E 7Y7	
Scale: 55	**Title: Lateral earth pressure**
File: Ex2	**Date: 26/03/2023**
Page No.:	**Project: Lateral earth pressure for layered soil (with cohesion)**

Lateral earth pressure

Active earth pressure from soil weight ea [kN/m2]



Active earth pressure from soil weight

Max. ea = 51.0 [kN/m2] at z = 8.00 [m], Min. ea = 0.1 [kN/m2] at z = 0.00 [m]

GEOTEC Software Inc PO Box 14001 Richmond Road PO, Calgary AB, Canada T3E 7Y7	
Scale: 482	**Title: Lateral earth pressure**
File: Ex2	**Date: 26/03/2023**
Page No.:	**Project: Lateral earth pressure for layered soil (with cohesion)**

1.3.4 Example 3: Lateral earth pressure for layered soil (without cohesion)

1.3.4.1 Description of the problem

For the given soil profile of three layers in Figure 13, determine the lateral earth pressure on the wall.

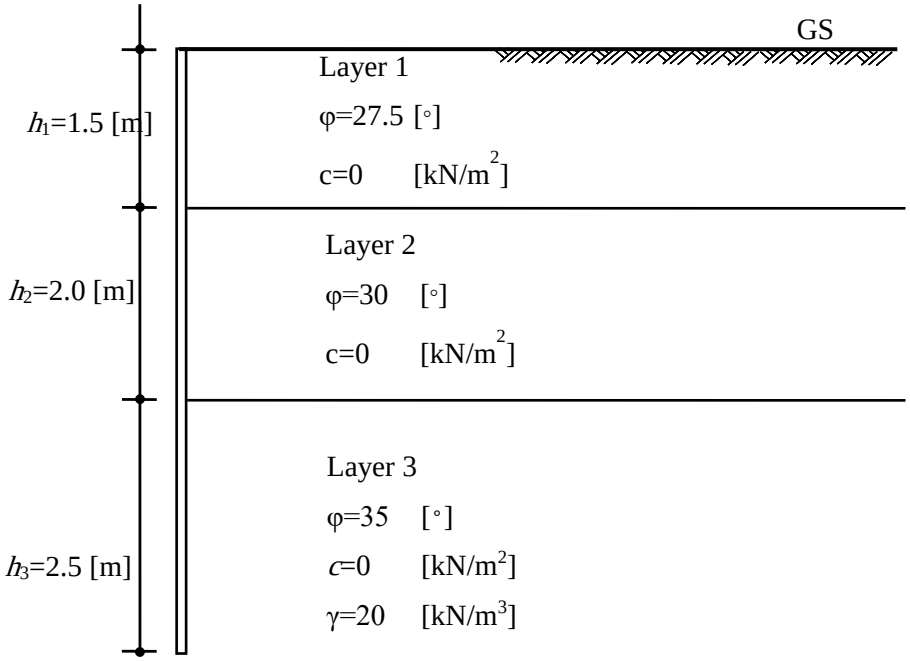


Figure 14 Soil profile

1.3.4.2 Lateral earth pressure on a wall in sand by GEO Tools

The lateral earth pressure on a wall for the three layers obtained by *GEO Tools* for this example are presented on the next pages.

```
************************************************************
                        GEO Tools
                       Version 13
          Program authors M. El Gendy/ A. El Gendy
************************************************************
Title: Lateral earth pressure
Date: 26/03/2023
Project: Lateral earth pressure for layered soil (without cohesion)
File: Ex3

------------------------------------------------------------
Lateral earth pressure
------------------------------------------------------------

Data:
Distributed load                          q    [kN/m2] = 0.0
Total thickness of soil layers            Ht   [m]     = 6.00

Element size/ Width of Working Area:
Element size                              Dz   [m]     = 0.25
Width of Working Area                     Bw   [m]     = 8.00

Soil Data:
Ground water depth                        Gwl  [m]     = 6.00

Layer No.: 1
Cohesion of the soil                      C    [kN/m2] = 0.000
Angle of internal friction                φ    [°]     = 27.50
Dry unit weight of the soil               γd   [kN/m3] = 18.00
Saturated unit weight of the soil         γsat [kN/m3] = 17.81
Layer thickness                           h    [m]     = 1.50
Soil type                                 BOD  [-]     = Sand

Layer No.: 2
Cohesion of the soil                      C    [kN/m2] = 0.000
Angle of internal friction                φ    [°]     = 30.00
Dry unit weight of the soil               γd   [kN/m3] = 19.00
Saturated unit weight of the soil         γsat [kN/m3] = 18.81
Layer thickness                           h    [m]     = 2.00
Soil type                                 BOD  [-]     = Sand

Layer No.: 3
Cohesion of the soil                      C    [kN/m2] = 0.000
Angle of internal friction                φ    [°]     = 35.00
Dry unit weight of the soil               γd   [kN/m3] = 20.00
Saturated unit weight of the soil         γsat [kN/m3] = 19.81
Layer thickness                           h    [m]     = 2.50
Soil type                                 BOD  [-]     = Sand
```

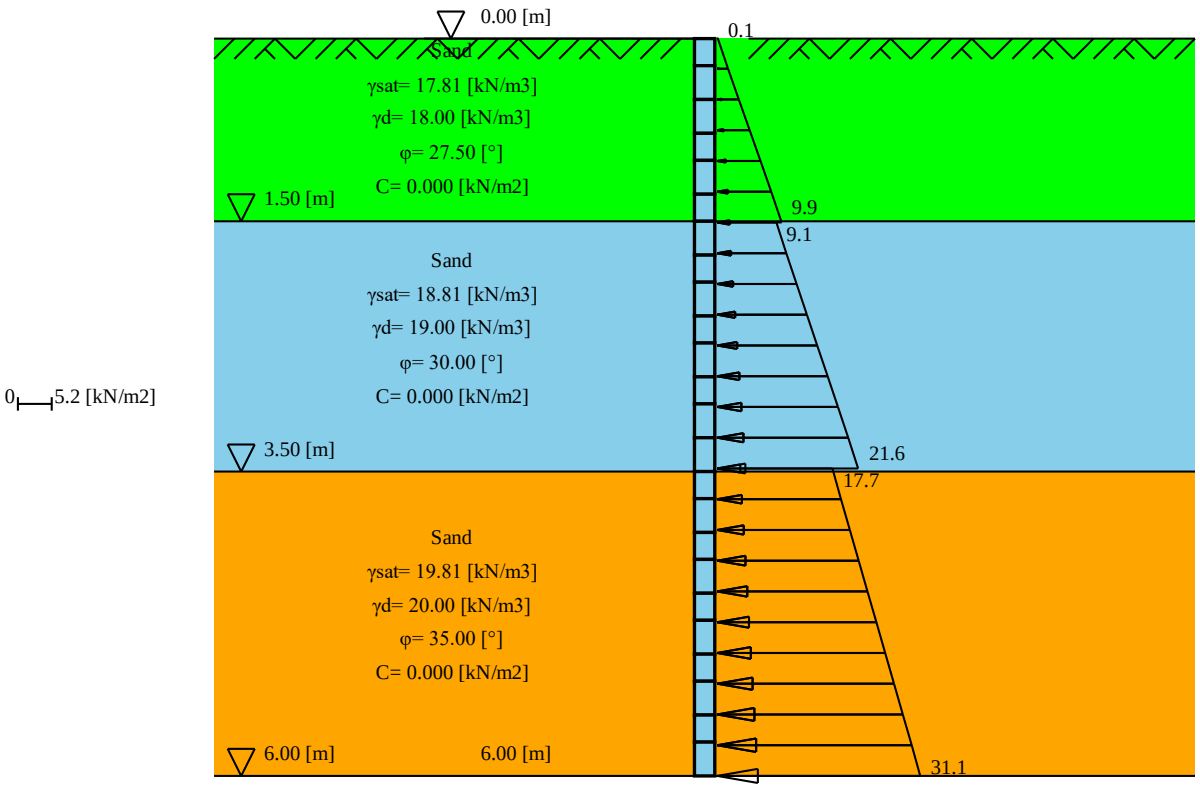
Result:
Resultant R [kN] = 99.3
Location of the resultant from the wall base Y [m] = 2.11

Earth pressures on the sheet pile:

No. I	Depth z1 [m]	Depth z2 [m]	Active earth pressure from soil weight σz1 [kN/m2]	Active earth pressure from soil weight σz2 [kN/m2]	Total lateral earth pressure σ'1 [kN/m2]	Total lateral earth pressure σ'2 [kN/m2]
1	0.00	0.25	0.1	1.7	0.1	1.7
2	0.25	0.50	1.7	3.3	1.7	3.3
3	0.50	0.75	3.3	5.0	3.3	5.0
4	0.75	1.00	5.0	6.6	5.0	6.6
5	1.00	1.25	6.6	8.3	6.6	8.3
6	1.25	1.50	8.3	9.9	8.3	9.9
7	1.50	1.75	9.1	10.6	9.1	10.6
8	1.75	2.00	10.6	12.2	10.6	12.2
9	2.00	2.25	12.2	13.7	12.2	13.7
10	2.25	2.50	13.7	15.3	13.7	15.3
11	2.50	2.75	15.3	16.9	15.3	16.9
12	2.75	3.00	16.9	18.5	16.9	18.5
13	3.00	3.25	18.5	20.1	18.5	20.1
14	3.25	3.50	20.1	21.6	20.1	21.6
15	3.50	3.75	17.7	19.0	17.7	19.0
16	3.75	4.00	19.0	20.3	19.0	20.3
17	4.00	4.25	20.3	21.7	20.3	21.7
18	4.25	4.50	21.7	23.0	21.7	23.0
19	4.50	4.75	23.0	24.4	23.0	24.4
20	4.75	5.00	24.4	25.7	24.4	25.7
21	5.00	5.25	25.7	27.1	25.7	27.1
22	5.25	5.50	27.1	28.5	27.1	28.5
23	5.50	5.75	28.5	29.8	28.5	29.8
24	5.75	6.00	29.8	31.1	29.8	31.1

Lateral earth pressure

Earth pressure



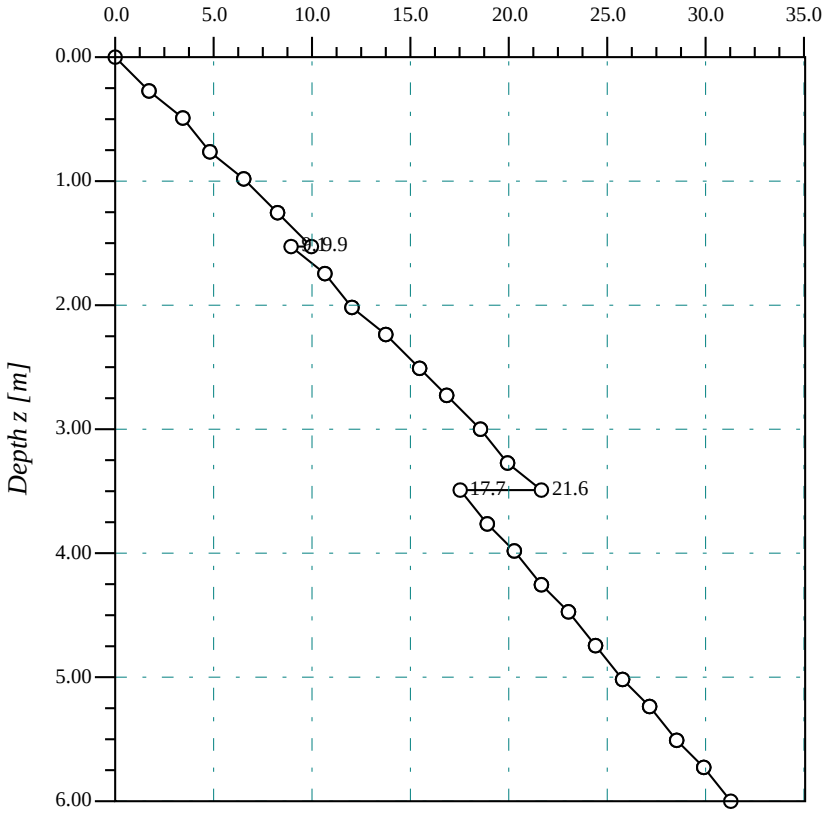
Earth pressure e [kN/m2]

Max. e = 31.1 at z = 6.00 [m], Min. e = 0.1 at z = 0.00 [m]

GEOTEC Software Inc **PO Box 14001 Richmond Road PO, Calgary AB, Canada T3E 7Y7**	
Scale: 55	**Title: Lateral earth pressure**
File: Ex3	**Date: 26/03/2023**
Page No.:	**Project: Lateral earth pressure for layered soil (without cohesion)**

Lateral earth pressure

Active earth pressure from soil weight ea [kN/m2]



Active earth pressure from soil weight

Max. ea = 31.1 [kN/m2] at z = 6.00 [m], Min. ea = 0.1 [kN/m2] at z = 0.00 [m]

GEOTEC Software Inc **PO Box 14001 Richmond Road PO, Calgary AB, Canada T3E 7Y7**	
Scale: 344	**Title: Lateral earth pressure**
File: Ex3	**Date: 26/03/2023**
Page No.:	**Project: Lateral earth pressure for layered soil (without cohesion)**

1.3.5 Example 4: Lateral earth pressure on a wall in sand

1.3.5.1 Description of the problem

For the given soil profile of sand in Figure 15, determine per meter length the following:

- Lateral earth pressure on the wall
- Lateral water pressure on the wall
- Lateral water pressure on the wall due to a surface surcharge load
- Total horizontal force on the wall.

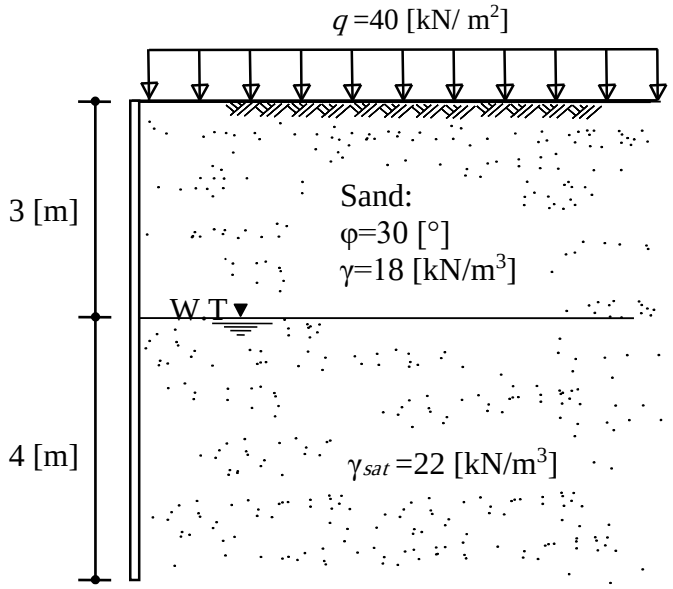


Figure 15 Wall in Sand

1.3.5.2 Lateral Active Earth Pressure

Lateral active earth pressure at point *A* in the soil is equal to the effective vertical stress σ'_v multiplied by a coefficient, $\sigma_h = k_a \sigma'_v$. If a water table exists, horizontal hydrostatic water pressure is considered. Lateral water pressure at point *A* in the soil is the weight of the water column above that point $w=\gamma_w z$.

Coefficient of lateral active earth pressure is given by:

$$k_a = \frac{1-\sin 30}{1+\sin 30} = 0.333$$

The determination of the lateral active earth pressure σ_a is tabulated in 0 and plotted in Figure 7 and Figure 8, while the total lateral earth pressure forces are plotted in Figure 9 and Figure 10.

Table 3 Determination of lateral active earth pressure with depth

Depth z [m]	lateral active earth pressure $\sigma_a = k_a \sigma'_v$ [kN/m^2]	Hydrostatic water pressure $w= \gamma_w z$ [kN/m^2]	Total lateral active earth pressure $E= \sigma_a + w$ [kN/m^2]
3	$\sigma_{a1}= k_a \sigma'_{v1}$ =0.333×54=18	0	18
7	$\sigma_{a2}= k_a \sigma'_{v2}$ =18+0.333×4× (22-9.81) =34.25	$w= \gamma_w h_2$ =9.81×4=39.24	73.49

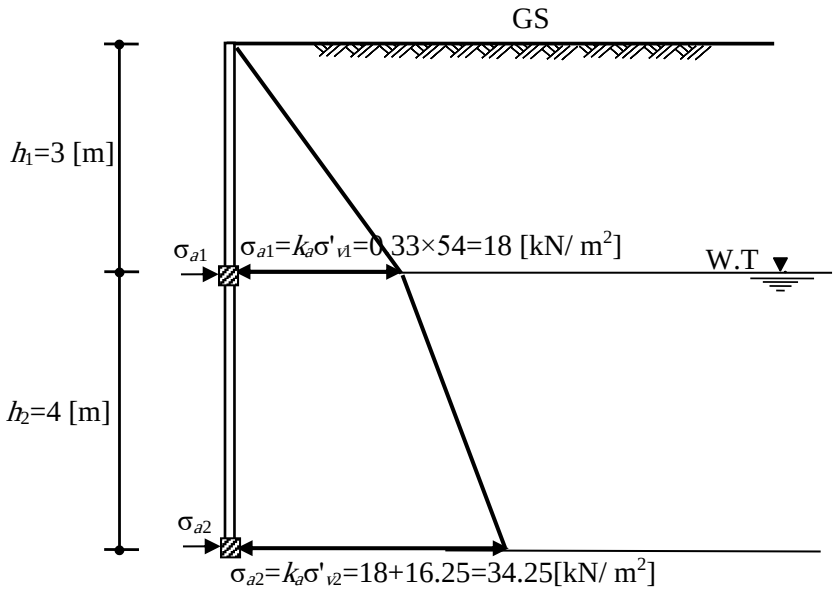


Figure 16 Lateral active earth pressure σ_a

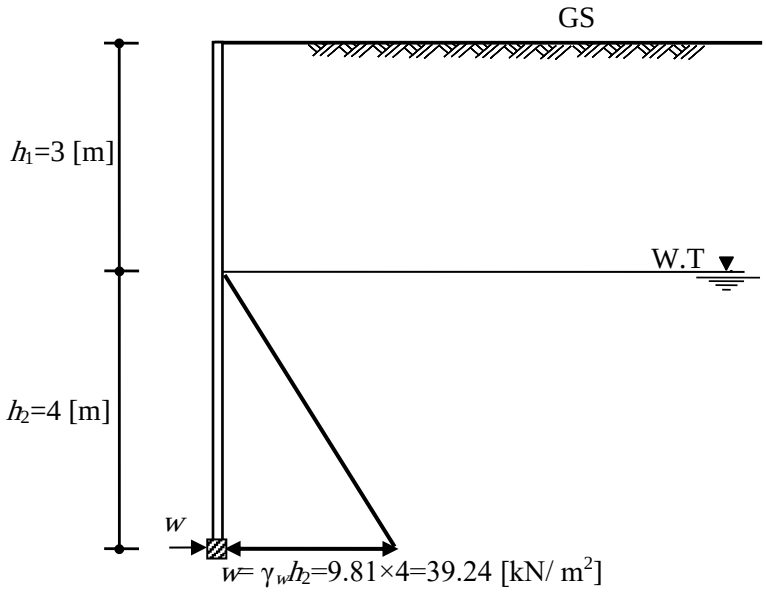


Figure 17 Hydrostatic pressure w

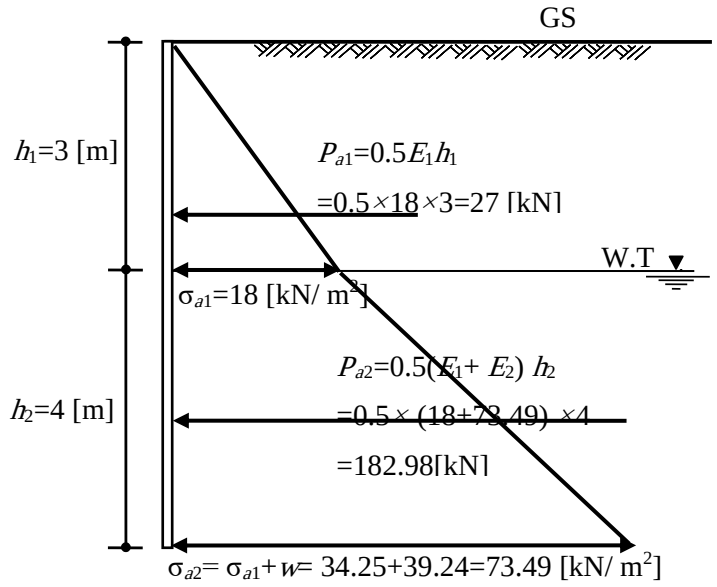


Figure 18 Total lateral earth pressure σ_a and active forces P_a

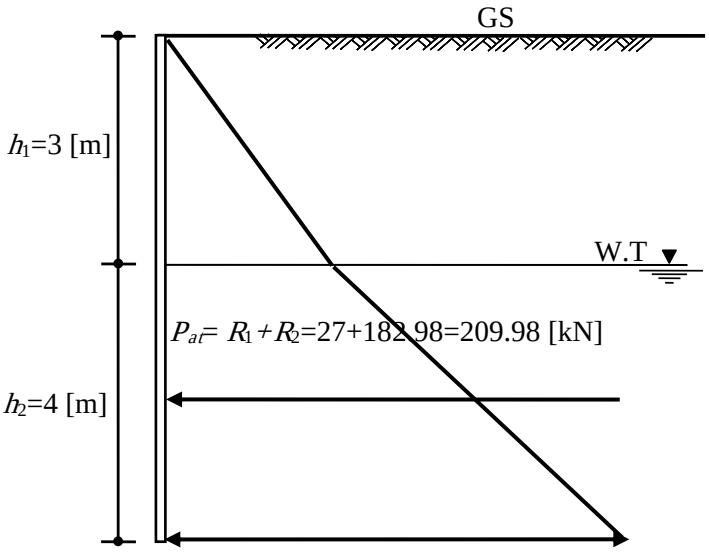


Figure 19 Total horizontal force on the wall P_{at}

1.3.5.3 Lateral earth pressure with a surface surcharge load (fill)

Since the surcharge load (fill) covers an extensive area on the surface, the lateral earth pressure at any point *A* in the soil increases by $k_a\ q$= 0.333×40=13.33 [kN/m^2] due to the weight of the fill, Table 2 and Figure 20.

Table 4 Determination of lateral active earth pressure with depth

Depth z [m]	Layer thickness h [m]	lateral active earth pressure $\sigma_a = k_a\ q + E$ [kN/m^2]
3	3	$\sigma_{a1}= k_a\ q + k_a\ \sigma'_{v1}$ = 0.333×40+18=31.33
7	4	$\sigma_{a2}= k_a\ q + k_a\ \sigma'_{v2}$ = 0.333×40+73.49=86.82

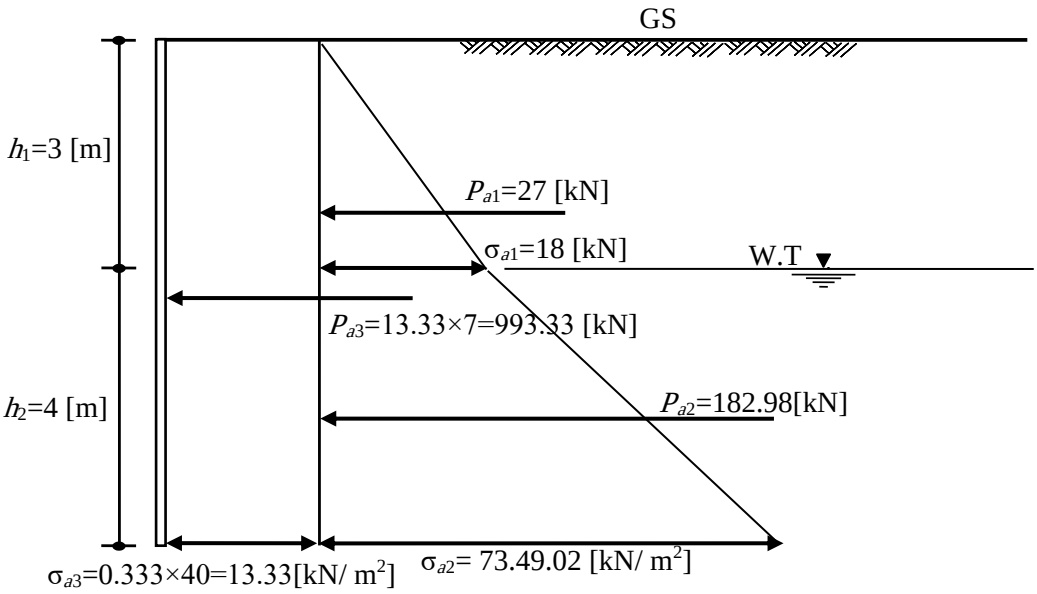


Figure 20 Total lateral earth pressure σ$_a$ and active forces P_a

Figure 21 shows the earth pressures and water presser in a single view

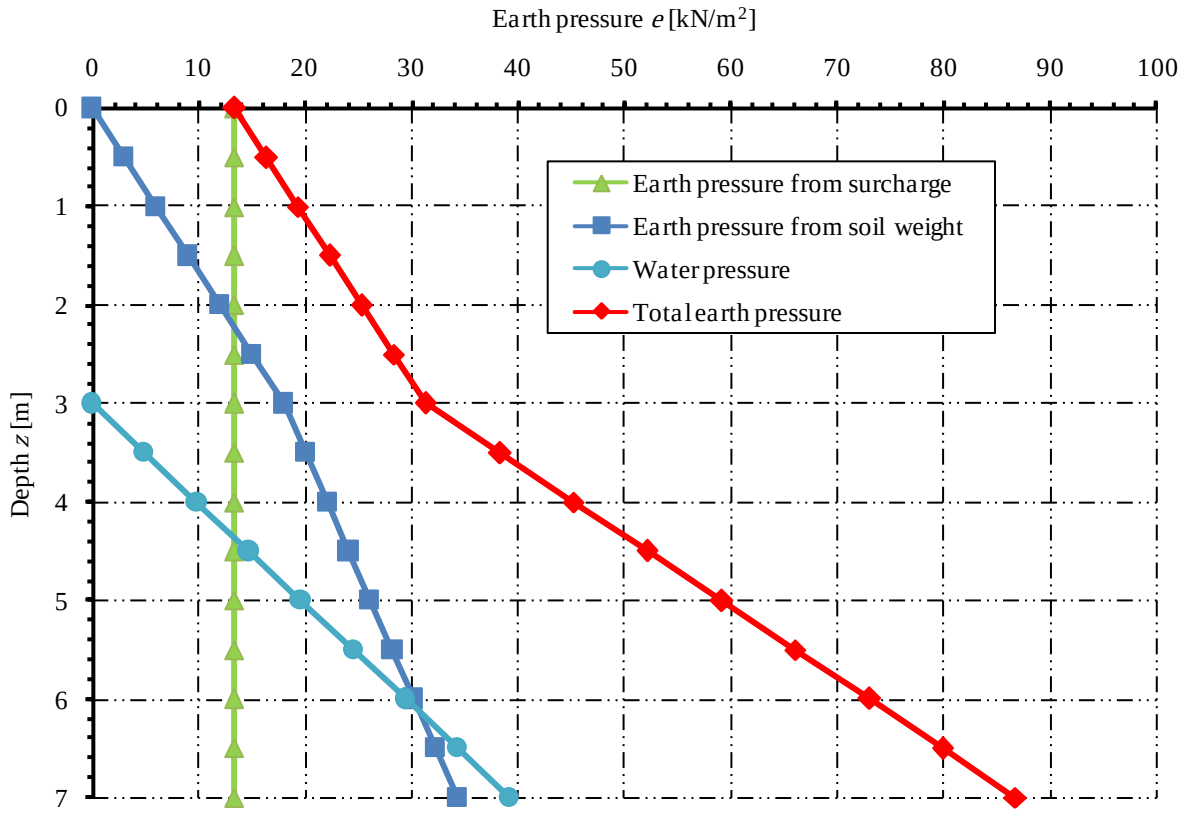


Figure 21 Earth pressure from the soil weight and surcharge and water pressure

1.3.5.1 Lateral earth pressure on a wall in sand by GEO Tools

The lateral earth pressure on a wall in sand obtained by *GEO Tools* is equal to that obtained by hand calculation. Also, the input data and results of GEO Tools for this example are presented on the next pages.

```
************************************************************
                        GEO Tools
                       Version 13
          Program authors M. El Gendy/ A. El Gendy
************************************************************
Title: Lateral earth pressure
Date: 26/03/2023
Project: Lateral earth pressure on a wall in sand
File: Ex4

------------------------------------------------------------
Lateral earth pressure
------------------------------------------------------------

Data:
Distributed load                          q    [kN/m2] = 40.0
Total thickness of soil layers            Ht   [m]     = 7.00

Element size/ Width of Working Area:
Element size                              Dz   [m]     = 0.25
Width of Working Area                     Bw   [m]     = 8.00

Soil Data:
Ground water depth                        Gwl  [m]     = 3.00

Layer No.: 1
Cohesion of the soil                      C    [kN/m2] = 0.000
Angle of internal friction                φ    [°]     = 30.00
Dry unit weight of the soil               γd   [kN/m3] = 18.00
Saturated unit weight of the soil         γsat [kN/m3] = 22.00
Layer thickness                           h    [m]     = 3.00
Soil type                                 BOD  [-]     = Sand

Layer No.: 2
Cohesion of the soil                      C    [kN/m2] = 0.000
Angle of internal friction                φ    [°]     = 30.00
Dry unit weight of the soil               γd   [kN/m3] = 18.00
Saturated unit weight of the soil         γsat [kN/m3] = 22.00
Layer thickness                           h    [m]     = 4.00
Soil type                                 BOD  [-]     = Sand
```

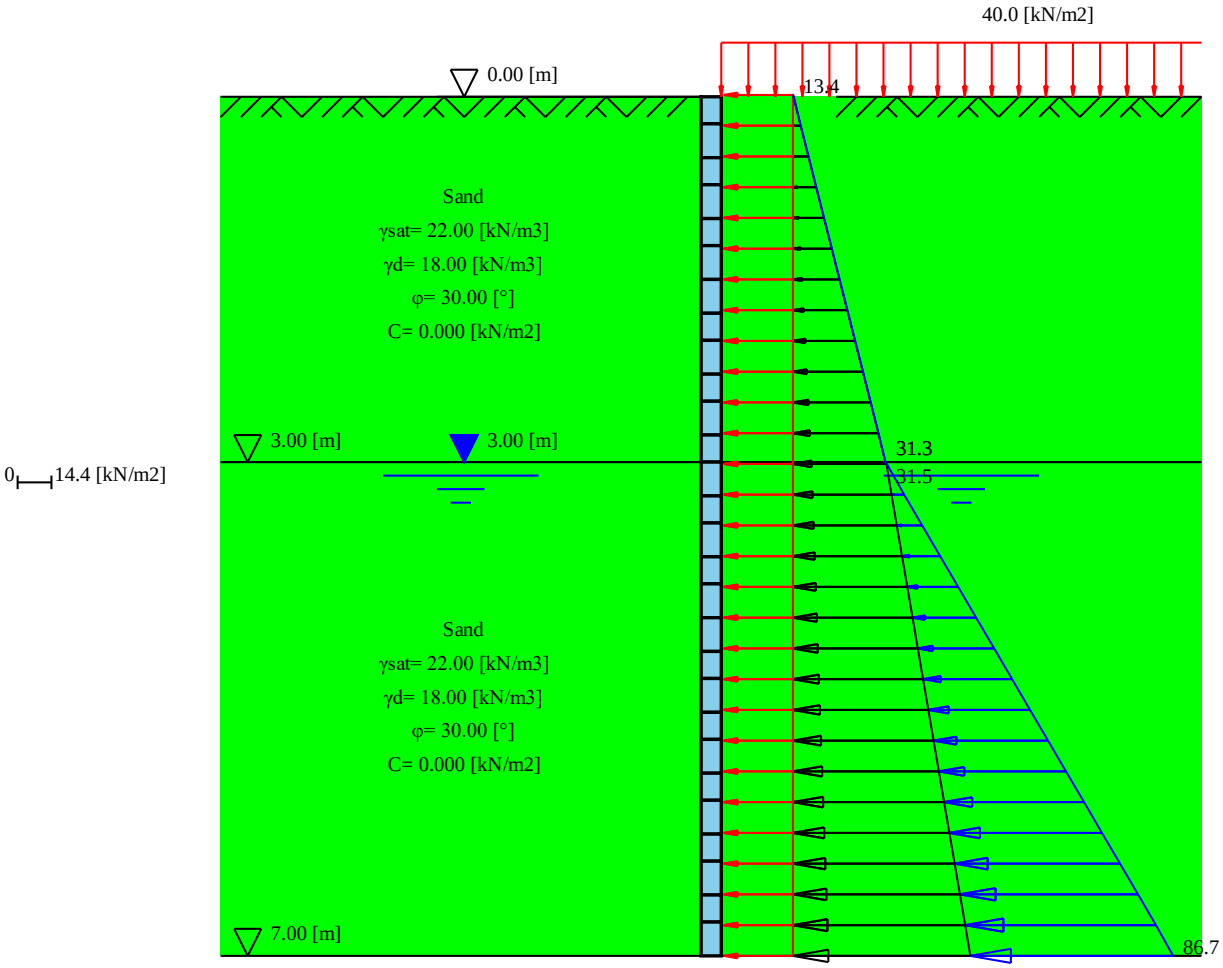
Result:
Resultant R [kN] = 303.7
Location of the resultant from the wall base Y [m] = 2.48

Earth pressures on the sheet pile:

No. I [-]	Depth z1 [m]	Depth z2 [m]	Active earth pressure from surcharge q1 [kN/m2]	Active earth pressure from surcharge q2 [kN/m2]	Active earth pressure from soil weight σz1 [kN/m2]	Active earth pressure from soil weight σz2 [kN/m2]	Water pressure u1 [kN/m2]	Water pressure u2 [kN/m2]	Total lateral earth pressure σ'1 [kN/m2]	Total lateral earth pressure σ'2 [kN/m2]
1	0.00	0.25	13.3	13.3	0.1	1.5	0.0	0.0	13.4	14.8
2	0.25	0.50	13.3	13.3	1.5	3.0	0.0	0.0	14.8	16.3
3	0.50	0.75	13.3	13.3	3.0	4.5	0.0	0.0	16.3	17.8
4	0.75	1.00	13.3	13.3	4.5	6.0	0.0	0.0	17.8	19.3
5	1.00	1.25	13.3	13.3	6.0	7.5	0.0	0.0	19.3	20.8
6	1.25	1.50	13.3	13.3	7.5	9.0	0.0	0.0	20.8	22.3
7	1.50	1.75	13.3	13.3	9.0	10.5	0.0	0.0	22.3	23.8
8	1.75	2.00	13.3	13.3	10.5	12.0	0.0	0.0	23.8	25.3
9	2.00	2.25	13.3	13.3	12.0	13.5	0.0	0.0	25.3	26.8
10	2.25	2.50	13.3	13.3	13.5	15.0	0.0	0.0	26.8	28.3
11	2.50	2.75	13.3	13.3	15.0	16.5	0.0	0.0	28.3	29.8
12	2.75	3.00	13.3	13.3	16.5	17.9	0.0	0.0	29.8	31.3
13	3.00	3.25	13.3	13.3	18.0	19.0	0.1	2.5	31.5	34.8
14	3.25	3.50	13.3	13.3	19.0	20.0	2.5	4.9	34.8	38.3
15	3.50	3.75	13.3	13.3	20.0	21.0	4.9	7.4	38.3	41.7
16	3.75	4.00	13.3	13.3	21.0	22.1	7.4	9.8	41.7	45.2
17	4.00	4.25	13.3	13.3	22.1	23.1	9.8	12.3	45.2	48.7
18	4.25	4.50	13.3	13.3	23.1	24.1	12.3	14.7	48.7	52.1
19	4.50	4.75	13.3	13.3	24.1	25.1	14.7	17.2	52.1	55.6
20	4.75	5.00	13.3	13.3	25.1	26.1	17.2	19.6	55.6	59.1
21	5.00	5.25	13.3	13.3	26.1	27.1	19.6	22.1	59.1	62.5
22	5.25	5.50	13.3	13.3	27.1	28.2	22.1	24.5	62.5	66.0
23	5.50	5.75	13.3	13.3	28.2	29.2	24.5	27.0	66.0	69.5
24	5.75	6.00	13.3	13.3	29.2	30.2	27.0	29.4	69.5	73.0
25	6.00	6.25	13.3	13.3	30.2	31.2	29.4	31.9	73.0	76.4
26	6.25	6.50	13.3	13.3	31.2	32.2	31.9	34.3	76.4	79.9
27	6.50	6.75	13.3	13.3	32.2	33.2	34.3	36.8	79.9	83.4
28	6.75	7.00	13.3	13.3	33.2	34.2	36.8	39.1	83.4	86.7

Lateral earth pressure

Earth pressure



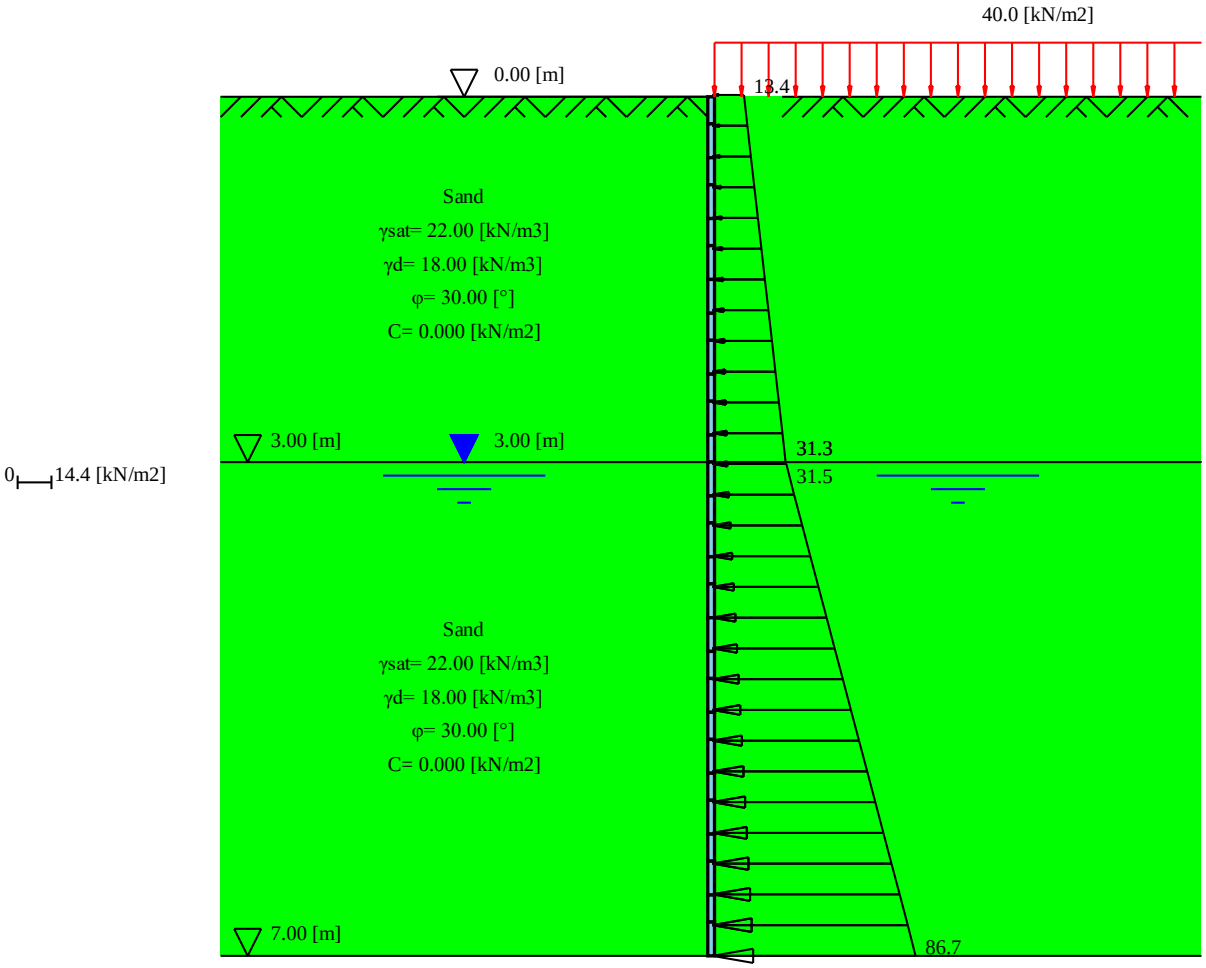
Earth pressure e [kN/m2]

Max. e = 86.7 at z = 7.00 [m], Min. e = 13.4 at z = 0.00 [m]

GEOTEC Software Inc PO Box 14001 Richmond Road PO, Calgary AB, Canada T3E 7Y7	
Scale: 55	**Title: Lateral earth pressure**
File: Ex4	**Date: 26/03/2023**
Page No.:	**Project: Lateral earth pressure on a wall in sand**

Lateral earth pressure

Earth pressure



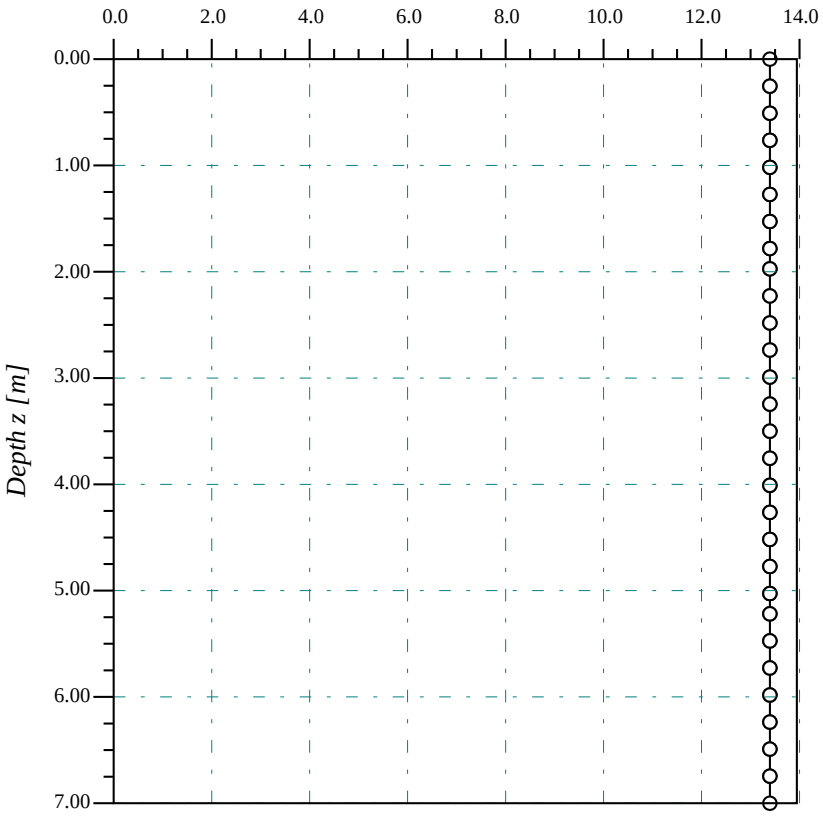
Total lateral earth pressure e [kN/m2]

Max. e = 86.7 at z = 7.00 [m], Min. e = 13.4 at z = 0.00 [m]

GEOTEC Software Inc **PO Box 14001 Richmond Road PO, Calgary AB, Canada T3E 7Y7**	
Scale: 55	**Title: Lateral earth pressure**
File: Ex4	**Date: 26/03/2023**
Page No.:	**Project: Lateral earth pressure on a wall in sand**

Lateral earth pressure

Active earth pressure from surcharge eq [kN/m2]



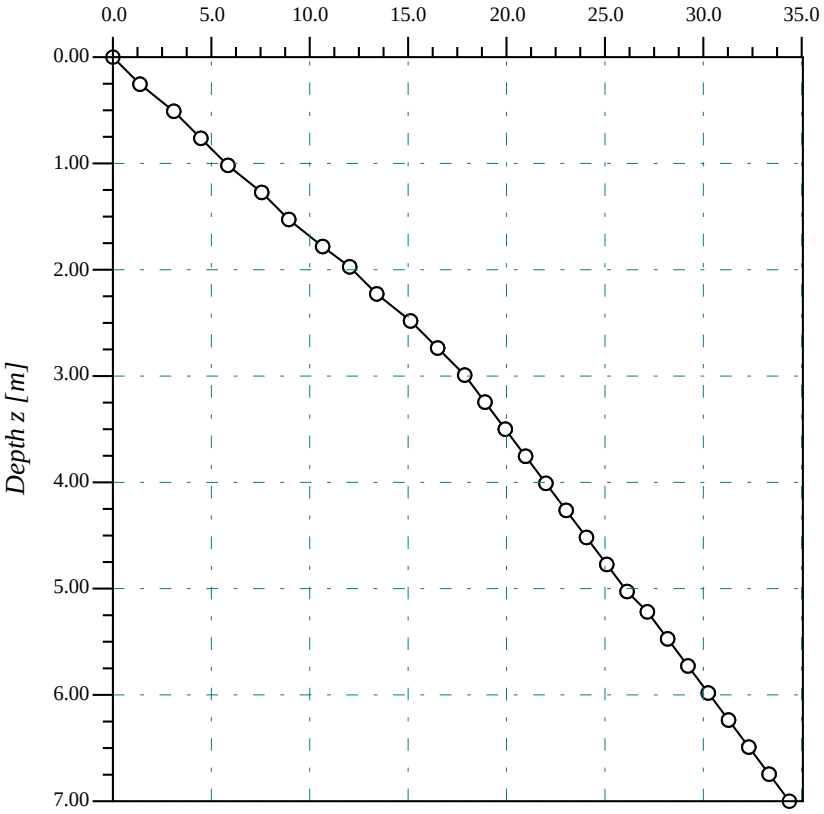
Active earth pressure from surcharge

Max. eq = 13.3 [kN/m2] at z = 0.00 [m], Min. eq = 13.3 [kN/m2] at z = 0.00 [m]

GEOTEC Software Inc	
PO Box 14001 Richmond Road PO, Calgary AB, Canada T3E 7Y7	
Scale: 138	**Title: Lateral earth pressure**
File: Ex4	**Date: 26/03/2023**
Page No.:	**Project: Lateral earth pressure on a wall in sand**

Lateral earth pressure

Active earth pressure from soil weight ea [kN/m2]



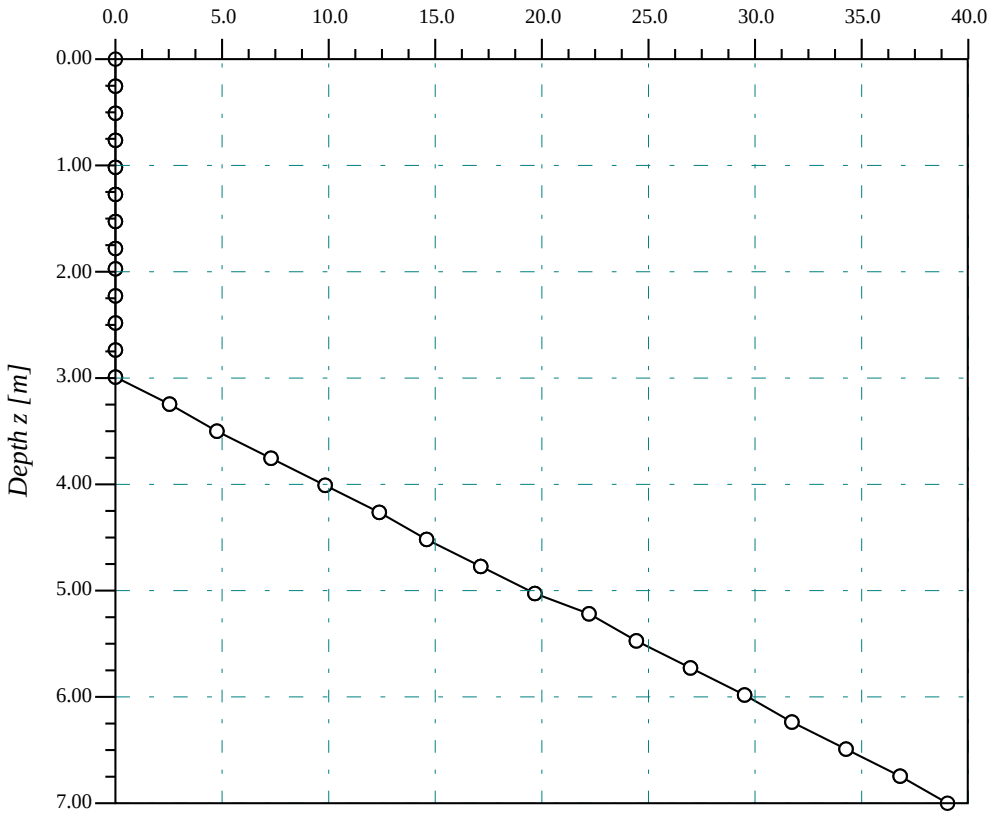
Active earth pressure from soil weight

Max. ea = 34.2 [kN/m2] at z = 7.00 [m], Min. ea = 0.1 [kN/m2] at z = 0.00 [m]

GEOTEC Software Inc **PO Box 14001 Richmond Road PO, Calgary AB, Canada T3E 7Y7**	
Scale: 344	**Title: Lateral earth pressure**
File: Ex4	**Date: 26/03/2023**
Page No.:	**Project: Lateral earth pressure on a wall in sand**

Lateral earth pressure

Water pressure wr [kN/m2]



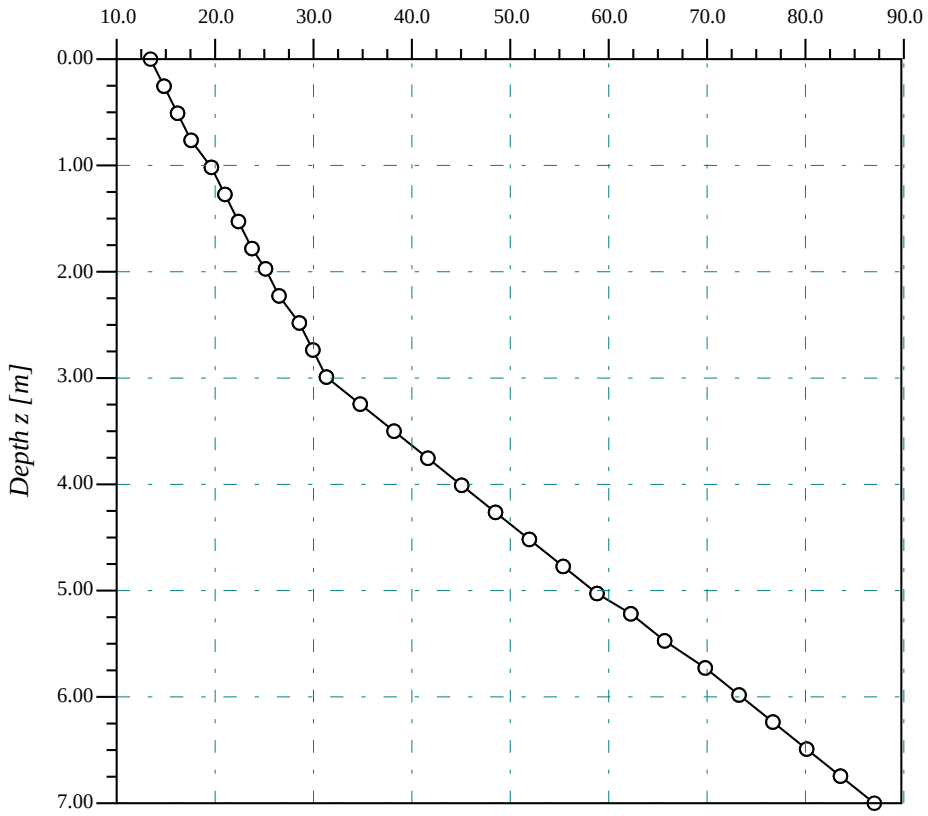
Water pressure

Max. wr = 39.1 [kN/m2] at z = 7.00 [m], Min. wr = 0.0 [kN/m2] at z = 0.00 [m]

GEOTEC Software Inc PO Box 14001 Richmond Road PO, Calgary AB, Canada T3E 7Y7	
Scale: 317	**Title: Lateral earth pressure**
File: Ex4	**Date: 26/03/2023**
Page No.:	**Project: Lateral earth pressure on a wall in sand**

Lateral earth pressure

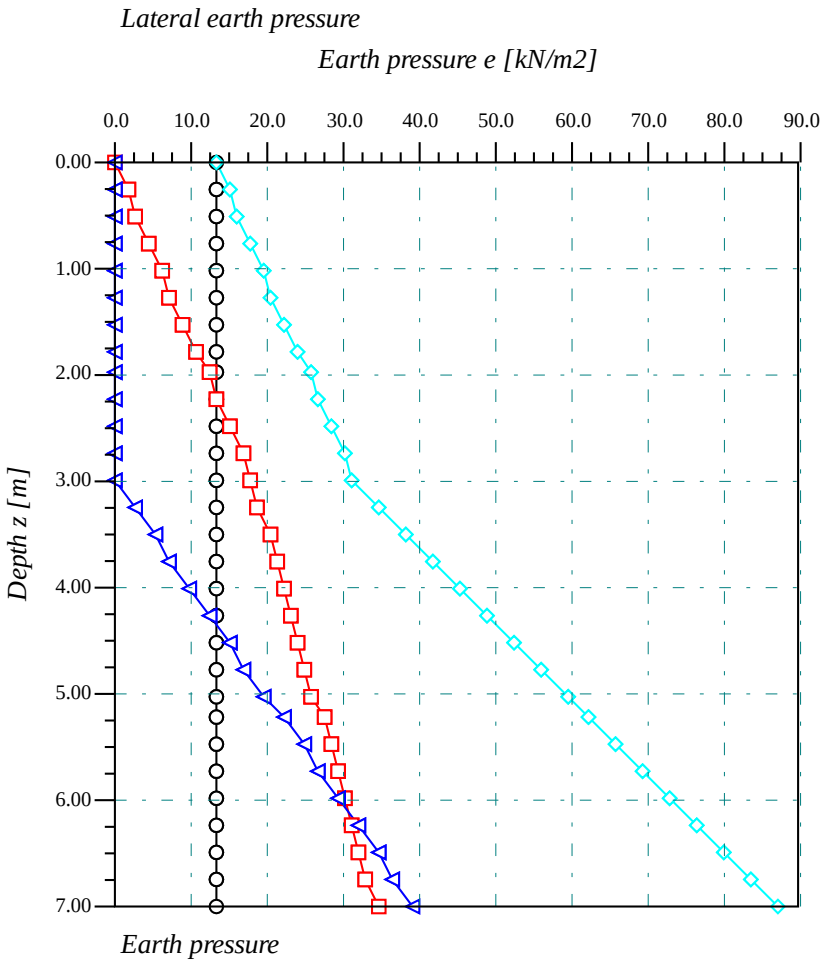
Total lateral earth pressure e [kN/m2]



Total lateral earth pressure

Max. e = 86.7 [kN/m2] at z = 7.00 [m], Min. e = 13.4 [kN/m2] at z = 0.00 [m]

GEOTEC Software Inc **PO Box 14001 Richmond Road PO, Calgary AB, Canada T3E 7Y7**	
Scale: 688	**Title: Lateral earth pressure**
File: Ex4	**Date: 26/03/2023**
Page No.:	**Project: Lateral earth pressure on a wall in sand**



GEOTEC Software Inc PO Box 14001 Richmond Road PO, Calgary AB, Canada T3E 7Y7	
Scale: 888	**Title: Lateral earth pressure**
File: Ex4	**Date: 26/03/2023**
Page No.:	**Project: Lateral earth pressure on a wall in sand**

1.3.6 Example 5: Lateral earth pressure on a wall within multi-layered soil

1.3.6.1 Description of the problem

To verify the analysis of lateral earth pressure on walls within multi-layered soil by *Geo Tools*, the active earth pressure diagram obtained by *Bowles* (1996), Example11-5, Page 606, is compared with that obtained by *Geo Tools*.

Plot the active earth pressure diagram and compute the resultant *R* and its location *y* for the wall system shown in Figure 22. This type of problem is often encountered in excavations for large structures where there may be two or more basement levels. The soil parameters φ, c may be estimated or else be obtained from performing consolidated isotropically undrained (CIU) tests on good-quality tube samples. The major approximation is defining the several strata by abrupt discontinuities (using lines as shown to delineate layers). In most real situations, the soil type grades through a finite length from one to the next.

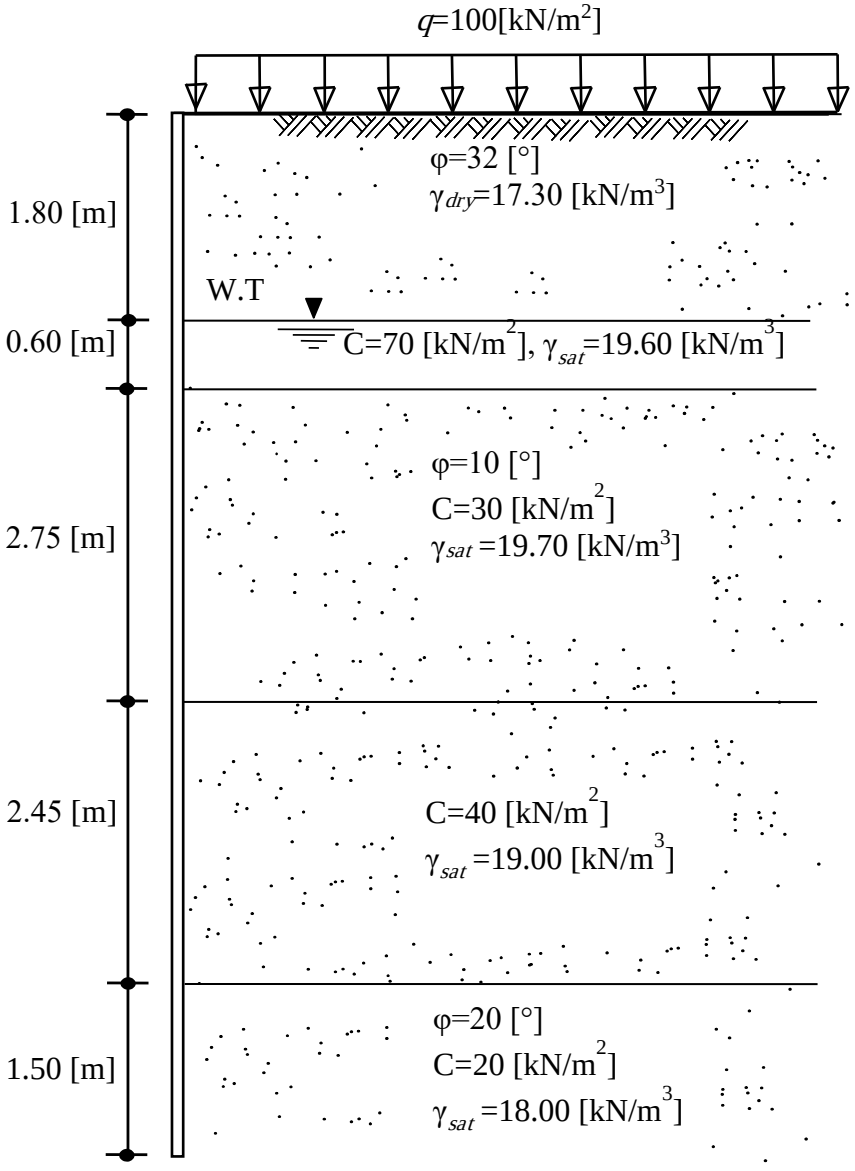


Figure 22 Soil Profile (*Bowles* 1996)

1.3.6.2 Lateral Active Earth Pressure

The lateral active earth pressure at point *A* in the soil is quale to the effective vertical stress σ'_v multiplied by a coefficient, $\sigma_h = k_a \sigma'_v$. If a water table exists, horizontal hydrostatic water pressure is considered. Lateral water pressure at point *A* in the soil is the weight of the water column above that point $w=\gamma_w z$. Coefficient of lateral active earth pressure is given by:

$$k_a = \frac{1-\sin\varphi}{1+\sin\varphi}$$

For instance, for φ = 32°, then, obtain *ka* = 0.307 and $\sqrt{k_a}$ =0.307 = 0.554, etc.

Typical computations for Δ*P'* are as follows (Table 5):

Table 5 Determination of lateral active earth pressure Δ*P'* with depth

Depth *z* [m]	ΔP'= *z*γ [kN/m^2]
0	100 [kN/m^2] (surcharge)
1.8	100+ 1.80(17.30) = 131.4 [kN/m^2]
2.4	131.4 + 0.6(19.60 - 9.807) = 131.4 + 0.6(9.79) = 137.02 [kN/m^2]
5.15	137.02 + 2.75(9.89) = 164.22 etc.

It will be convenient to tabularize the computations as in Table 6 following. Notice that at the interface between two soils, we use the interface pressure two times: first with -*dz* and the upper *ka* coefficients, and second with +*dz* and the *ka* coefficients of the lower soil. Note also that the $2c\sqrt{k_a}$ term can be simplified for the second use. The water pressure is included (*ka* = *kp* = *kw* = 1) if the water cannot drain through the wall or away by other means. Since the water contribution is significant, it is obvious that drainage should be allowed if possible. The tension zone (-) *qh* is a problem. Should it be included to reduce the wall force or neglected, as it may pull away from the wall? A more conservative case is made if the tension zone is neglected, which we will do here, so neglect the tension zone.

Table 6 Determination of lateral active earth pressure with depth

Soil	Depth *z* [m]	k_a	$\sqrt{k_a}$	Δ*P'*= *z*γ [kN/m^2]	Wall pressure *E*== *z*γ*k* [kN/m^2]
1	0	0.307	0.554	100	100×0.307 = 30.7
	1.8-*dz*			131.14	131.14×0.307 =40.3
2	1.8+*dz*	1.000	1.000	131.14	131.14×1.00 - 2×70×1.00 = - 8.9
	2.4-*dz*			137.02	137.02×1.00 - 2×70×1.00 = -3.0
3	2.4+*dz*	0.704	0.839	137.02	137.02×0.704-2×30×0.839 = 46.1
	5.15-*dz*			164.22	164.22×0.704 - 60×0.839 =65.3
4	5.15-*dz*	1.000	1.000	164.22	164.22×1.000 - 2×40×1.00 = 84.2
	7.6-*dz*			186.73	186.73×1.000 - 80×1.00 =106.7
5	7.6+*dz*	0.49	0.700	186.73	186.73×0.490-2×20×0.700 = 63.5
	9.1			199.02	199.02×0.490 - 40×0.700 = 69.5

Figure 23 shows the lateral earth pressures and water presser on the wall according to *Bowles* (1996)

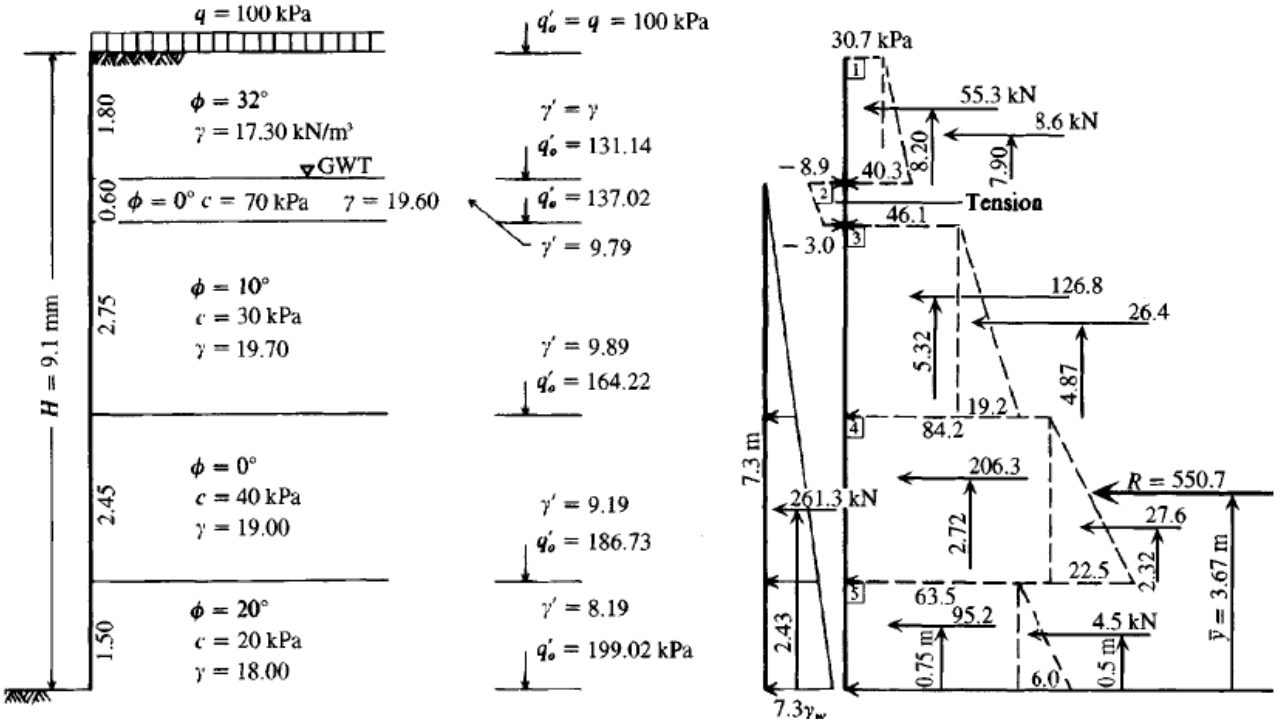


Figure 23 Earth pressure from the soil weight and surcharge and water pressure (*Bowles* 1996)

1.3.6.3 Lateral earth pressure on a wall in sand by GEO Tools

The lateral earth pressure on the wall within multi-layered soil obtained by *GEO Tools* is equal to that obtained by *Bowles* (1996) through hand calculation. Also, the input data and results of *GEO Tools* for this example are presented on the next pages.

```
************************************************************
                        GEO Tools
                       Version 13
          Program authors M. El Gendy/ A. El Gendy
************************************************************
Title: Lateral earth pressure on a wall within multi-layered soil
Date: 30-03-2023
Project: Example11-5, Page 606, Foundation Analysis and Design,  Bowles 1996
File: Ex5

------------------------------------------------------------
Lateral earth pressure
------------------------------------------------------------

Data:
Distributed load                          q    [kN/m2] = 100.0
Total thickness of soil layers            Ht   [m]     = 9.10

Element size/ Width of Working Area:
Element size                              Dz   [m]     = 0.25
Width of Working Area                     Bw   [m]     = 8.00

Soil Data:
Ground water depth                        Gwl  [m]     = 1.80

Layer No.: 1
Cohesion of the soil                      C    [kN/m2] = 0.000
Angle of internal friction                φ    [°]     = 32.00
Dry unit weight of the soil               γd   [kN/m3] = 17.30
Saturated unit weight of the soil         γsat [kN/m3] = 17.30
Layer thickness                           h    [m]     = 1.80
Soil type                                 BOD  [-]     = Soil 1

Layer No.: 2
Cohesion of the soil                      C    [kN/m2] = 70.000
Angle of internal friction                φ    [°]     = 0.00
Dry unit weight of the soil               γd   [kN/m3] = 19.70
Saturated unit weight of the soil         γsat [kN/m3] = 19.70
Layer thickness                           h    [m]     = 0.60
Soil type                                 BOD  [-]     = Soil 2

Layer No.: 3
Cohesion of the soil                      C    [kN/m2] = 30.000
Angle of internal friction                φ    [°]     = 10.00
Dry unit weight of the soil               γd   [kN/m3] = 19.70
Saturated unit weight of the soil         γsat [kN/m3] = 19.70
Layer thickness                           h    [m]     = 2.75
Soil type                                 BOD  [-]     = Soil 3

Layer No.: 4
Cohesion of the soil                      C    [kN/m2] = 40.000
Angle of internal friction                φ    [°]     = 0.00
Dry unit weight of the soil               γd   [kN/m3] = 19.00
Saturated unit weight of the soil         γsat [kN/m3] = 19.00
Layer thickness                           h    [m]     = 2.45
Soil type                                 BOD  [-]     = Soil 4

Layer No.: 5
Cohesion of the soil                      C    [kN/m2] = 20.000
Angle of internal friction                φ    [°]     = 20.00
Dry unit weight of the soil               γd   [kN/m3] = 18.00
Saturated unit weight of the soil         γsat [kN/m3] = 18.00
Layer thickness                           h    [m]     = 1.50
Soil type                                 BOD  [-]     = Soil 5
```

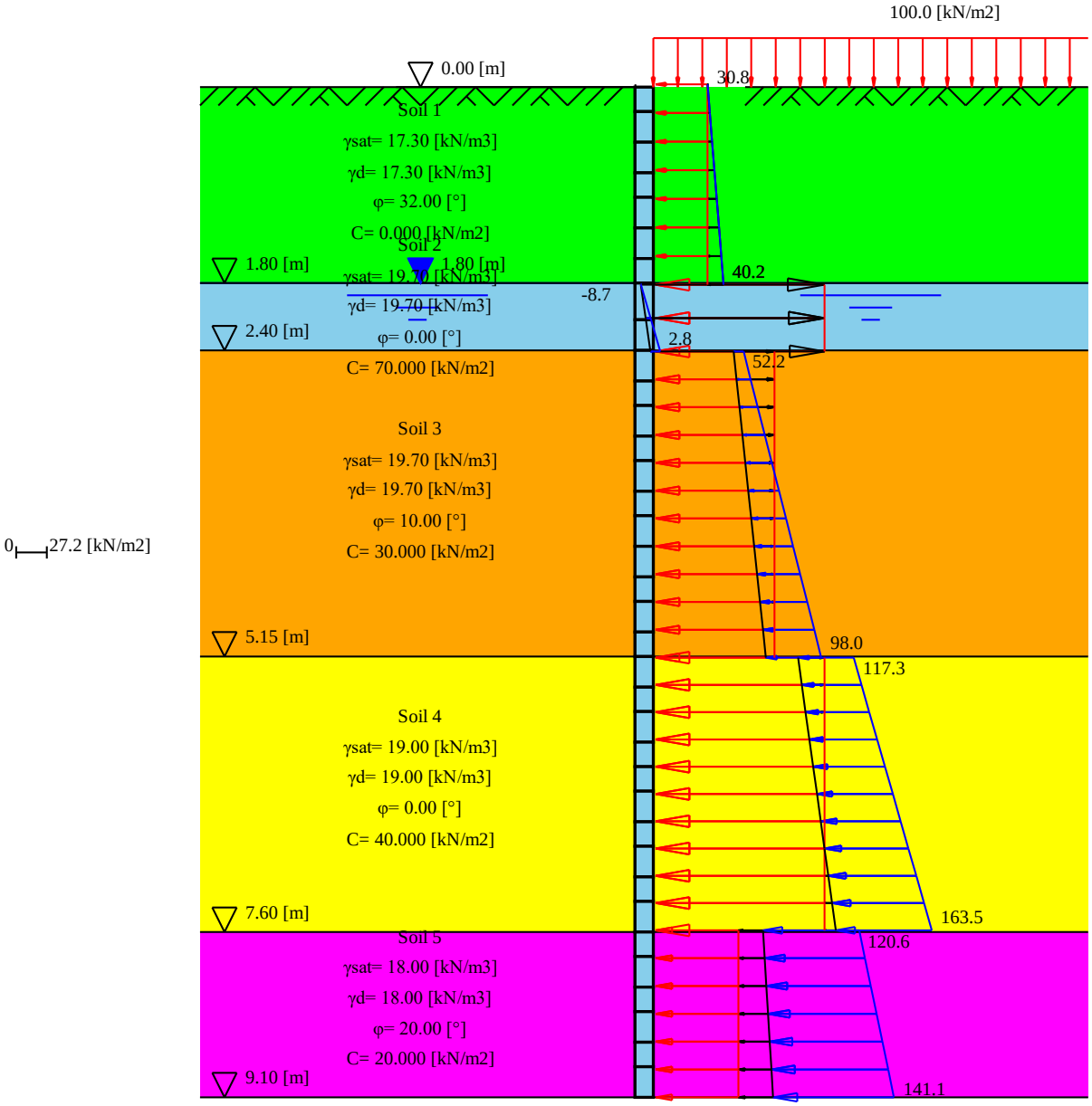
Result:
Resultant R [kN] = 811.3
Location of the resultant from the wall base Y [m] = 3.27

Earth pressures on the sheet pile:

No. I [-]	Depth z1 [m]	Depth z2 [m]	Active earth pressure from surcharge q1 [kN/m2]	Active earth pressure from surcharge q2 [kN/m2]	Active earth pressure from soil weight σz1 [kN/m2]	Active earth pressure from soil weight σz2 [kN/m2]	Water pressure u1 [kN/m2]	Water pressure u2 [kN/m2]	Total lateral earth pressure σ'1 [kN/m2]	Total lateral earth pressure σ'2 [kN/m2]
1	0.00	0.26	30.7	30.7	0.1	1.4	0.0	0.0	30.8	32.1
2	0.26	0.51	30.7	30.7	1.4	2.7	0.0	0.0	32.1	33.4
3	0.51	0.77	30.7	30.7	2.7	4.1	0.0	0.0	33.4	34.8
4	0.77	1.03	30.7	30.7	4.1	5.5	0.0	0.0	34.8	36.2
5	1.03	1.29	30.7	30.7	5.5	6.9	0.0	0.0	36.2	37.6
6	1.29	1.54	30.7	30.7	6.9	8.2	0.0	0.0	37.6	38.9
7	1.54	1.80	30.7	30.7	8.2	9.5	0.0	0.0	38.9	40.2
8	1.80	2.10	100.0	100.0	-108.8	-105.9	0.1	2.9	0.0	0.0
9	2.10	2.40	100.0	100.0	-105.9	-103.0	2.9	5.8	0.0	2.8
10	2.40	2.65	70.4	70.4	-24.2	-22.5	6.0	8.3	52.2	56.2
11	2.65	2.90	70.4	70.4	-22.5	-20.8	8.3	10.8	56.2	60.4
12	2.90	3.15	70.4	70.4	-20.8	-19.0	10.8	13.2	60.4	64.6
13	3.15	3.40	70.4	70.4	-19.0	-17.3	13.2	15.7	64.6	68.8
14	3.40	3.65	70.4	70.4	-17.3	-15.5	15.7	18.1	68.8	73.0
15	3.65	3.90	70.4	70.4	-15.5	-13.8	18.1	20.6	73.0	77.2
16	3.90	4.15	70.4	70.4	-13.8	-12.1	20.6	23.1	77.2	81.4
17	4.15	4.40	70.4	70.4	-12.1	-10.3	23.1	25.5	81.4	85.6
18	4.40	4.65	70.4	70.4	-10.3	-8.6	25.5	28.0	85.6	89.8
19	4.65	4.90	70.4	70.4	-8.6	-6.8	28.0	30.4	89.8	94.0
20	4.90	5.15	70.4	70.4	-6.8	-5.2	30.4	32.8	94.0	98.0
21	5.15	5.39	100.0	100.0	-15.6	-13.4	33.0	35.3	117.3	121.9
22	5.39	5.64	100.0	100.0	-13.4	-11.2	35.3	37.7	121.9	126.4
23	5.64	5.88	100.0	100.0	-11.2	-8.9	37.7	40.1	126.4	131.2
24	5.88	6.13	100.0	100.0	-8.9	-6.7	40.1	42.5	131.2	135.7
25	6.13	6.37	100.0	100.0	-6.7	-4.4	42.5	44.9	135.7	140.5
26	6.37	6.62	100.0	100.0	-4.4	-2.2	44.9	47.3	140.5	145.1
27	6.62	6.86	100.0	100.0	-2.2	0.0	47.3	49.6	145.1	149.6
28	6.86	7.11	100.0	100.0	0.0	2.3	49.6	52.1	149.6	154.4
29	7.11	7.35	100.0	100.0	2.3	4.5	52.1	54.4	154.4	158.9
30	7.35	7.60	100.0	100.0	4.5	6.7	54.4	56.8	158.9	163.5
31	7.60	7.85	49.0	49.0	14.6	15.5	57.0	59.4	120.6	123.9
32	7.85	8.10	49.0	49.0	15.5	16.5	59.4	61.8	123.9	127.4
33	8.10	8.35	49.0	49.0	16.5	17.5	61.8	64.3	127.4	130.8
34	8.35	8.60	49.0	49.0	17.5	18.6	64.3	66.7	130.8	134.3
35	8.60	8.85	49.0	49.0	18.6	19.6	66.7	69.2	134.3	137.7
36	8.85	9.10	49.0	49.0	19.6	20.5	69.2	71.5	137.7	141.1

Lateral earth pressure

Earth pressure



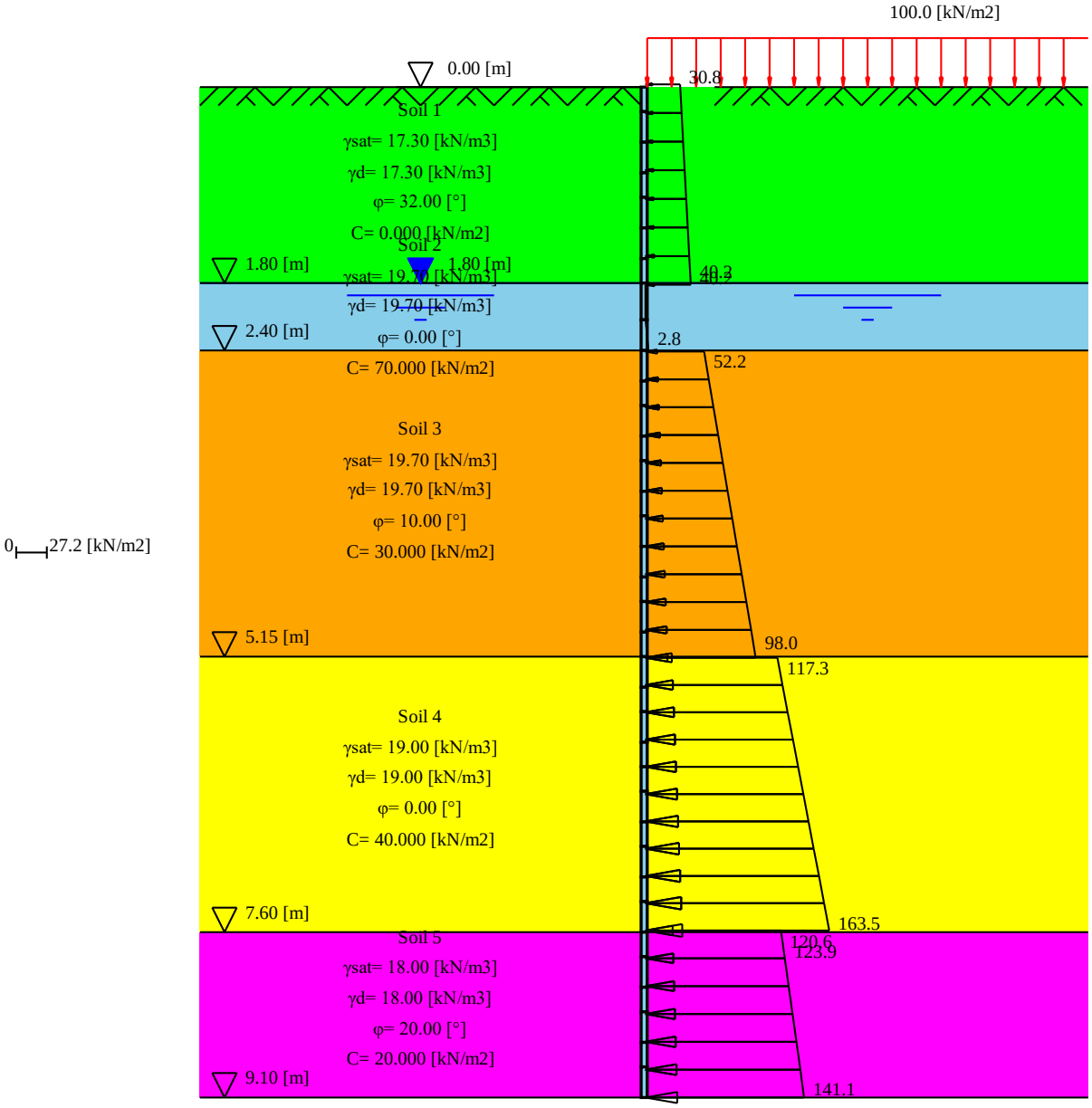
Earth pressure e [kN/m2]

Max. e = 163.5 at z = 7.60 [m], Min. e = 0.0 at z = 1.80 [m]

GEOTEC Software Inc	
PO Box 14001 Richmond Road PO, Calgary AB, Canada T3E 7Y7	
Scale: 55	**Title: Lateral earth pressure on a wall within multi-layered soil**
File: Ex5	**Date: 30-03-2023**
Page No.:	**Project: Example11-5, Page 606, Foundation Analysis and Design, Bowles 1996**

Lateral earth pressure

Earth pressure



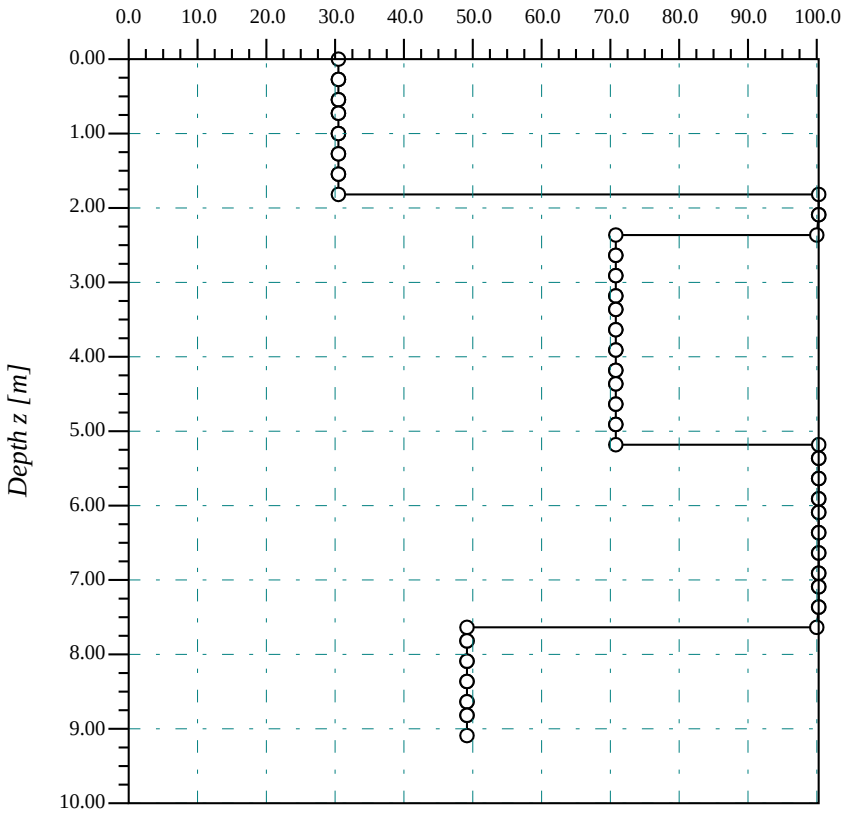
Total lateral earth pressure e [kN/m2]

Max. e = 163.5 at z = 7.60 [m], Min. e = 0.0 at z = 1.80 [m]

GEOTEC Software Inc **PO Box 14001 Richmond Road PO, Calgary AB, Canada T3E 7Y7**	
Scale: 55	**Title: Lateral earth pressure on a wall within multi-layered soil**
File: Ex5	**Date: 30-03-2023**
Page No.:	**Project: Example11-5, Page 606, Foundation Analysis and Design, Bowles 1996**

Lateral earth pressure

Active earth pressure from surcharge eq [kN/m2]



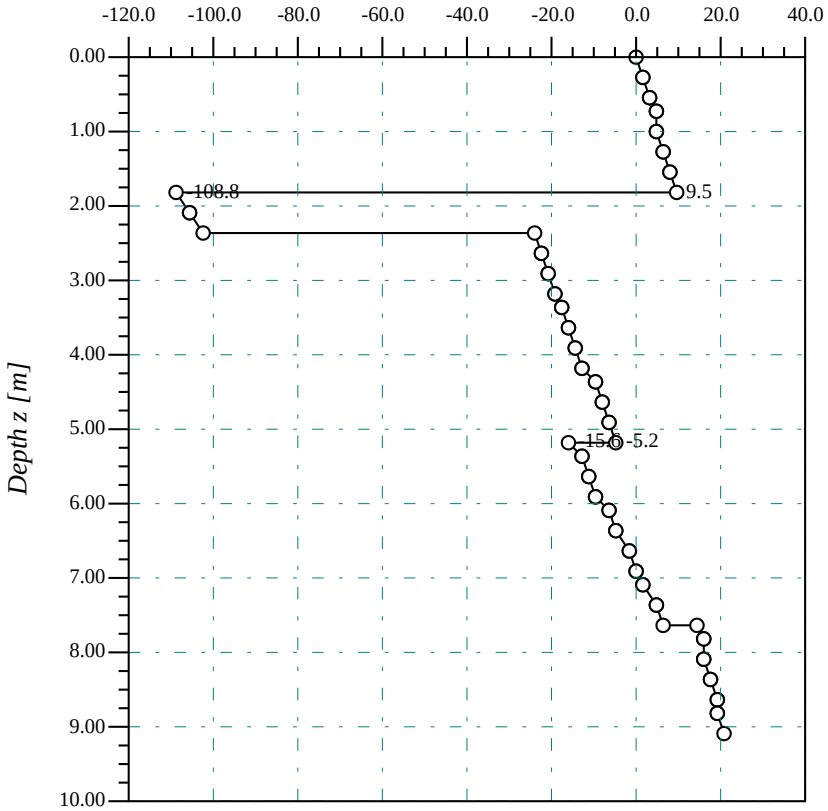
Active earth pressure from surcharge

Max. eq = 100.0 [kN/m2] at z = 1.80 [m], Min. eq = 30.7 [kN/m2] at z = 0.00 [m]

GEOTEC Software Inc	
PO Box 14001 Richmond Road PO, Calgary AB, Canada T3E 7Y7	
Scale: 983	**Title: Lateral earth pressure on a wall within multi-layered soil**
File: Ex5	**Date: 30-03-2023**
Page No.:	**Project: Example11-5, Page 606, Foundation Analysis and Design, Bowles 1996**

Lateral earth pressure

Active earth pressure from soil weight ea [kN/m2]



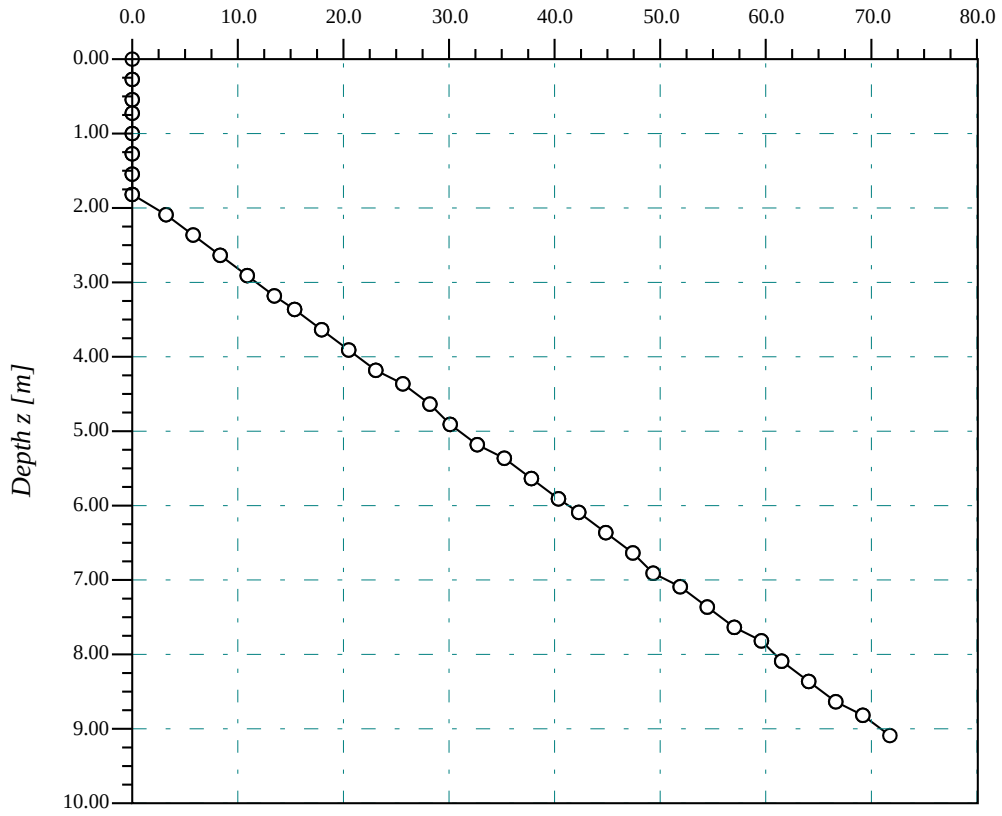
Active earth pressure from soil weight

Max. ea = 20.5 [kN/m2] at z = 9.10 [m], Min. ea = -108.8 [kN/m2] at z = 1.80 [m]

GEOTEC Software Inc **PO Box 14001 Richmond Road PO, Calgary AB, Canada T3E 7Y7**	
Scale: 1600	**Title: Lateral earth pressure on a wall within multi-layered soil**
File: Ex5	**Date: 30-03-2023**
Page No.:	**Project: Example11-5, Page 606, Foundation Analysis and Design, Bowles 1996**

Lateral earth pressure

Water pressure wr [kN/m2]



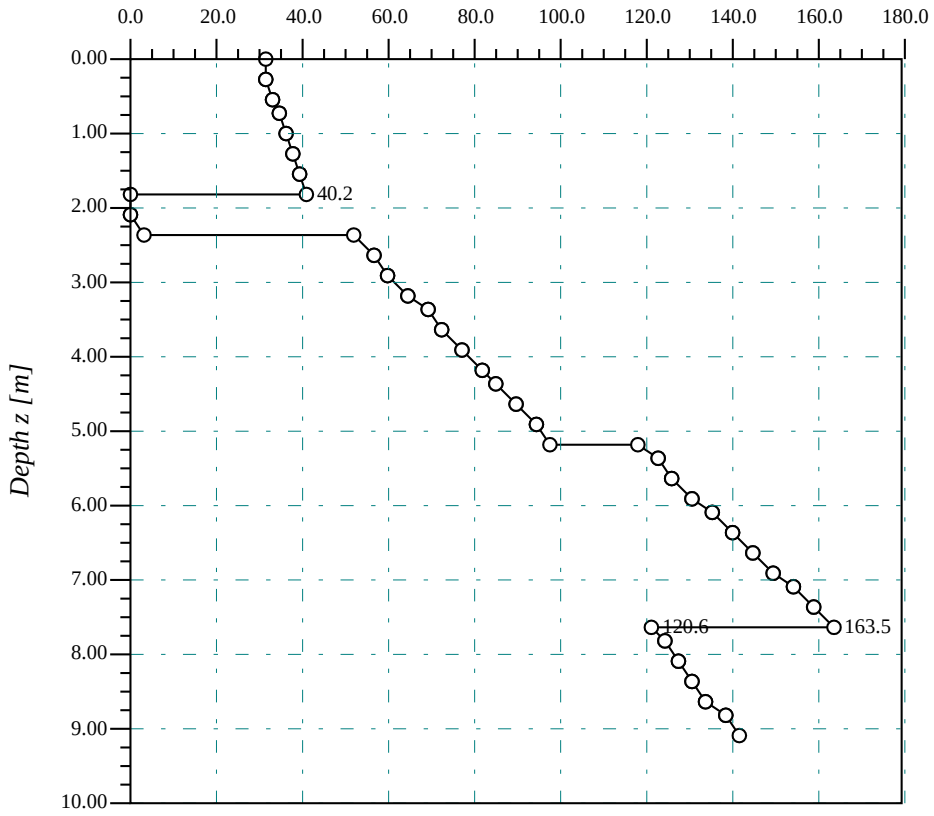
Water pressure

Max. wr = 71.5 [kN/m2] at z = 9.10 [m], Min. wr = 0.0 [kN/m2] at z = 0.00 [m]

GEOTEC Software Inc **PO Box 14001 Richmond Road PO, Calgary AB, Canada T3E 7Y7**	
Scale: 641	**Title: Lateral earth pressure on a wall within multi-layered soil**
File: Ex5	**Date: 30-03-2023**
Page No.:	**Project: Example11-5, Page 606, Foundation Analysis and Design, Bowles 1996**

Lateral earth pressure

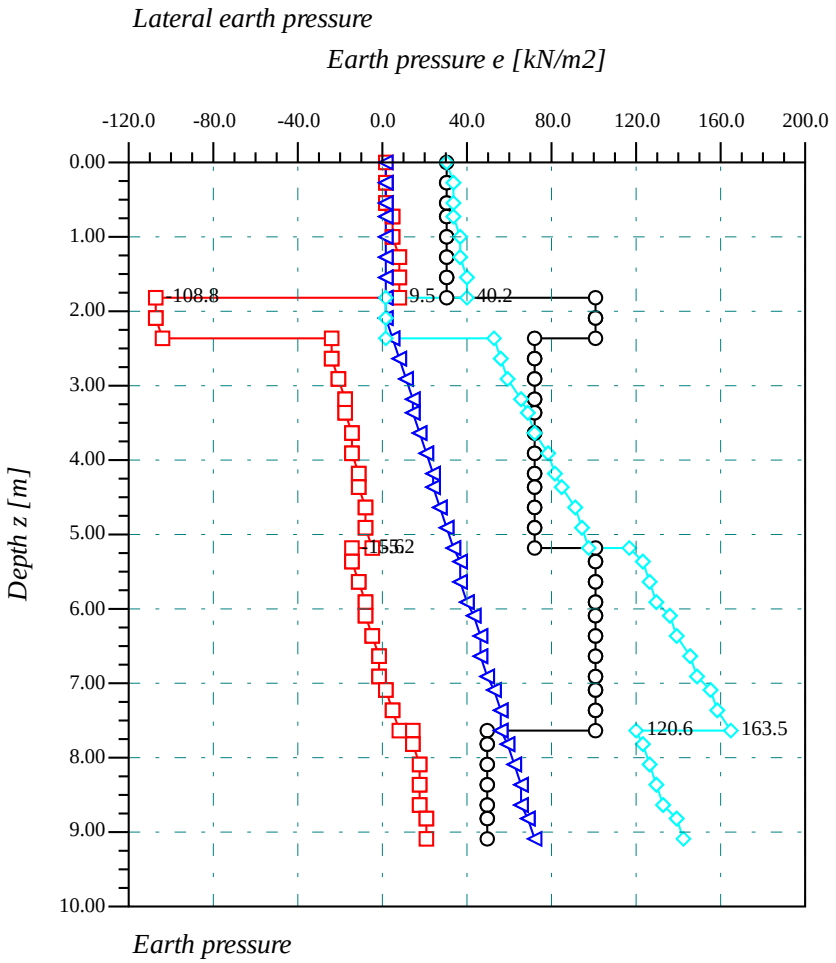
Total lateral earth pressure e [kN/m2]



Total lateral earth pressure

Max. e = 163.5 [kN/m2] at z = 7.60 [m], Min. e = 0.0 [kN/m2] at z = 1.80 [m]

GEOTEC Software Inc **PO Box 14001 Richmond Road PO, Calgary AB, Canada T3E 7Y7**	
Scale: 1572	**Title: Lateral earth pressure on a wall within multi-layered soil**
File: Ex5	**Date: 30-03-2023**
Page No.:	**Project: Example11-5, Page 606, Foundation Analysis and Design, Bowles 1996**



GEOTEC Software Inc PO Box 14001 Richmond Road PO, Calgary AB, Canada T3E 7Y7	
Scale: 3200	**Title: Lateral earth pressure on a wall within multi-layered soil**
File: Ex5	**Date: 30-03-2023**
Page No.:	**Project: Example11-5, Page 606, Foundation Analysis and Design, Bowles 1996**

1.4 References

Bowles, J. (1996): "Foundation Analysis and Design", The McGraw-Hill Companies, Inc.