User manual

Reinforced concrete

cantilever walls

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Software for Architecture, Engineering and Construction

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Presentation

Reinforced concrete cantilever walls *is a program for the design and analysis of reinforced concrete soil retaining cantilever walls. It carried out an automatic initial design of the geometry, section reinforcement and geometric design of the wall footing reinforcement.*

Different soil layers may be defined as well as indicating the presence of the water table, rock layers and loads on the infill and backfill.

Different construction phases or stages may be defined.

Allows for design in seismic conditions.

Provides reports on the data introduced, drawings of the phases, analysis results, force diagram drawings and deformations for each phase or selected phase group, and reinforcement layout drawings.

A simple and easy to follow assistant is also available to generate the wall and its loads.

Reports may be obtained via printer (with optional preliminary view, page setup, etc.) or have them generated as HTML, PDF, RTF or TXT files.

Drawings can be exported to the printer, in DXF or DWG format to any graphic peripheral.

1. Program introduction

1.1. Onscreen help

CYPE programs have on screen help icons to provide the user with the necessary information on the program menus, dialogue boxes and options.

There are four different ways to access the help options:

1.1.1. Pressing F1

To obtain help on a menu option, press F1. All the icons with help explanations available will be highlighted in blue. If you wish to obtain help on an option within a menu, having pressed F1, unfold the menu and click on the desired option.

1.1.2. Question mark icon

A question mark icon  can be seen at the top right hand corner of the title bar. Specific help on a program option can be obtained the following way: click on the question mark icon then unfold the menu containing the option for which the help is sought and click on the option. A window will appear containing the required information. This option provides the same information as when the **F1** key is pressed.

This help can be deactivated in three ways: by clicking on the right mouse button, by clicking on the question mark icon or by pressing the **Esc** key.

You can equally obtain information on the toolbar icons. Upon selecting the question mark icon , the icons will be highlighted in **blue** (as with the F1 option). By then clicking on the icon, the help information will be displayed.

Option windows that open within the program also contain the question mark icon in their title bar. By clicking on it, the option or icon help can be accessed.

1.1.3. Book icon

Within the title bar of several windows, an open book icon  can be found which upon clicking on it will display general information on the contents of the window.

1.1.4. Quick guide

The option information displayed using the F1 key can also be consulted and printed out by selecting **Help > Quick guide**. These explanations are those corresponding to the options found within the screen tabs.

2. Calculations

2.1. Parts of the wall

The wall is considered to be composed of several different parts:

- **Wall.** Elevation of the wall from its start to the top of the wall.
- **Soil.** Fills composed of one or several layers, as infill or backfill, with optional rock layer and/or water table.
- **Foundation.** Strip footing below the wall. The wall may have a shear key to provide stability against sliding.

2.2. Geometry

Below is a list of the terms used in the program:

- **Backfill.** Side of the wall in contact with the soil.
- **Infill.** Side of the wall not in contact with the soil, although in some cases may have some fill.
- **Height.** Vertical distance between the start of the wall and the top.
- **Top thickness.** Thickness of the top of the wall.
- **Bottom thickness.** Thickness at the start of the wall (must be greater than or equal to the top thickness). They may be different; a tapered wall can be defined. When defining the geometry of the wall the thicknesses may be fixed as of the backfill, infill or vertical mid-plane, in which case the thicknesses are measured partially to either face. The sum of both values will be the total thickness.
- **Steps.** Height spans which have a abrupt change in thickness. These are used instead of tapered to provide easier formwork. The steps may be located at one side of the wall or both. The reinforcement is interrupted, bent and placed overlapping that from the span above.
- **Splices.** The vertical reinforcement may be divided into several spans with overlaps/ splices. These may be provided when designing high walls with constant or variable thickness, where the reinforcement mesh corresponding to its entire height cannot be placed, due to its complexity, danger or because the formwork is not high enough. Hence it is recommended it be carried out in several spans. For example, the height of the formwork used is usually 2.50m. Therefore, in order to build a 7m high wall, three building phases must be undertaken: 2.50m, 2.50m and 2m.

The program designs reinforced concrete footings below the wall. The depth of this footing is constant. There are three types of footing:

- Overhang on both sides
- Overhang only to the left
- Overhang only to the right

A shear key may be defined when using any of the three options listed above.

2.3. Loads

The general load state can be as that shown in the diagram below:

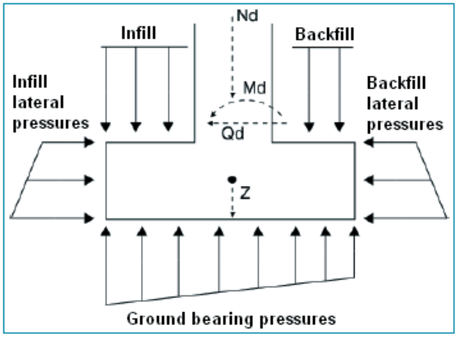

Fig. 1.1.

As fills can be defined on either side of the wall, it can clearly be seen that for each state or situation that may be considered, one side will have more lateral pressures applied to it than the other. The greater lateral pressures produce an 'action' on the wall. The side which receives the smaller lateral pressures will produce a 'reaction', as the wall tends to displace itself towards that side, compressing it.

Hence, different types of lateral pressures can develop:

- **Active pressure.** The soil exerts lateral pressures on the wall allowing enough deformation to arise in the direction of the acting pressure so to cause the wall to fail. The case is common when an 'action' is applied to the soil.
- **Pressures at rest.** The soil exerts lateral pressures on the wall but hardly suffers any deformation, i.e. are null or negligible. This is the case for walls which have an applied movement restriction at their top due to the presence of other elements, for example in the case of basement walls which support a slab at their crown. The value of the lateral pressure is greater than the active pressure. It is not recommended this case be used in the program. However, for special cases, the restriction may be simulated by applying a horizontal load at the top of the wall as long as the user has previously checked that the load cancels outs any displacements at the top of the wall.
- **Passive pressure.** When the wall is displaced towards the soil, the soil is compressed and provides a reaction. Depending on the displacement of the wall and the type of soil, a percentage of this passive pressure or all of it (however, for this to occur, large displacements are required) can develop, unless the soil is very rigid (very compact) or rock is present. The passive pressure does not generally completely develop, and so it is recommended a percentage of it be considered. Its value is much greater than the active pressure. It should be considered with caution.

  The 'elevation of the passive pressure' is the point under which the passive pressure is considered. It is never considered above this elevation. For example, let the starting point of a wall be at elevation '0' and the elevation of the passive pressure also '0'. If a percentage of the passive pressure is activated, it will only act on the depth of the footing. If the elevation of the passive pressure is increased, the resultant of the passive pressure may result to be greater than the active pressure which is not logical.

  Check the shear force diagrams so this does not occur, or always leave the passive pressure elevation below the starting point elevation of the wall.
- **No pressures.** This situation allows for the soil which is reacting to not develop any type of pressure and only its weight is considered as a gravitational vertical component on the footing.

2.4. Results

2.4.1. Wall elevation

A list of all the checks carried out by the program can be consulted on screen (displayed as a report) when using the design and verification options of the program. Next to each check, the corresponding section or article of the code which is verified is displayed. For those cases where no criteria has been established, the Spanish concrete codes and renown bibliography will be used.

It is therefore, very interesting the report be revised as it indicates all the checks that have been undertaken, the design values and codes used.

It is to be consulted whenever the user deems necessary and, if in doubt, view it to ensure all the sections are verified.

The states which are verified by the program are:

2.4.1.1. Check for shear at the base of the wall

The program verifies that the design shear at the wall-footing interface is less than what the section resists at that joint, taking into account the concrete section and reinforcement used.

2.4.1.2. Minimum thickness

The minimum thickness is limited in accordance with the selected code.

2.4.1.3. Minimum geometrical steel ratio

In order to control any cracking that may occur due to he deformations which may arise because of temperature effects and retraction, minimum steel areas are imposed. These vary depending on the selected code.

2.4.1.4. Minimum mechanical steel ratio

Minimum steel ratios are required for the vertical reinforcement so no fissures appear due to compressive bending.

2.4.1.5. Maximum geometrical steel area

A maximum value is imposed for the total vertical reinforcement.

2.4.1.6. Minimum reinforcement spacing

So concrete may be poured correctly, the reinforcement is to have a minimum free distance between its bars. This value used is that of the corresponding code.

2.4.1.7. Maximum reinforcement spacing

This value is limited so no areas remain without reinforcement. It can be considered as it being a minimum condition to be able to refer to it as ‘reinforced concrete’ and not ‘mass concrete’.

2.4.1.8. Check for combined axial force and bending

The resistance check of the section is carried out using the simplified parabola-rectangle stress-deformation diagram of the concrete to establish the area where the wall would fail for compressive bending for the reinforced concrete section. The check for combined axial force and bending is implemented in all the design codes used by the program with its indications regarding the integrations of stresses in the section and the allowable deformation limiting values for the materials making up the section (steel and concrete).

When the check for combined axial and bending is undertaken, the reinforcement is designed to be anchored so it may be considered effective in the design. Additionally, as the combined axial and bending forces act jointly with the shear forces, there is interaction between both forces. This phenomenon is taking into account by shifting the bending moment diagram a distance equal to the effective depth in the most unfavourable direction.

2.4.1.9. Check for shear

The check for this ultimate limit state is carried out in the same way as the combined axial and bending check. As there is no transverse reinforcement in the section only the concrete's contribution is considered to resist the shear forces. The value of the concrete's contribution is established by the term V_{cu} which is obtained in an experimental manner. This term is usually included within the shear check due to tensile failure of the section. The various different expressions which evaluate this V_{cu} component in accordance with the selected codes are considered in the program.

2.4.1.10. Check for cracking

The limit state for cracking is checked with the aim to control the appearance of fissures in the concrete structures. In the case of walls, fissure control is very important as this usually occurs in the backfill face. This area cannot usually be observed and cracks can proliferate which can lead to reinforcement corrosion. The structure can deteriorate without the negative effects being noticeable. It is a case of controlling the fissures which arise due to the loads acting on the wall (soil, water table, surcharges…) and not those due to material retraction and temperature variations, which have been taken into account by considering the minimum geometric values.

To calculate the limiting crack width, a simplified process has been followed when bending is present. Results with an applied safety factor have been obtained compared to those that would be obtained when combined axial force and bending are present.

The general crack width calculation method is used for the various codes used in the program. The results obtained are then compared with the limits imposed by each code, depending on the type of exposure or environment which the structure is found to be in. To establish the ultimate limit states for combined axial force and bending and for shear, the load combinations for the corresponding ultimate limit states are used. However, in the case of cracking, the load combinations corresponding to the characteristic loads are used. The program calculates the characteristic crack width Wk for all the loadcases.

The calculation is repeated at different wall elevations in the same way as is done for when checking for combined axial force and bending and for shear. The most unfavourable value is extracted and is compared with the limiting crack width indicated by each code. This way, it is possible to check whether the serviceability limit state is verified or not.

2.4.1.11. Splice lengths

The program calculates the splice lengths in accordance with the implemented codes.

2.4.1.12. Check of the base reinforcement anchorage at the top of the wall

The program calculates the anchorage lengths in accordance with the implemented codes.

2.4.2. Wall footing

The loads acting on the wall are transformed into a discrete force diagram along the length of the wall. It is as if a resultant were changed into an applied force diagram applied along the base of the wall, discretised in steps internally by the program depending on its dimensions.

The states which are verified by the program are:

2.4.2.1. Stability check

By applying the corresponding limit state combinations, the program checks the resultant lies within the footing and calculates a safety factor against sliding and overturning.

2.4.2.2. Ground bearing pressures

A flat deformation diagram is assumed for the footing. Hence, depending on the forces, a trapezoidal bearing pressure diagram will be obtained. Tensile forces are not admitted. Therefore, when the resultant lies outside the central nucleus, areas without pressure will appear. The resultant must lie within the footing, otherwise there is no equilibrium. The self weight of the footing is taken into account. The program checks the mean bearing pressure does not exceed the allowable bearing pressure and that the maximum pressure at the edges does not exceed the mean pressure by a percentage of the mean.

2.4.2.3. Minimum depth

The program checks that the minimum depth of the footing specified in the corresponding code is complied with.

2.4.2.4. Anchorage lengths

The anchorage of the reinforcement is checked, placing the corresponding hooks where required.

2.4.2.5. Minimum bar diameter

The program checks the diameter of the bars used is at least that indicated in the code.

2.4.2.6. Maximum bar spacing

This value is limited so no areas remain without reinforcement. It can be considered as it being a minimum condition to be able to refer to it as ‘reinforced concrete’ and not ‘mass concrete’.

2.4.2.7. Minimum bar spacing

So concrete may be poured correctly, the reinforcement is to have a minimum free distance between its bars. This value used is that of the corresponding code.

2.4.2.8. Bending in the footing

Bending is checked at the reference section situated at 0.15 times the width of the wall towards the inside of the wall. When designing for bending, footing depths are provided whereby compression reinforcement is not required. If tensile forces appear at the top of the footing, a top reinforcement mesh will be placed.

2.4.2.9. Shear

Shear is checked at the reference section situated at a distance equal to the effective depth from the edges of the wall. When designing for shear, footing depths are provided so no transverse reinforcement is required.

2.4.2.10. Geometric and mechanical ratios

The program checks the geometric and mechanical steel area criteria specified by the code are met.

2.4.2.11. Geometry design

The program allows the user to design the geometry of the wall elevation and footing.

The design criteria used for the wall elevation is:

- Top thickness = 0.25 (h)
- Bottom thickness = 0.11 × equivalent soil height (h). The program calculates the moment at the start of the wall due to the backfill soil and at the top of the wall. Based on that moment, the equivalent soil height is calculated, i.e. the height that would produce the same moment as that previously calculated.

The design criteria used for the footing is:

- Depth = greatest value of the following:
  a) 0.10 × Equivalent soil height (h)
  b) 0.50 × Maximum overhang (If the option **Job > Options > Footing > Design depth as > Rigid** has been selected)
  c) 0.33 × Maximum overhang (If the option **Job > Options > Footing > Design depth as > Flexible** has been selected)
- Overhangs. The overhangs are designed in such a way that the footing is in equilibrium (overturning and sliding) and the allowable bearing pressure of the soil is not overcome.

3. Program description

3.1. Assistant

When creating a new job, the program offers the possibility to use an assistant, which generates the necessary data to describe the wall based on a reduced number of parameters introduced sequentially by the user. It includes the pre-design of the geometry and the load generation. Any data that is generated can be revised and/or modified once the job has been generated.

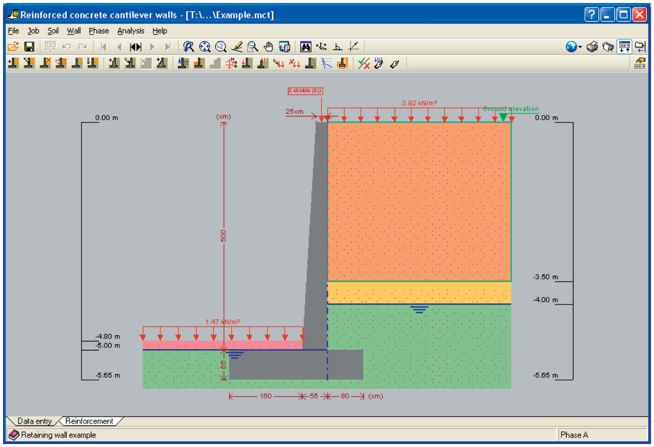

Fig. 3.1

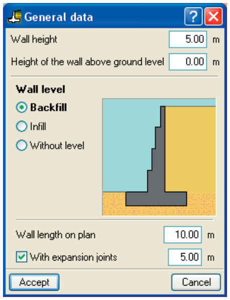

Fig. 3.2

3.2. Reports

Reports can be obtained using the following option **File > Print > Job report**.

The reports may be printed out via printer (with optional previous view, page setup, etc.) or generate HTML, PDF, RTF or TXT files.

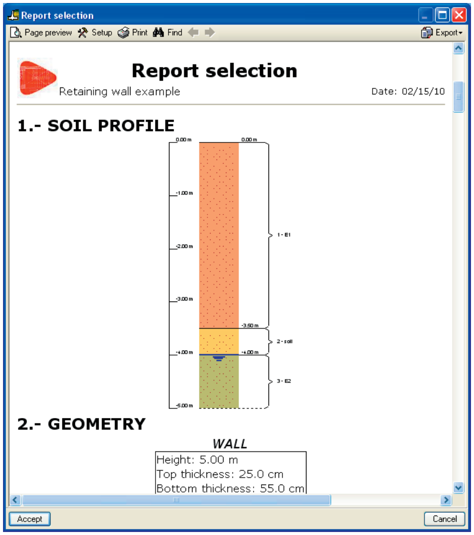

Fig. 3.3

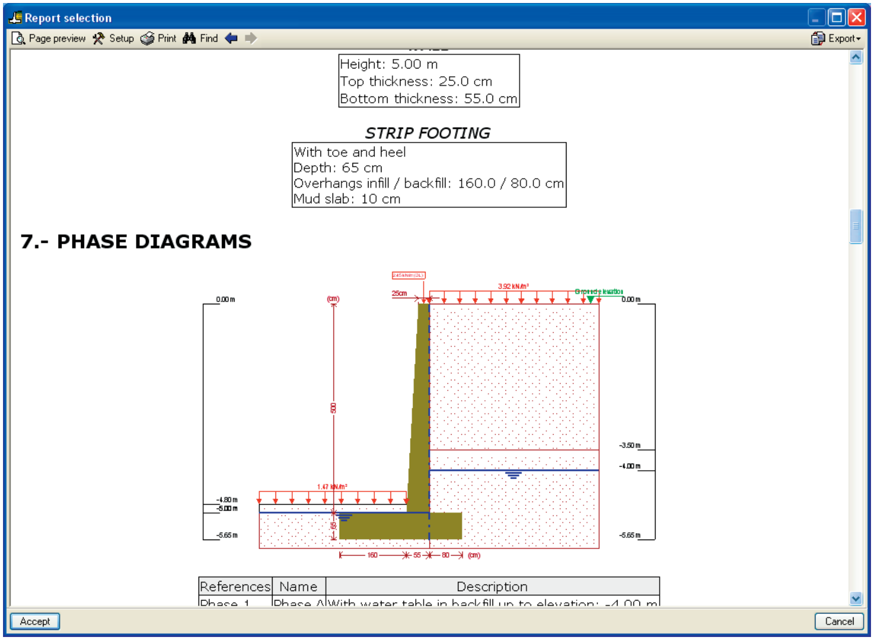

Fig. 3.4

3.3. Drawings

Drawings can be obtained using the option **File > Print > Job drawings**.

The following options can be carried out:

- The **Drawing selection** window allows the user to add one or several drawings to print out simultaneously and specify the output peripheral: printer, plotter, DXF or DWG; select a title block (CYPE's or any other defined by the user) and configure layers.

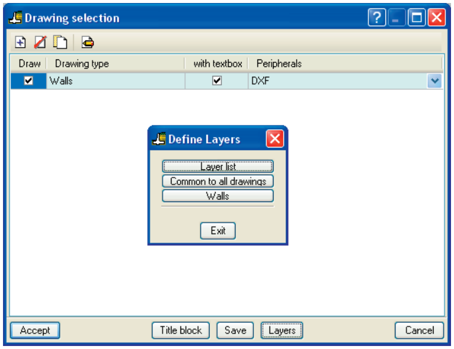

Fig. 3.5

- The elements to be printed can be configured for each drawing, with the possibility to include previously imported user details.

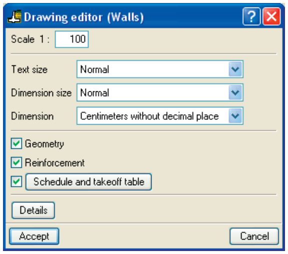

Fig. 3.6

• Modify text positions.

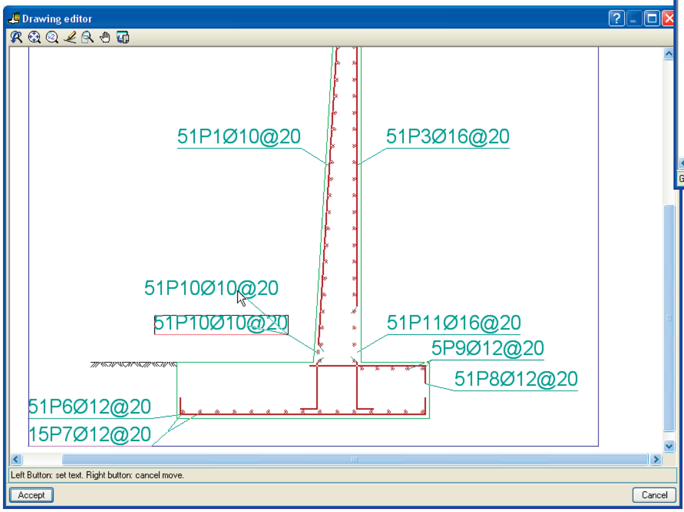

Fig. 3.7

• Place objects in the same drawing or move them to another drawing.

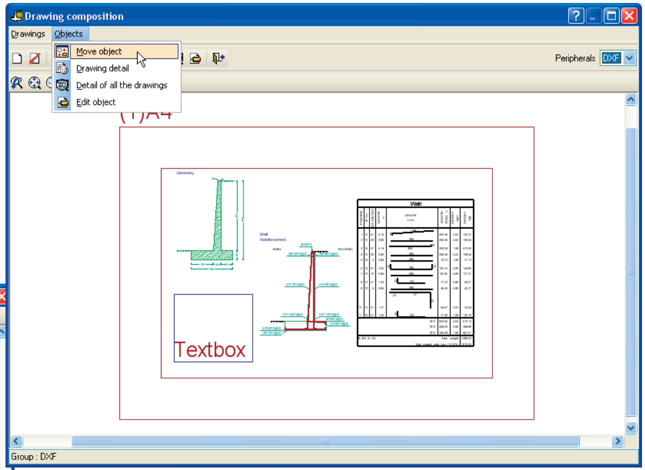

Fig. 3.8