CONCRETE DESIGN ACCORDING TO EUROCODE 2 (referred to the NATIONAL ANNEX for GERMANY)

INTRODUCTION

Name: REGBEM v 2.5

The following program determines for a rectangular concrete beam the reinforcement both on top (***As2*** on compressive side) and at the bottom (tensile area ***As1***, see fig. 1), if the dimensions, concrete quality, loads Md and/or Nd and the ratio As2/As1 are given.
Afterwards the results are depicted in a plot (fig. 18).
For a small ratio Md/Nd see section HINTS AND WARNINGS (page 4).
Calculations are carried out on the basis of EUROCODE 2 (DIN EN 1992-1-1:2011-01) [**1**] and the accompanying national annex for Germany [**2**].
The consideration of the net area $Ac_{,net}$ in the compressive area ($Ac_{,comp}$ = x * b) is optional,
if As2 > 0: $Ac_{,net} = Ac_{,comp} - As_2$
Quality of reinforcement: BSt 500 S (A) .
Allowed quality of concrete f_{ck}: C 12/15 - C 50/60, where the first number stands for the strength f_{ck} and the second one for $f_{ck,cube}$
Allowed ratio of reinforcement As2/As1: 0<=As2/As1<=1

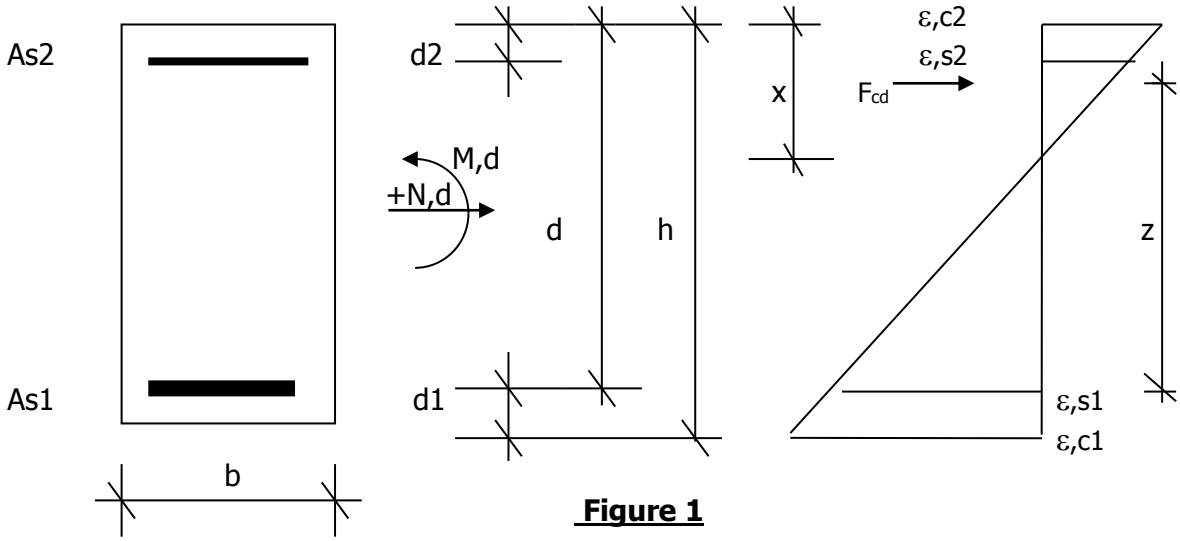


Figure 1

Taken into consideration is the distribution of concrete stress based on the „Parabel-Rechteck-Diagramm (P-R) " (index ***3*** , default value) , bilinear distribution (***2***) or block form of stress (***1***) (figures 3.3 – 3.5 of [**1**]).
As well as $f_{tk,cal}$ = 525 N/mm² and the simplified assumption $f_{tk,cal}$ = 500 N/mm² according to [**1**], fig. 3.8 for the relation of stress-strain of steel are provided.

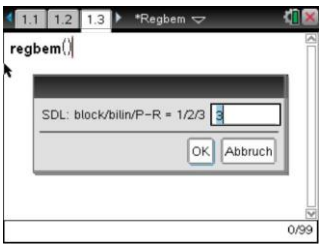
INSTALLATION:

Store the file „Regbem" in the MyLib-folder and start „regbem()" on page 1.1 of the document.

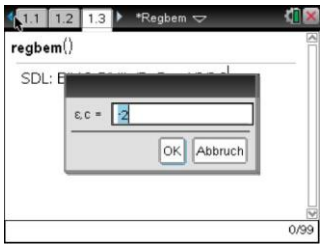
DESCRIPTION (explained in form of the following example) :

A rectangular concrete beam having a concrete quality of C30/37 with dimensions b / h = 35 / 55 cm and the distances of the layers of reinforcement d2 / d1 = 5 / 5.5 cm is reinforced with **3** bars diameter #**14** (As2 = 4.62 cm²) on the top and **4** bars diameter #**25** (As1 = 19.63 cm²) at the bottom.
Will the selected reinforcement be sufficient for the loads of M_d = 387 kNm and N_d = -58 kN (pressure force)?

Taken into account are the „Parabel-Rechteck-Diagramm (P-R) " with Eps,c2 = - 2‰ and a steel stress of $f_{tk,cal}$ = 525 N/mm². The net area of the compressive zone is not to be considered.
Select ***regbem()*** from the **var**-menu and enter the appropriate index for the used diagram concerning the distribution of concrete stress (Default: ***3*** , which will be the right value for this example), see fig. 2). Then use the default for ε,c2 (= **-2‰**) as input (or enter ε,c2) (fig. 3).



2)

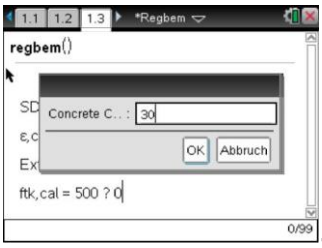


3)

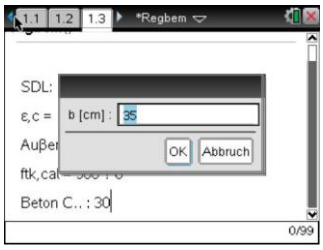
4)

In the next screen (fig. 4) you may enter ***1*** for an extraordinary loadcase or ***2*** if a pre-fabricated beam is examined. That will change the normal safety factors (γc = 1.5 , γs = 1.15) to γc = 1.3 , γs = 1.0 or γc = 1.35 , γs = 1.15, respectively. As this example handles a "*normal*" situation, leave the default value ***0*** (or enter it) in the input box.

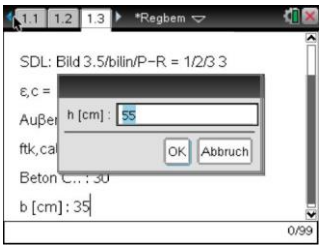
Just do so in the following request: enter (or leave as default value) ***0*** for $f_{tk,cal}$ = 525 N/mm², otherwise key in ***1*** for "σ=500".
In the next request enter the quality in form of strength f_{ck} of the concrete "C..". (optional: 12, 16, 20, 25, 30, 35, 40, 45, 50), in this example key in ***30***. (fig. 5)



5)

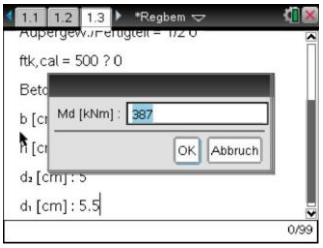


6)

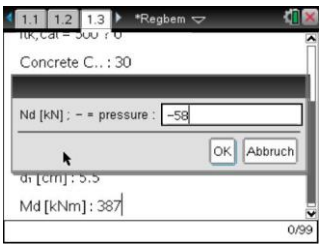


7)

In the following screen enter ***35*** for b, ***55*** as value for h (fig. 6 - 7), then ***5*** and ***5.5*** for d2 and d1



8)

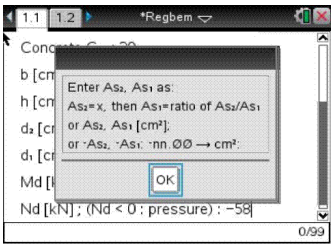


9)

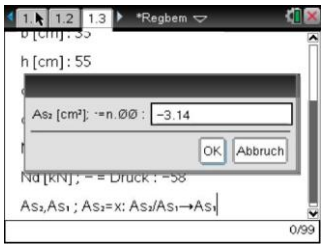
Now key in ***387*** for Md (fig. 8) and ***-58*** for Nd (fig. 9). Be sure to use **(-)** as minus-key !

To enter the ratio As2/As1 there are three options available (fig. 10):

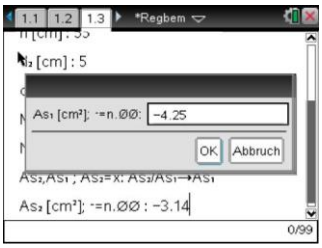
(1) You enter a default ratio ⟶ key in ***x*** for As2 and the ratio ***As2/As1*** (<= 1 !) in As1.
(2) Enter an area [cm²] for As2 and do so for As1. (Make sure that 0 <= As2 <= As1 !!!)
(3) Enter a ***negative*** value in form of ***–nn.dd***, where ***nn*** is the number and ***dd*** the diameter # [mm] of bars.



10)



11)



12)

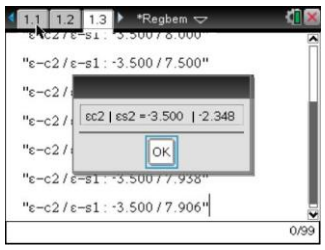
In our example enter ***-3.14*** in As2 and ***-4.25*** in As1 (fig. 11 – 12). The ratio will be set to ***4.618/19.635*** = ***0.2352.***

In the next prompt for the input of the net area $Ac_{,net}$ enter ***0*** (no consideration in this example), otherwise you would have to key in ***1***.

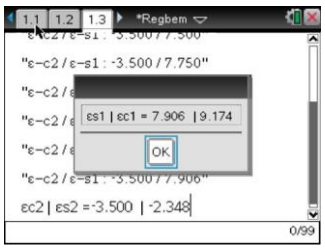
After some seconds of iteration the results are presented in text-boxes (fig. 13 – 17) in the following order (for the meaning of ε..., x, z see pict. 1, press ***ENTER*** to continue the output:

ε,c2 / ε,s2 = -3.500 / -2.348
ε,s1 / ε,c1 = 7.906 / 9.174
ξ / x = 0.307 / 15.2
ζ / z = 0.872 / 43.2
As2 / $As1_{,req}$ = 4.61 / 19.58 [cm²]

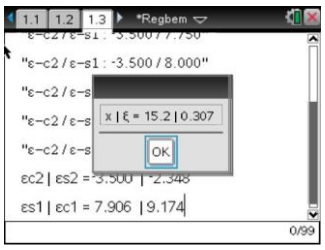
with : x : width of compression zone ξ * d in [cm]
z : width of internal lever ζ * d [cm], see pict. 1)



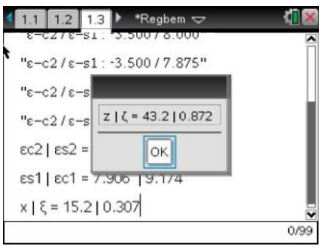
13)



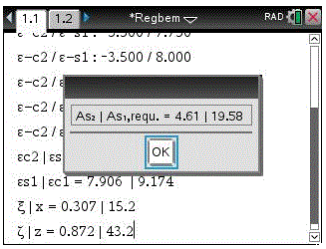
14)



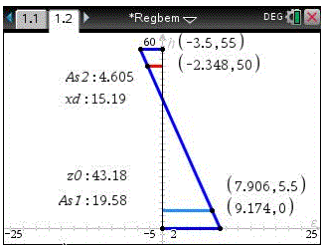
15)



16)



17)



18)

As the required reinforcement $As1_{,requ}$ is less than the chosen area (19.63), the reinforcement of the beam is sufficient ($As2_{,requ}$ =~ $As2_{,chosen}$) !

If As2 = 0 , the output of ε,s2 and As2 is omitted. Therefore, if you run the example again with As2 being 0 (enter ***x*** for As2 and ***0*** for As1 according to option (1) above), the result will be: $As1_{,requ}$ = 20.91 [cm²],

which is greater then the set area of 4 bars # 25 (19. 63 cm²) for the bottom layer !

On page 1.2 you will find a plot showing the distribution of strains along the height (ε [‰], h [cm]), the required reinforcement As2, $As1_{,req}$ and the values for x and z (depicted as xd and z0) , see fig. 18).

HINTS AND WARNINGS:

The form of the output of the recent version may slightly differ from the figures of that documentation!
If there is no solution possible, an appropriate warning will be issued.
This may be in the following cases:
M/(|N| * h) ~ 0 and |N| < (b * h * 0.85 * f_{ck} / 1.5) , if N < 0
Minimum reinforcement according to section 9.5.2 (2) of [**1**] and [**2**] is not taken into account.

VERSION:

Vers. 1.0: first version submitted to the file archive
Vers. 2.0: plot of results added
Vers. 2.1: plot improved, some changes in the documentation
Vers. 2.5: plot revised

LITERATURE:

[**1**]: DIN EN 1992-1-1:2004 + AC 2010 (EUROCODE 2)
[**2**]: National Appendix DIN EN 1992-1-1/NA on the base of [**1**]
[**3**]: Wommelsdorff/Albert "Stahlbetonbau Teil 1 ; 10th edition (Werner publisher's)
[**4**]: Deutscher Ausschuss für Stahlbeton – Heft 525 "Erlaeuterungen zu DIN 1045-1" 2nd edition (Beuth publisher's)

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