MicroPile.exe
PC-program for calculation of load capacity for steel tube piles

User Manual
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Introduction
The MicroPile.exe PC-program runs on most PC-units. It is developed with Microsoft XP. A printout containing input and output data can be made on a printer connected to the PC. Input data can be stored for further use. The program is used inter actively to design a micro pile having a desired load bearing capacity. Piles are supposed to be mainly point bearing. The bearing capacity of the soil or rock at the pile tip is assumed to be larger than the pile capacity given by the program.

The calculations are carried out as recommended in the latest reports published by the Swedish Pile Commission. The methods used are employed as a standard for most evaluations for slender steel tube piles ('micropiles') in Scandinavia. The diameter of these varies typically today from 60 mm up to 300 mm.

Program start
The easiest way to start the program is to put a shortcut pointing at the MicroPile.exe on the desk top and double click the short cut. This will make the program to start and you will se the form in which all calculations takes place.

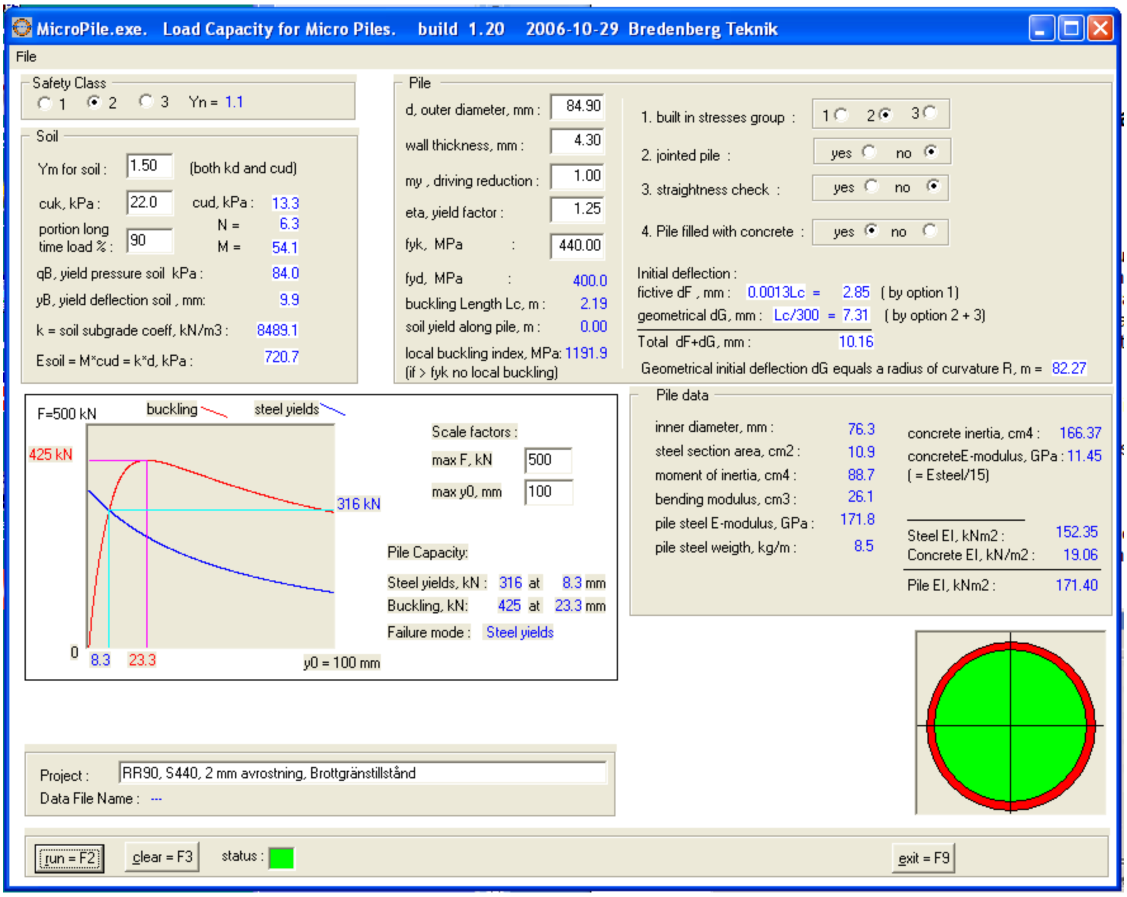

fig 1. MicroPile.exe calculation sheet

Calculation flow, start and stop.
In general, input data are supplied in the white text boxes and by choosing options marking the radio buttons. Any of these actions will make a green status box at the bottom of the sheet to become red. When the desired input data have been supplied, the calculation is invoked by clicking the leftmost button marked run=F2 at the bottom control frame. As indicated, pressing F2 on the key board will also make the start of a calculation run.

Calculated data are shown in blue text, with exception for the graphic window. A detailed description of output data is given below.

When the program shall stop, the button marked exit=F9 will do just that. A confirmation request will be given prior to leaving the program in order to prevent a stop by mistake.

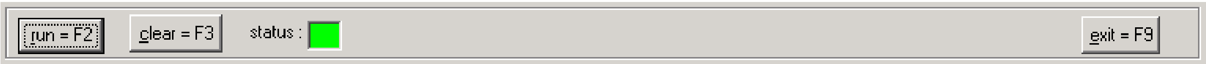

fig 2. Control frame at the bottom of the sheet contains buttons to start a calculation and to stop the program. The status box tells if input data has changed since last calculation. The clear button will erase the content of the graphic window (see below).

Input data, safety class
In Sweden, building elements are divided into 3 classes. The class mirrors the risk for personal injuries and economic loss in case the element collapses. The class 1 is chosen when there is no or insignificant such risks. The safety class 3 is active when these risks are at their highest level. Class 2 is chosen where class 1 and class 2 do not apply.

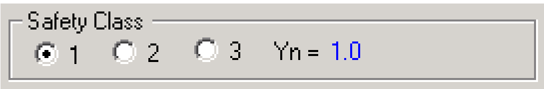

Fig 3. Safety classes

The classes 1,2 and 3 corresponds to a partial safety factor Yn, which has the value 1.0, 1.1 and 1.2 respectively. The use of the factor is explained below.

The choice is made by the user by marking one of the radio buttons. The corresponding value of Yn is shown to the right in the box. The default value is class 1, giving Yn = 1.

Input data and calculated values for soil
The frame for soil input data is shown below. The input data are given in the white text boxes. Also calculated data are shown (in blue). They are updated when the run=F2 button is pressed.

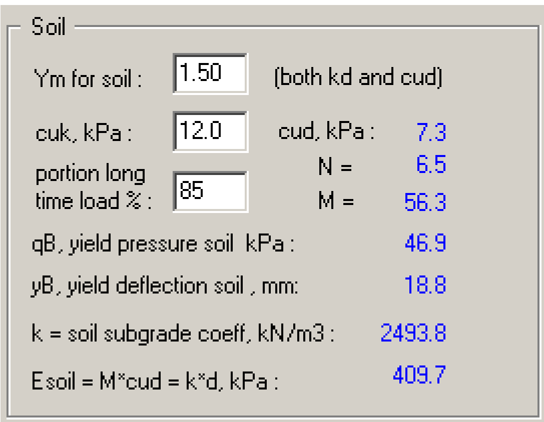

Fig 4. Soil input data and output

Input text boxes at the soil input frame
The first input data is the partial coefficient Ym for the undrained strength of the soil around the pile. The default value is 1.0, but building codes usually requires 1.6 or higher. Give the value that suits your task.

Next value is the undrained real shear strength cuk of the soil, in kPa. For the conversion to other units, se below.

The last textbox contains the portion of the load on the pile that is acting over a long period of time. Usually one week, or more, is considering ‘long’ and loads with shorter duration are depicted ‘not long’. 100 % in the box means all load there all the time, whereas 0 % means all load is short term, in other words a pile carrying only temporary.

Calculated data in the soil frame
The design value cud for the undrained shear strength of the soil is calculated as

cud = cuk/(Yn*Ym) ... (1)

The value is shown with 1 decimal digit, but in the program there are much more accuracy than that. All maths is carried out in double precision.

The next two shown calculated values, N and M, are a bearing factor and a modulus factor respectively. The N-value is defined by

qB = N*cud … (2)

where

qB is the contact pressure that causes yielding between the pile and the soil (se figure 5). The soil is assumed to behave in a bilinear elastic plastic manner.

As shown in picture 5, the relationship between pile deflection y and contact pressure q is

q = k*y … (3).
where k = modulus of subgrade for the pile. It is calculated as

k = Esoil/ d … (4)
where
E soil = e-modulus of the soil
d = diameter of the pile

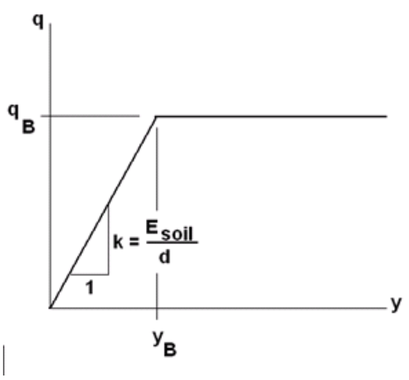

Figure 5 Assumed behaviour of soil around the pile. Contact pressure =q. Displacement = y.

The value of depends on the load duration. N is chosen as :

N = 6 for long term loading
N = 9 for short tem loading

The value M is the multiplier used to get the soil E-modulus, that is

Esoil = M*cud ... (5)

M is chosen as :

M = 50 for long term loading
M = 200 for short tem loading

For values between 0 % and 100 % in the text box for load duration, intermediate values for N and M are calculated by the program.

In conclusion, the values N, M, yB, qB and k are calculated by the program and shown in blue as the run=F2 button is pressed. Displacements are shown in mm. The values of k and Esoil are also shown in blue at the lower part of the frame.

Pile input and output data
When data for the soil has been entered, the pile data must be defined. This is done in the Pile-frame shown below.

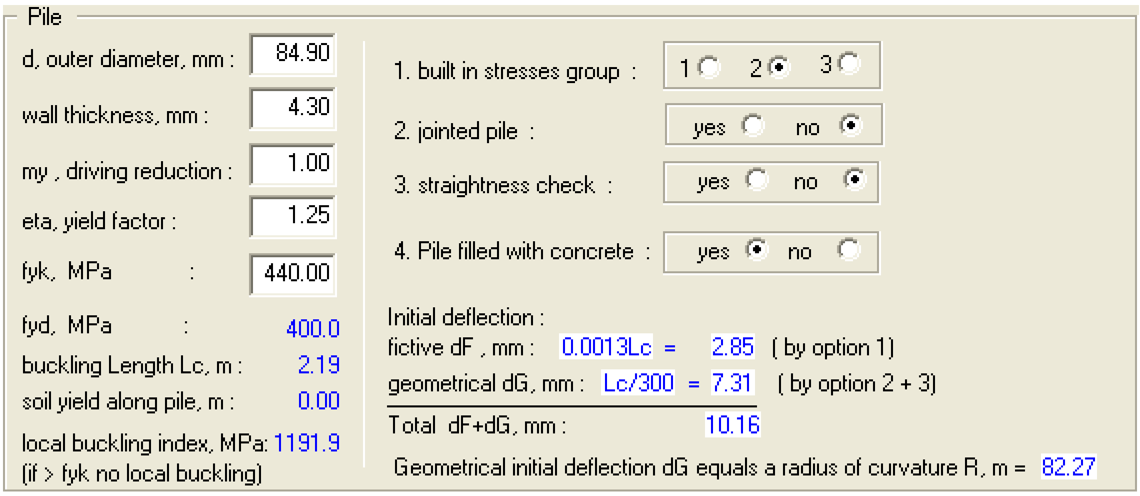

Fig 6. The Pile-frame for input and some output for the pile

The first two text boxes are for input of the outer diameter and the steel tube thickness respectively. The values are given in mm.

Next box is for input of the my-factor. It is a steel strength reduction factor, which reflects pile installation conditions. The value goes from 0.7 for difficult and 0.9 easy driving conditions.

The next box is for input of the eta-factor. It is the plastic/elastic ratio for the pile cross section. In Swedish building codes the maximum allowed value is 1.25. The theoretical value for a tube with very thick wall approaches 1.68 (a circular section). Default value here is 1.0, which corresponds to no plastic action for the cross section.

The last text box in the list is for input of the steel strength fyk in MPa.

Below this box, there are two calculated values shown in blue. The first is the design value for the steel strength in MPa calculated as

fyd = my*fyk/Yn … (8)

The next value is the buckling length in m of the pile, assuming a sine buckling curvature:

Lc = pi*(EI/(Esoil)^1/4 … (9)

If the limit deflection yB is exceeded, the contact pressure will not longer be proportional to the deflection. Instead the contact pressure is constant = qB, as illustrated in fig 5. Below the buckling length is shown the distance along the pile where this plastic condition exist.

Finally, there is figure named 'local buckling index'. This index is describing limiting conditions considering local buckling of the steel tube wall. It is calculated as follows :

Empty steel tube pile : 12600*t/di
Concrete filled tube : 21150*t/di

where t = wall thickness and di = inner diameter of the steel tube.

The index shall be larger than the steel strength fyk to avoid local buckling. Should the index be lower, the index is written in red in the frame. A local buckling condition can be solved by concrete filling of increasing the awll thickness.

Radio buttons

At upper right in the Pile-frame input, there are three arrays of radio buttons., see fig 7. The use of each is explained below.

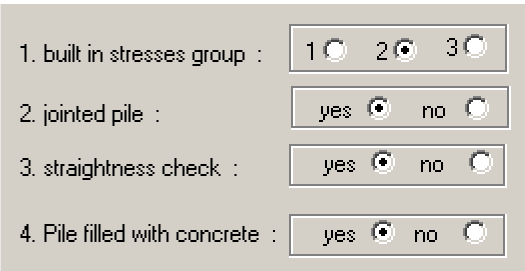

Fig .7 Radio buttons within the Pile input frame.

The first array is to define the cross section class with respect to built in stresses. Group 1 is for hot rolled tubes, not often used for piles. Next class, 2, is for usual thin wall tubes manufactured by welding. The last class is for massive sections or sections with very large wall thickness.

Next array contains two radio buttons. The choice depends whether the pile contains joints or not.

Next array has also two radio buttons. If a straightness check is made for the installed pile, ‘yes’ is marked, otherwise ‘no’. For slender steel tube piles, straightness checking is the the most common routine.

The last array have two radio buttons and defines if the steel tube is has a concrete filling. Concrete filling is not supposed to increase the axial capacity of the pile. For small diameter micro piles the contribution from low strength concrete to the capacity is rather small. The concrete filling then serves as inner corrosion protection and local buckling prevention. it is also easier to get the pile capacity calculations approved if the contribution of the concrete is not considered in the calculation of the axial and flexural stiffness. However, in case of larger diameters and projects with many piles it is justified to investigate and include such contributions. If this program, MicroPile.exe is used for this, a fictive increased wall thickness can be calculated.

Initial deflection of the installed pile

At the lower right of the Pile input frame, the calculated values of the deflection in mm of the pile before it is loaded are shown. The values given are the peak deflections over a length equal to Lc, the buckling length.

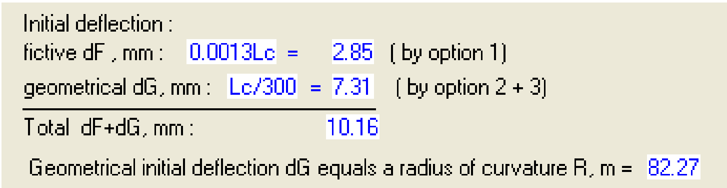

***Fig 8. Calculated values of the initial deflection the installed pile, mm*.**

The initial deflection is consists of two terms, one fictive and one geometrical.

The fictive deflection dF, is taken from the class 1, 2 or 3. The values are 0.0003*Lc, 0.0013*Lkc and 0.0025*Lc respectively. These fictive deflections are included in order to consider built in stresses I the pile section.

The second term, the geometrical initial deflection dG, is, if there are no straightness check made, taken as Lc/300 for a pile without joints and a Lc/200 if there is on joint within the buckling length Lc. The corresponding values for a pile where a straightness is made is Lc/600 and Lc/400, respectively.

The total initial deflection yi for the calculation is the sum of dF and dG.

At the last line of the frame the radius of curvature corresponding to the initial geometrical deflection dG is calculated, assuming the pile axis is a part of a circle radius:

Rg = Lc^2/(8*dG) … (10)

The value of Rg can be measured by a slope indicator.

Calculated pile section data

Below the Pile frame is the frame called Pile data.

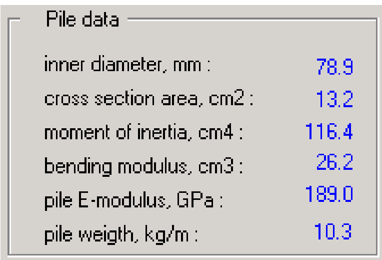

Fig 9. Frame Pile data gives calculated pile cross section data.

The inner diameter is given in mm. The cross section area is given in cm2. The polar inertia I is given in cm4. The bending modulus W is calculated as

$W = eta*2*I/d$ … (11)

The design value of the pile E-modulus is calculated as

$Ered= 0.9*E/Yn$ … (12)

The factor 0.9 is used in order to take into account consideration built in stresses in the pile section material. It might appear redundant to reduce the Emodulus this way since the built in stresses already considered by introducing the fictive initial deflection dF, but this is the usual recommended procedure. The assumed nominal value of E is 210 GPa.

At the last line, the pile weight in kg/m is calculated, assuming the material is steel.

Pile section graph
Below the frame mentioned above, there is a graph of the cross section drawn, fig 12. The purpose is to offer a check that the input diameter and wall thickness are correct. If there is a concrete filling the interior will be shown in green colour.

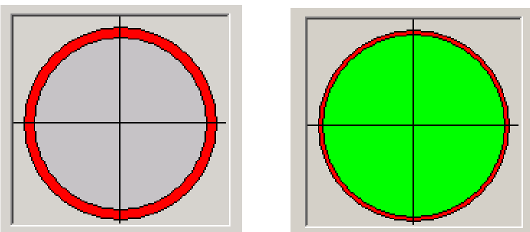

Fig 12. Graph of pile cross section shows input geometry and eventual filling

Saving and retrieving pile data
In order to save a particular pile profile, press the File marker at the upper left of the form, se fig 13. Saving and opening files follows the usual Windows dialogs. From this menu it is also possible to start a print out of the input data and the calculated data.

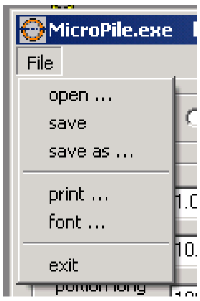

Fig 13. The File menu.

The printout fills an ordinary A4 page. The font can also be chosen. The default value is Courier. It is also possible to exit the programme from this menu, last line.

Project frame
At the left bottom part of the main form there is a frame containing in input text box and a field where the name of the data file that contains the pile data used is displayed in blue, in case a file has been loaded.

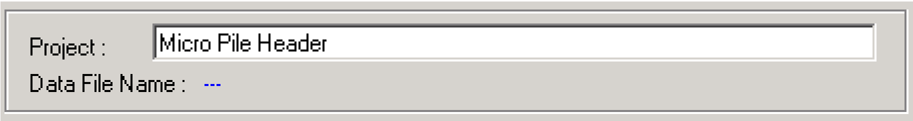

Fig 14. Project and data file name display frame.

In the text box any text can be written. The text written there is included in the printout. The name of the project and the name of the person who has made the calculation are suitable input data here.

Graphical output frame
The graphic output frame and window presents the final results of the calculation. On the horizontal axis of the window, the additional deflection y0 at the middle of the length Lc is presented in mm. This deflection is caused by the load applied at the top of the pile.

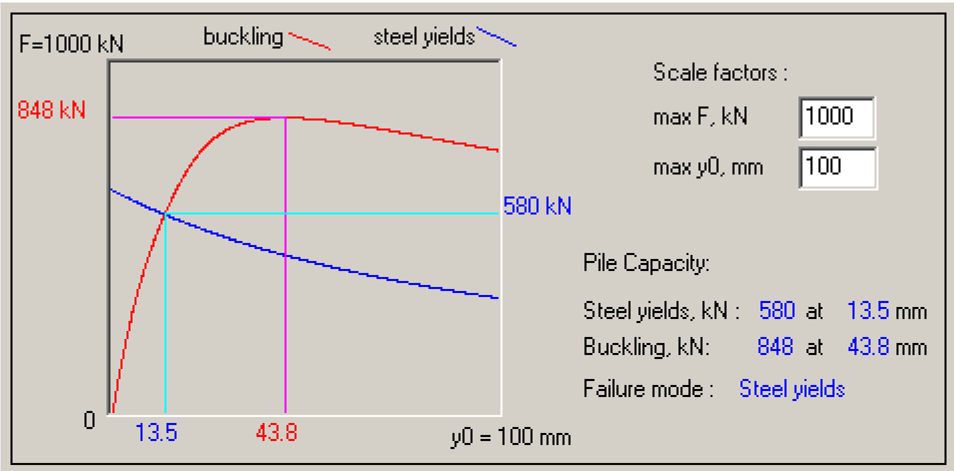

Fig 15 Graphical output window and frame displays pile capacity data

On the vertical scale, the applied force F is shown in kN.

The interval for F and yo shown can be determined by the two input text boxes at the upper right corner of the frame. For example, if the peak buckling force value of interest is above the window, a higher value in the text box Fmax can be inserted and the calculation repeated. This will lower the peak in the window.

The curves in the window are not erased when a new calculation is made. Instead the new curves are drawn along the ones from the calculation before. In this way the influence of changes in input data can be evaluated. When it is desired to erase the content of the window, press the clear=F3 button on the control frame at the bottom of the sheet.

Buckling or steel compression yield failure ?
There are two curves shown in the window. The red curve shows the buckling load as function of the deflection y0. The blue curve shows the steel compressive yield capacity as a function of the same deflection y0). The theory behind, and the functions are described in ref (1).

The buckling force Fc(y0) is calculated as

if y0<=yB : Fc =2 * Sqr(EI * kd * B) * (y0 / (y0 + yi)) : no soil yielding ...(13 a)

or

if y0>yB : Fc = 2 * Sqr(EI * ked * B) * (y0 / (y0 + yi)) : soil yields ...(13 b)

where

yi = initial deflection

y0 = additional deflection at middle of a pile segment with length Lc

ke = a modified soil coefficient. It is calculated using the principle of equivalent work, as shown in appendix A.

The steel yield compression value Fyield(y0) is calculated as

Fyield = fyd * Area / (1 + (y0 + yi) * Area / (2 * W) ... ... (14)

In the window is marked the peak buckling force and the corresponding deflection yo. If this peak is below the blue curve, this buckling load is the pile axial capacity.

If instead the peak buckling load is above the blue curve, the pile capacity is given by the intersection of the blue and the red curve. This means that the section strength determines the capacity, and the value is written in blue at the right vertical of the graphical window. This case is most common in practice. The value of this force and the corresponding deflection is shown in blue.

At the lower right in the pile capacities corresponding to the two different failure modes are echoed together with a line defining actual mode of failure.

Other checks
Some building codes require a check at the pile tip and at pile joints assuming a certain degree of eccentricity there.

Further, when steel tube piles are driven to refusal, a point force which is equal to the working load multiplied with a safety factor (typically 1.7 to 2.2) must be validated. The CASE-method can be used for this.

Note : The stresses during this process often are a limiting factor for the capacity that can be obtained. The compressive stress at the pile tip shall not exceed the yield strength of the steel.

References

Bredenberg H., Influence of initial deflection of micro piles, ISM, Schrobenhausen 2006.

Conversions

The program uses the SI-system adopted in Europe. In order to make a translation to US units, the following relationships are given :

force
1 lb = 4.54 N

lenght
1 inch = 25.4 mm
1 foot = 0.305 m

pressure
1 lb/sq-in =7.04 kPa
1 lb/sq-ft = 0.49 kPa

APPENDIX A

Calculation of equivalent subgrade coefficient ke.

From report 84a from the Swedish Pile Commission, 24 - 25 :

ke = k*(2/pi)* (alpha + 1.5*sin(2*alpha) - (pi-2*alpha)*sin^2alpha)

where

alpha = arcsin(qB/(k*y0))