Structural Analysis Software

Reference Manual

MCAP

Version 1.0

© C. Lugtmeier

COPYRIGHT AND DISCLAIMER OF WARRANTY

All files of the MCAP library are copyrighted © by Caspar Lugtmeier.

MCAP is distributed in the hope that it will be useful, but THE COPYRIGHT HOLDER PROVIDES THE PROGRAM "AS IS" WITHOUT WARRANTY OF ANY KIND, EITHER EXPRESSED OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. IN NO EVENT WILL THE COPYRIGHT HOLDER BE LIABLE TO YOU FOR DAMAGES, INCLUDING ANY GENERAL, SPECIAL, INCIDENTAL OR CONSEQUENTIAL DAMAGES ARISING OUT OF THE USE OR INABILITY TO USE THE PROGRAM.

This version of MCAP is a Giftware release. You may use it as long as you like, but only for non-commercial purposes and only as a private person. Permission to copy the whole, unmodified, MCAP library is granted provided that the copies are not made or distributed for resale (excepting nominal copying fees) and provided that you include on each copy this copyright notice and disclaimer of warranty.

HSL Bouwcombinatie Hollandse Meren	onderwerp:	datum:
		naam:
		bl. nr.: van

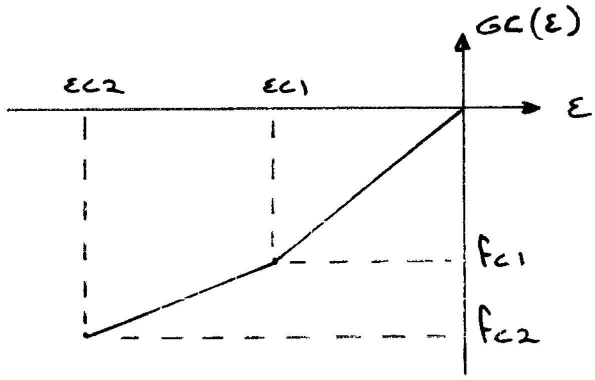
Commands

MCAP	starts menu interface for easy use
ULS	solves ULS for current input → solves x.uls with $\Sigma N = 0$
SLS	solves SLS for current input → solves x.sls & εct.sls with $\Sigma N = 0$ & $\Sigma M = 0$
MNK	calculates MNk diagram for current input → uses Nd for axial force and Ψ.uls (!) → uses SLS solver & ULS solver
INFOS	plots section and displays section properties
PROPS	calculates section properties
PLOTS	plot section
RIBO	rotate section, rebar & prestr for 180°
EMOD	calculates E moduli and displays them

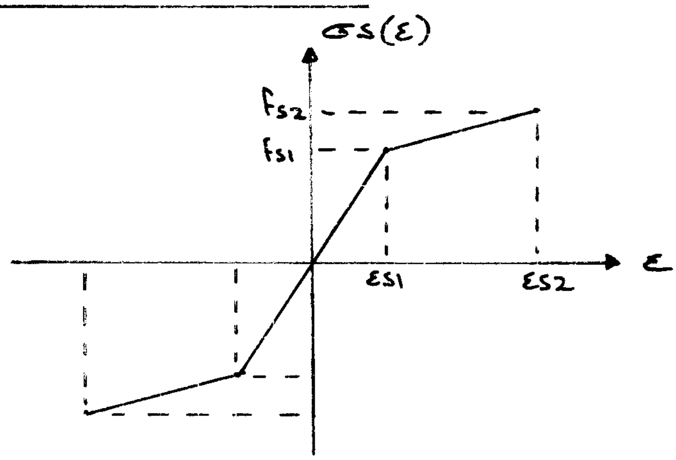
HSL Bouwcombinatie Hollandse Meren	onderwerp:	datum: .... naam: .... bl. nr.: .... van ....

→ σc	calculates concrete stress $\varepsilon \rightarrow \sigma c$
→ σp	calculates prestr stress $\varepsilon \rightarrow \sigma p$
→ σs	calculates rebar stress $\varepsilon \rightarrow \sigma s$
→ N_c	calculates "concrete force" $x \quad \varepsilon ct \rightarrow N_c$
→ y	calculates distance of N_c to top of sect $x \quad \varepsilon ct \rightarrow y$
→ N_s	calculates "rebar force" $x \quad \varepsilon ct \quad \Psi \rightarrow N_s$
→ M_s	calculates "rebar moment" $x \quad \varepsilon ct \quad \Psi \rightarrow M_s$
→ ΔN_p	calculates increase of "prestr force" $x \quad \varepsilon ct \quad \Psi \rightarrow \Delta N_p$
→ ΔM_p	calculates increase of "prestr. moment" $x \quad \varepsilon ct \quad \Psi \rightarrow \Delta M_p$

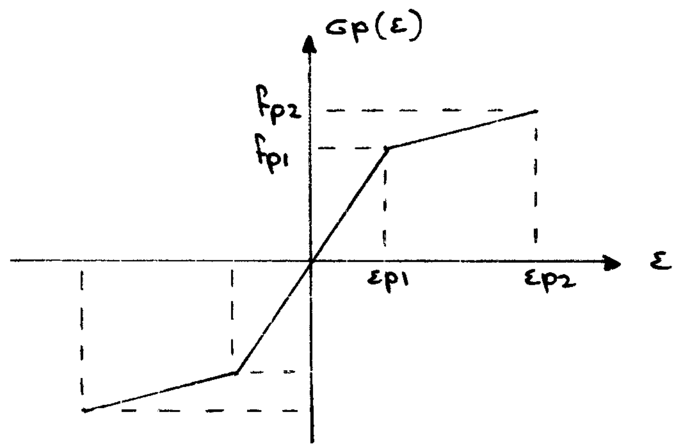
stress-strain concrete



stress-strain rebar



stress-strain prestressing



User variables

Input

SECT : describes concrete section with array

$$\begin{matrix} [[\,width_1, & height_1\,] & (slice_1) \\ [\,width_i & height_i\,] & (slice_i) \\ [\,width_N & height_N\,]] & (slice_N) \end{matrix}$$

RBAR : describes reinforcement bars with array

$$\begin{matrix} [[\,ds_1 & As_1\,] \\ [\,ds_i & As_i\,] \\ [\,ds_N & As_N\,]] \end{matrix}$$

ds : distance from top
As : area of rebar

PSTR : describes prestressing strands with array

$$\begin{matrix} [[\,dp_1 & Ap_1 & \sigma pw_1\,] \\ [\,dp_i & Ap_i & \sigma pw_i\,] \\ [\,dp_N & Ap_N & \sigma pw_N\,]] \end{matrix}$$

dp : distance from top
Ap : area of prestr.
σpw : stress in prestr.

$\varepsilon c1, \varepsilon c2, fc1, fc2$: see stress - strain diagram concrete

$\varepsilon s1, \varepsilon s2, fs1, fs2$: " " " " rebar

$\varepsilon p1, \varepsilon p2, fp1, fp2$: " " " " prestr.

$\psi s.sls$: bond factor rebar SLS ($0 \leq \psi \leq 1$)

$\psi s.uls$: " " " ULS "

$\psi p.sls$: " " prestr. SLS "

$\psi p.uls$: " " " ULS "

Nd : axial force on section for ULS (including prestressing!!) + = tension

Nrep : axial force on section for SLS (including prestressing !!) + = tension

Mrep : moment on section for SLS (including prestressing !!) always > 0 !

note: if $M_{rep} < 0$, use RIBO command

σcr : stress at rupture (used by MNK command)

Output

εct.uls : strain at top of section for ULS

εcb.uls : " " bottom " " " "

σct.uls : stress " top " " " "

σcb.uls : " " bottom " " " "

x.uls : strain state for ULS (see formulas)

y.uls : distance to top of Nc for ULS

εs.uls : strain array of rebar for ULS [ds; εs;]

εp.uls : strain array of prestr for ULS [dp; Δεp; Σεp;]

σs.uls : stress array of rebar for ULS [ds; σs;]

σp.uls : stress array of prestr for ULS [dp; Δσp; Σσp;]

Mu : ultimate moment capacity for ULS

$\varepsilon ct.sls$	:	strain at top of section for SLS
$\varepsilon cb.sls$	:	" " bottom " " " "
$\sigma ct.sls$	:	stress " top " " " "
$\sigma cb.sls$	:	" " bottom " " " "
x.sls	:	strain state for SLS (see formulas)
y.sls	:	distance to top of Nc for SLS
$\varepsilon s.sls$	:	strain array of rebar for SLS $[ds_i \;\; \varepsilon s_i]$
$\varepsilon p.sls$	:	strain array of prestr for SLS $[dp_i \;\; \Delta\varepsilon p_i \;\; \Sigma\varepsilon p_i]$
$\sigma s.sls$	:	stress array of rebar for SLS $[ds_i \;\; \sigma s_i]$
$\sigma p.sls$	:	stress array of prestr for SLS $[dp_i \;\; \Delta\sigma p_i \;\; \Sigma\sigma p_i]$
Ac	:	area of concrete section
zct	:	distance of top to neutral axis
zcb	:	" " bottom " " "
Ic	:	moment of inertia
h	:	total height of concrete section
Ace	:	Ac using elastic properties
zcte	:	zct " " "
zcbe	:	zcb " " "
Ice	:	Ic " " "

Notes

- rebar and prestr. can be placed anywhere in section
- moment (Md / Mrep) yields tension at bottom of section. If this should be at the top, use the following "trick" : keep moment positive (tension at bottom) but rotate the section, rebar and prestr 180° (using the R180 command)
- bond factor ψ : see national code

  possible values are :

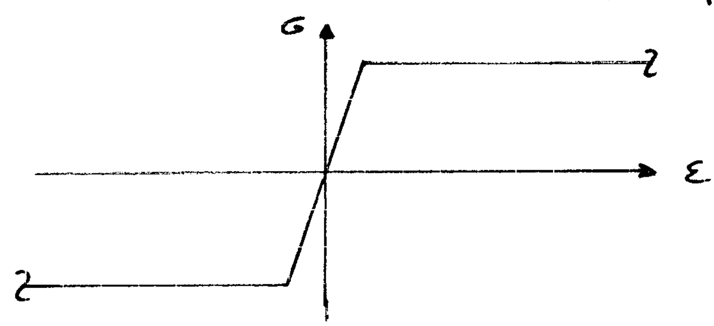
	ψ sls	ψ uls
prof. rebar in concrete	1.0	1.0
unprof. rebar in concrete	0.5	1.0
prestr. strands in concrete	0.75	1.0
prestr. strands in grout	0.5	1.0

usually 1.0 !

! - stress-strain diagram of rebar :

To use the ULS solver correctly the ultimate strain of the rebar should be very large. The ULS solver assumes the section "cracks" when the concrete at the top of the section has reached the strain ε_{c2}. Thus, if $\varepsilon_s > \varepsilon_{s2}$, the strain of the concrete at the top of the section is Not reduced. This should not be a problem since the influence of this on Mu is very small. So use something like this (substitute own values):

ε_{s1} = 0.002175 f_{s1} = 435 ε_{s2} = 9E499 f_{s2} = 435



Bouwcombinatie Hollandse Meren

onderwerp: ....

datum: .... naam: .... bl. nr.: .... van ....

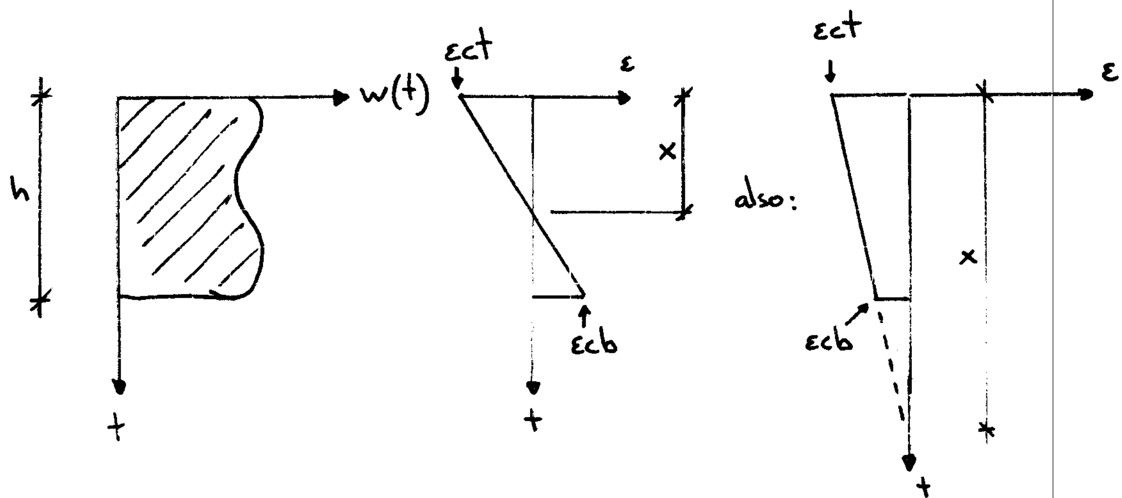
- if the ULS and SLS solver don't meet your needs, just use the provided commands like →Nc →Ns →ΔNp etc etc and use different (custom) solvers with your own programs

- it might be useful to write your own USERRPL "preprocessor" to generate material variables etc

- you could also write your own USERRPL "postprocessor" to execute your code checks

- the SLS solver is sensitive for the provided "first guesses" !
  the default guesses are :
  x.sls = h/2
  εct.sls = εc2/4

Formulas



note: $\varepsilon > 0$ = tension
$\varepsilon < 0$ = pressure

$$\varepsilon(t) = -\frac{\varepsilon ct}{x} * t + \varepsilon ct$$

- concrete

$$N_c = \int_0^h \sigma c\{\varepsilon(t)\} * w(t)\, dt$$

$$y = \frac{\int_0^h \sigma c\{\varepsilon(t)\} * w(t) * t\, dt}{N_c}$$

- rebar

$$N_s = \sum_{i=1}^{N} \sigma s\{\Psi s * \varepsilon(ds_i)\} * As_i$$

$$M_s = \sum_{i=1}^{N} \sigma s\{\Psi s * \varepsilon(ds_i)\} * As_i * (ds_i - zct)$$

(zct will be zcte if using elastic properties)

BOUWCOMBINATIE HOLLANDSE MEREN

onderwerp: ...

datum: ...
naam: ...
bl. nr.: ... van ...

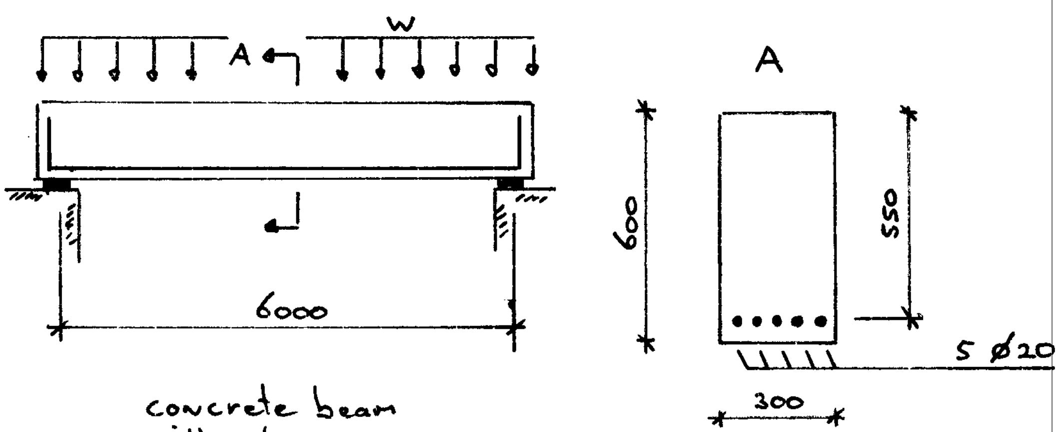
- prestressing

$$\Delta N_p = \sum_{i=1}^{n}$$

$$\Delta M_p = \sum_{i=1}^{n}$$

- section

Examples



concrete beam with rebar

materials: $\varepsilon_{c1} = -0.00175$ $f_{c1} = -21$ $\varepsilon_{c2} = -0.0035$ $f_{c2} = -21$
$\varepsilon_{s1} = 0.002175$ $f_{s1} = 435$ $\varepsilon_{s2} = 9E499$ $f_{s2} = 435$
$\psi_{s.uls} = 1.0$ $\psi_{s.sls} = 1.0$
$\varepsilon_{p1} = 1$ $f_{p1} = 1$ $\varepsilon_{p2} = 1$ $f_{p2} = 1$ $\psi_{p.uls} = 1$ $\psi_{p.sls} = 1$
(dummy values for prestr !)

section : SECT [[300 600]]
RBAR [[550 1570]] $(5 * \frac{1}{4}\pi 20^2 = 1570)$
PSTR [[0 0 0]]

loads : selfweight load : $0.3 * 0.6 * 24 =$ 4.3 kN/m
dead load : 34.8 kN/m
live load : 12.6 kN/m

$N_d = 0$ (no axial force)
$N_{rep} = 0$ "

$$M_d = \frac{1}{8} * \{1.2 * (4.3 + 34.8) + 1.5 * 12.6\} * 6^2$$
$$= 296 \text{ kNm} = 296 * 10^6 \text{ (Nmm) } (!)$$

$$M_{rep} = \frac{1}{8} * \{4.3 + 34.8 + 12.6\} * 6^2$$
$$= 233 \text{ kNm} = 233 * 10^6 \text{ (Nmm) } (!)$$

note : M_d not needed for input, but used to check $M_u > M_d$ (!)

=> solve ULS (you can provide a "first guess" of x.uls for the ULS solver)

=> solve SLS (you can provide a "first guess" of x.sls & εct.sls for the SLS solver)

condensed results :

$M_u = 337.2 * 10^6$ (Nmm) (> Md => "OK")

$\sigma s.sls = 315$ (MPa) $\sigma s.uls = 435$ (MPa)

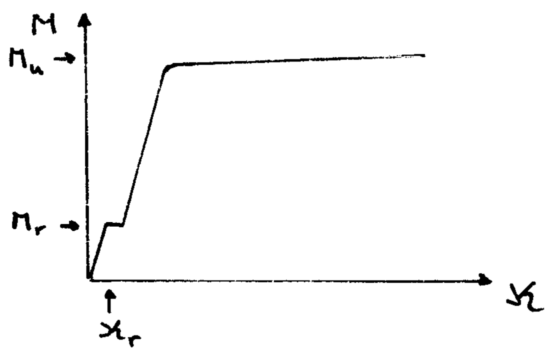
=> calculate MNk diagram (MNK command)

use $\sigma cr = 2.8$ (MPa)

condensed results :

$M_r = 50.4 * 10^6$ (Nmm) $\left(= \left\{ \sigma cr - \frac{Nd}{A_c} \right\} * \frac{I_c}{zcb} \right)$

$\kappa_r = 7.8 * 10^{-7}$ (1/mm) $\left(= \frac{A_c * \sigma cr - Nd}{A_c * E_c * zcb} \right)$



note : ~~using~~ elastic ~~properties you get the following results~~

~~$M_u = 337 * 10^6$ (Nmm)~~