Atir Software Development LTD

# STRAP - Slab Deflection

## Step by step



© Atir Engineering software LTD
13 Kehilat saloniki, Tel Aviv, Israel
Tel: +972-3-6480129
Website: http://www.atir.com
Email: atir@atirsoft.com

# Table of contents

# 1. Abstract

STRAP calculates the linear elastic deflection of a concrete slab based on the gross cross-section moment-of-inertia. However, the actual slab deflections are much greater due to several important factors:

- Cracking.
- reinforcement ratio.
- time-dependent non-linear factors, such as creep and shrinkage.

The STRAP results module has an option to calculate the deflection using a method which takes into account these factors. The method is an empirical one based on an "effective" moment-of-inertia approach and it important to understand that this method is not an exact one.

The method calculates an "effective" (reduced) moment-of-inertia that is a function of the ratio of the actual moment to the cracking moment of the element.

Eurocode 2:

$$Ie = 0.5\left[\frac{Mcr}{M}\right]^2 Ig + \left(1 - 0.5\left[\frac{Mcr}{M}\right]^2\right) Icr \leq Ig$$

ACI 318:

$$Ie = \left[\frac{Mcr}{Ma}\right]^4 Ig + \left(1 - \left[\frac{Mcr}{Ma}\right]^4\right) Icr \leq Ig$$

where the fourth power is used as suggested by Branson for continuous integration.

for both codes:

Ie = effective moment-of-inertia.

Ig = gross moment-of-inertia, including reinforcement.

Icr = cracked moment-of-inertia.

M = service moment.

Mcr = cracking moment

STRAP calculates the effective moment-of-inertia and for each element in both direction and then solves the model again using the reduced stiffness values.

The total deflection at is the sum of the immediate deflection ai from all service loads and the long-term deflection at from the sustained service loads, therefore different stiffness values are used for immediate and long-term deflection calculations based on the value of M derived from the loads applied; the user must define different load combinations for immediate and long-term loads.

The slab deflections will be calculated according to Eurocode 2.

## 2. Geometry Definition

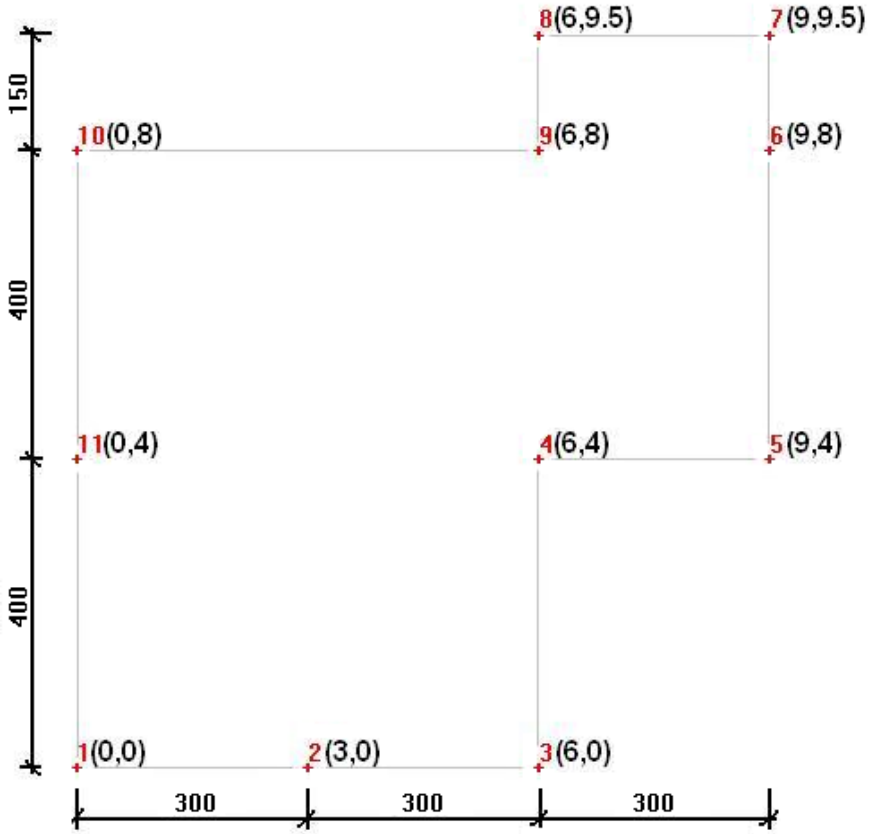
New model:

- click the  new model icon.
- select 

and click 

Nodes:

define the eleven corner nodes that form the slab contour:

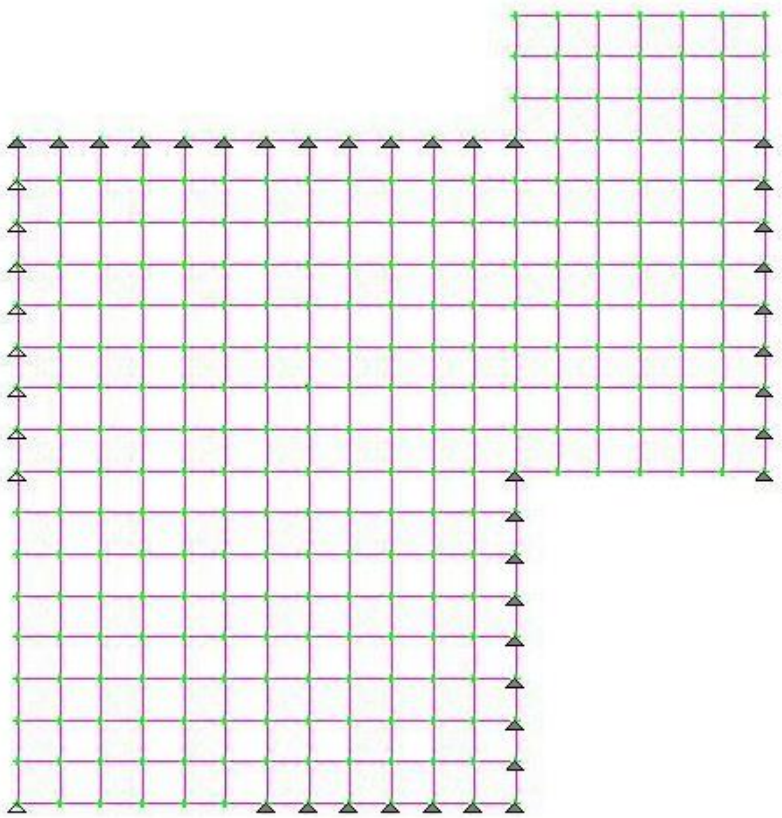



Elements:

- click Elements and then select Mesh in the side menu.
- click *OK* in the following menu.
- select the eleven corner nodes (in the order they are numbered) to define the floor contour and close by selecting the first node again.
- select *End contour definition*.
- click *OK* in the following menu to accept the default mesh parameters; the program creates and displays the floor slab.
- click Properties in the side menu and click and highlight Property 1 in the table.
- Define thickness = 200 mm and E = 30,000 mPa (30 x 106 kN/m2)

Restraints:

- Define pinned supports at the nodes as shown in the following drawing:



## 3. Loads Definition

Define dead and live service loads in separate load cases:

- click  at the top of the screen.
- click  and type in "Dead" as the load case title.
- select  in the side menu.
- select  and  and define a load = -10 kN/m2:

- select *Select all elements*.
- select End load case.
- repeat for a second load case titled "Live" with a uniform load = -3 kN/m2 applied to all elements.
- click 1+2 Solve to solve the model.

## 4. Results - Combinations

Three load combinations are required:

- ultimate loads - total - to calculate the reinforcement
- service loads - total - to calculate the immediate deflection ai
- service loads - sustained - to calculate the long-term deflections. Assume that 30% of the live load is sustained.

To define the combinations:

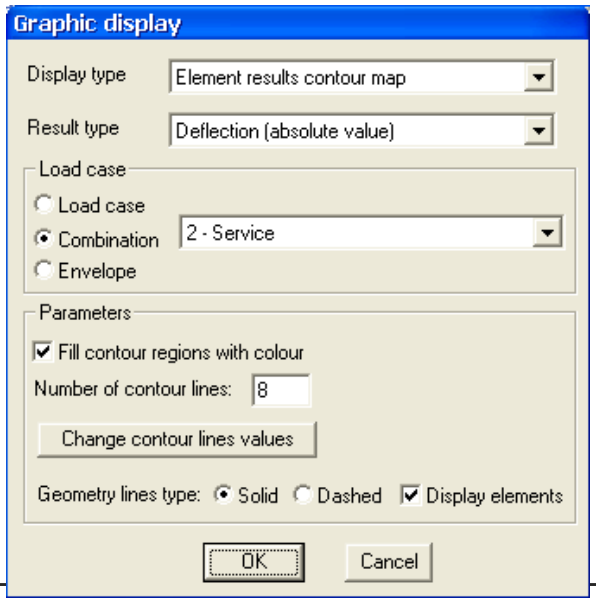
- select Combinations in the side menu and Define/rev...
- define the following combinations:

Combinations definition

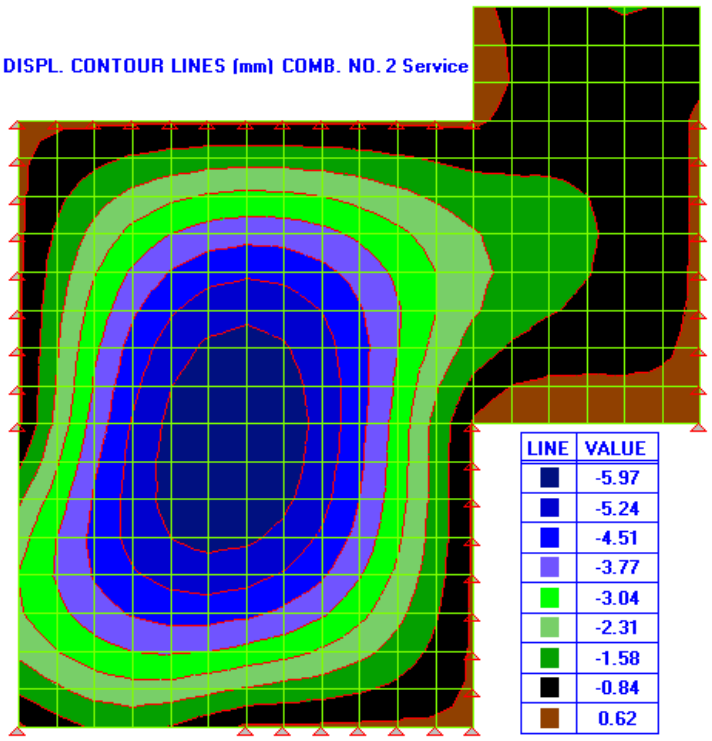
| No. | Title | 1:Dead | 2:Live |
|---|---|---|---|
| 1 | Ultimate | 1.35 | 1.5 |
| 2 | Service | 1. | 1. |
| 3 | Sustained | 1. | 0.3 |

## 5. Results - Elastic Deflections

- click General results in the side menu and Draw result
- arrange the menu as follows, click *OK*.



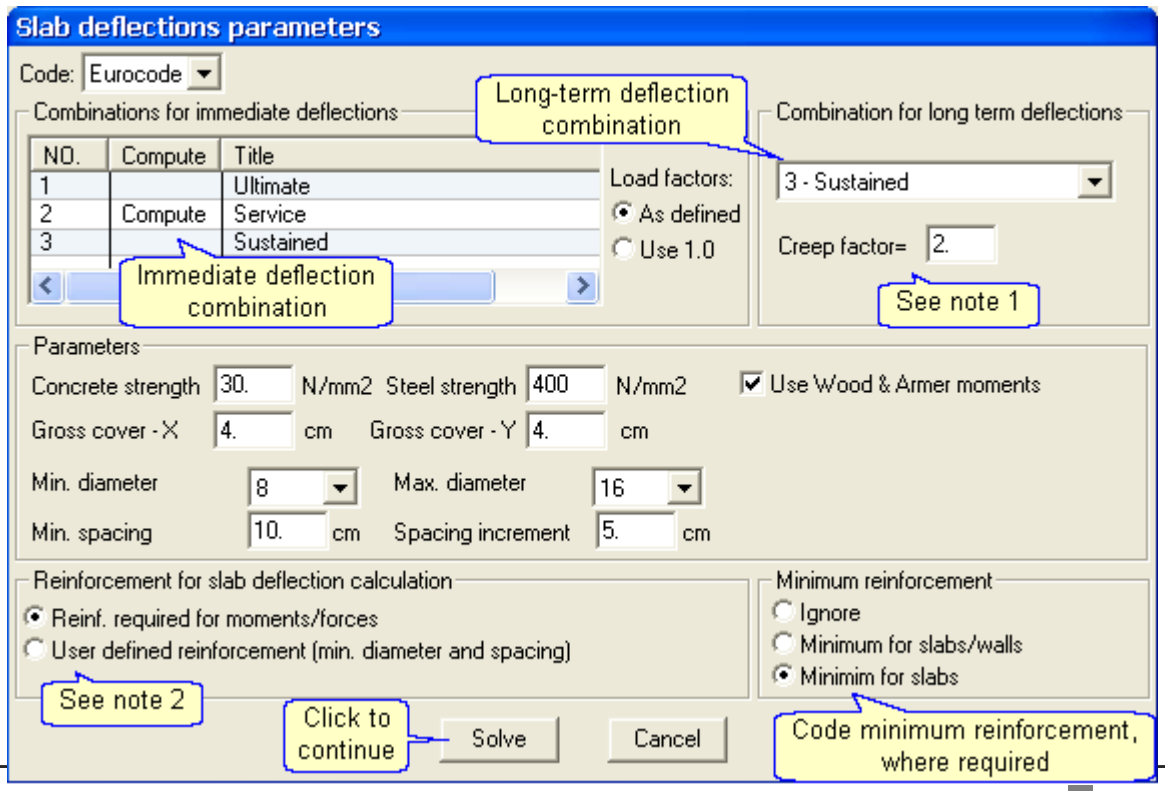
the program displays the deflection contour map:




The maximum elastic deflection is 5.97 mm.

## 6. Results – Cracked Section & Long Term Deflections

- click Slab deflection in the side menu and 1+2 Solve
- specify the deflection parameters:



- Notes:

  - The "creep factor" is used to calculate the total long-term deflection. The deflections calculated from the long-term combination using the effective moment-of inertia are multiplied by this factor. The factor corresponds to:

    Eurocode 2: Equation (7.20)

    ACI 318: Equation (9-11)

  - The reinforcement values used to calculated the effective moments-of-inertia are determined as follows:

    ◉ Reinf. required for moments/forces -

    The program calculates the area required and then selects actual reinforcement according to the specified range of diameters and spacings. This actual area is used to calculate the effective moments-of-inertia.

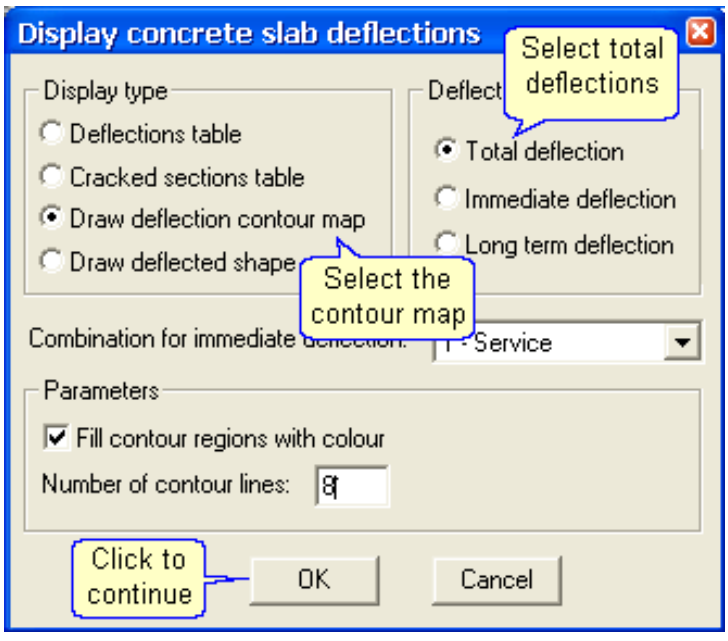
    ◉ User defined reinforcement

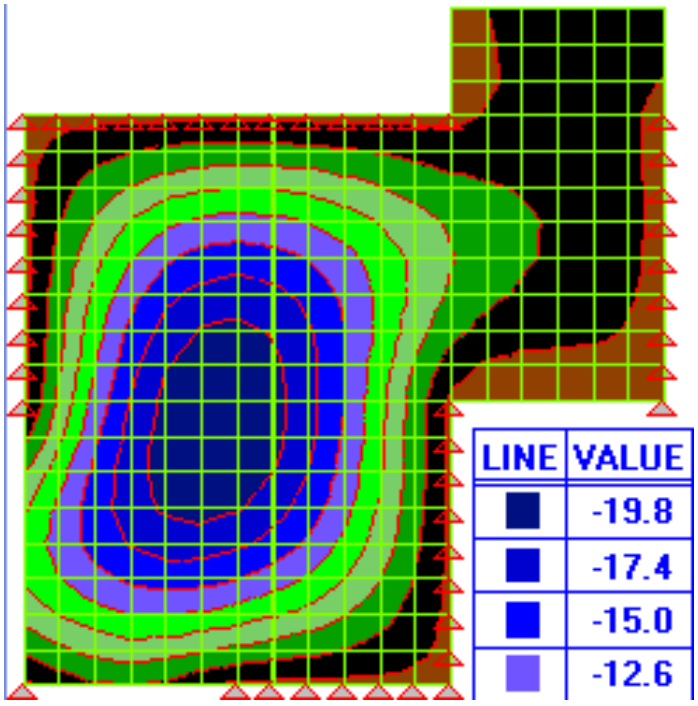
    The program uses the spacing and diameter specified in the reinforcement option in this dialog box for all elements, top and bottom, both directions. However, different reinforcement area may be defined for selected elements, as follows:

    - select Options in the side menu
    - select reinf. para...

- click *Solve* to calculate the reinforcement, the effective moments-of-inertia and to solve the model again with the reduced stiffnesses.

- click Display





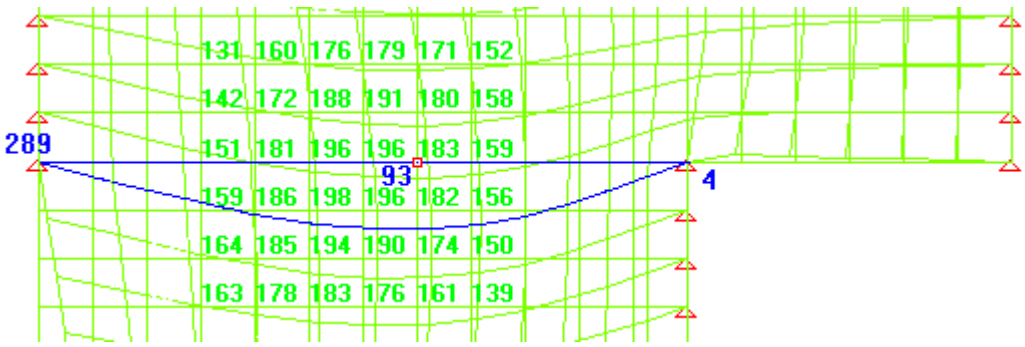

The maximum deflection is 19.8 mm, (19.8/5.97) = 3.3 times greater than the elastic deflection.

## 7. Results – Relative displacement

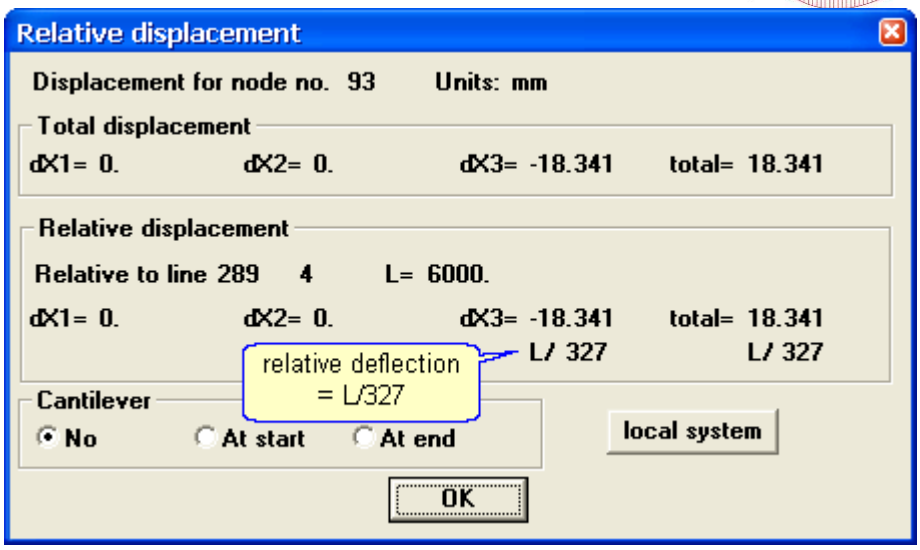
Estimate the deflection at node 93 in terms of L/x, relative to support nodes 289 and 4:

- click 

- select Draw deflected shape and click *OK*; the program superimposes the deflected shape and deflection values:




- click *Relative* button at the bottom of the display.
- click on nodes 93, 289 and 4 (in that order). The program displays the relative deflection:

- 
Relative displacement
Displacement for node no. 93
Units: mm
Total displacement
dX1= 0.
dX2= 0.
dX3= -18.341
total= 18.341
Relative displacement
Relative to line 289 4
L= 6000.
dX1= 0.
dX2= 0.
dX3= -18.341
total= 18.341
L/ 327
L/ 327
relative deflection
= L/327
Cantilever
No
At start
At end
local system
OK

Cracked section property table:

- click Display
- select Cracked sections table and click *OK*; the program displays the following table:

Slab deflection parameters for load no. 2 (Units: ton, ton*meter)

Exit Goto Print Copy

Concrete: 30 Steel: 400 Cover: 4.0 Code: EURO 2 (Wood&Armer moments)
Creep factor 2.0

| Elem. | Comb | Dir | Mcr | M | F | As | As' | x | Ir/Ig | Ie/Ig |
|---|---|---|---|---|---|---|---|---|---|---|
| 89 | 2 | X | 20.32 | 33.00 | 0.00 | 10 | 0 | 4.1 | 0.183 | 0.338 |
| | | Y | 19.92 | 18.09 | 0.00 | 6 | 0 | 3.3 | 0.120 | 1.000 |
| 90 | 2 | X | 20.23 | 32.30 | 0.00 | 9 | 0 | 4.0 | 0.170 | 0.332 |
| | | Y | 19.85 | 18.47 | 0.00 | 5 | 0 | 3.1 | 0.109 | 1.000 |

where:

**Elem** = element number.

**Comb** = combination used for deflection calculation.

**Dir** = direction. Properties are calculated in both reinforcement directions.

**Mcr** = cracking moment.

**M** = moment at the element center.

**F** = The element axial force.

**As** = the tension reinforcement (calculated, minimum or user-defined).

**As'** = the compression reinforcement (calculated, minimum or user-defined).

**X** = height of the compression block in the section.

**Ir/Ig** = ratio between the cracked and uncracked moments-of-inertia.

**Ie/Ig** = ratio between the effective and uncracked moments-of-inertia.

For example, in element 90

- the moment in the X-direction = 32.3 kN-m is greater than the cracking moment = 20.23 kN-m
- the section is cracked; hence the effective moment-of-inertia is 33.2% of the uncracked moment-of-inertia.
- in the Y-direction, the moment = 18.47 is less than the cracking moment, hence the program uses the uncracked section (Ie/Ig = 1.000)