SSLS135 - Reinforcement of a square tank according to the method of Capra and Maury

Summary:

This test relates to the study of the square tank used like example in the descriptive document of the method of Capra and Maury. The goal is to calculate densities of reinforcement longitudinal and transverse for elements Plates or Hull.

1 Problem of reference

1.1 Geometry

One considers a square concrete tank of dimensions $L \times l \times h = 10\,m \times 10\,m \times 5\,m$ (of average layer with average layer) and thickness $0.4\,m$.

1.2 Properties of material

Isotropic linear elastic material:

Young modulus: $E = 3.10^4\,MPa$,
Poisson's ratio: $\nu = 0.15$,
Density: $\mu = 2500\,kg/m^3$.

1.3 Boundary conditions and loadings

The density of stiffness of ground applied under the tank is of $50\,kN/m^3$.

The integral of this density on the basis of the tank is thus $5 10^6\,kN/m$.
This quantity is then distributed on the nodes of the base.

The loading is made up:

- actual weight of the tank
- water drive of the tank filled (constant push on the bottom and gradual on the edges)
- of an overload distributed on contour on the top of the tank ($20\,kN/m$)

2 Reference solution

2.1 Method of calculating

The densities of longitudinal steels are calculated according to the method of Capra and Maury, for the directions X and Y of each element and according to the 2 faces, I (Lower) and S (Higher), defined by their position according to the normal Z elementary. The transverse density of steel is also calculated as described in the article entitled “automatic Calculation of the optimal reinforcement of the plates or reinforced concrete hulls” by Alain CAPRA and Jean-Francis MAURY.

2.2 Results of reference

The various results are published in the article of Capra and Maury in the form of graphs (for a quarter of model only) are:

- deformation of the tank,
- Iso-moments Mxx and Myy ,
- densities of reinforcement in the directions X and Y as a superior and an inferior.

Below the extract of the article for the deformation and the moments Mx , My .

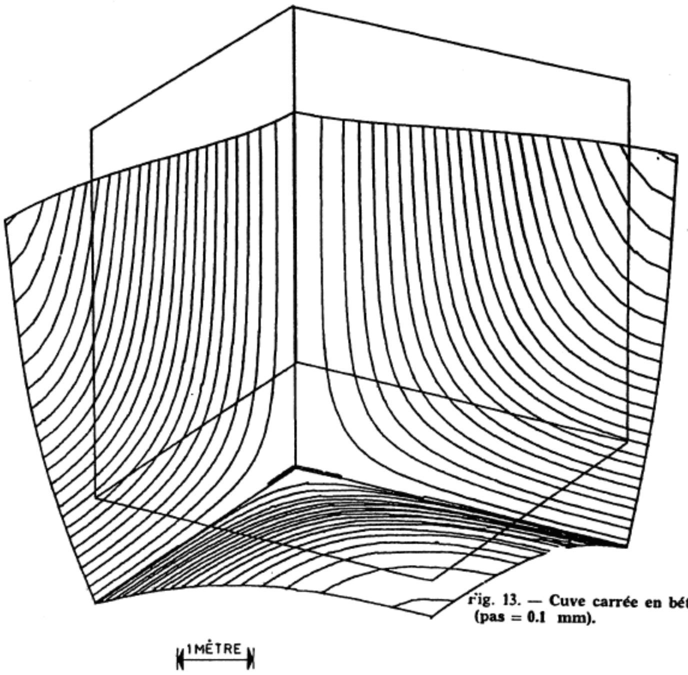

Fig. 13. — Cuve carrée en béton armé. Déformée (pas = 0.1 mm).

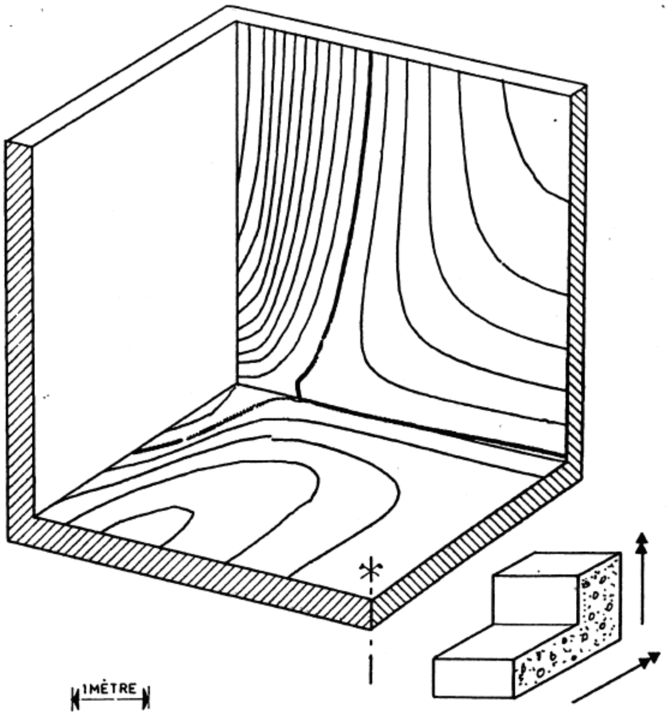

Fig. 14. — Cuve carrée en béton armé. Tracé des iso-moments M_{XX} (pas : 10^4 Nm par mètre).

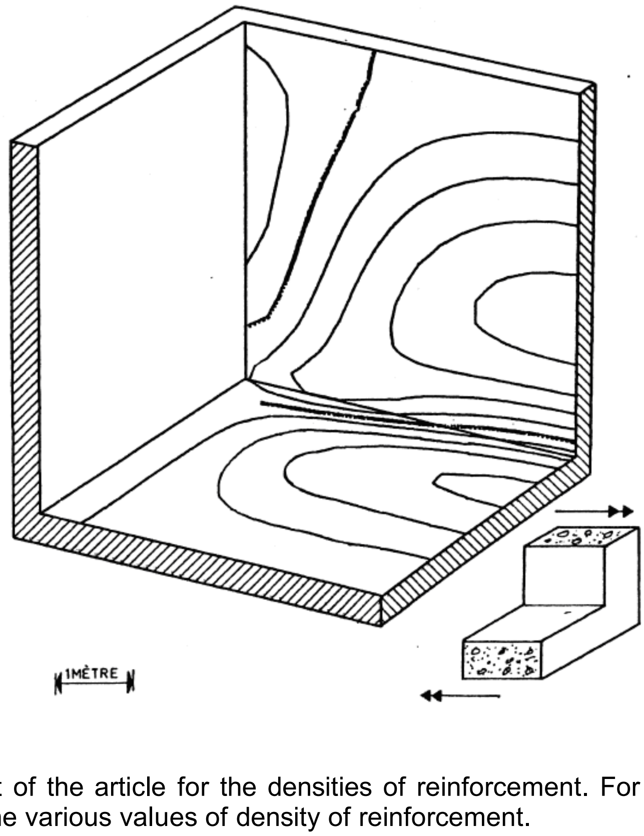

Fig. 15. — Cuve carrée en béton armé. Tracé des iso-moments M_{YY} (pas : 10^4 Nm par mètre).

Below the extract of the article for the densities of reinforcement. For a better legibility, colors were associated with the various values of density of reinforcement.

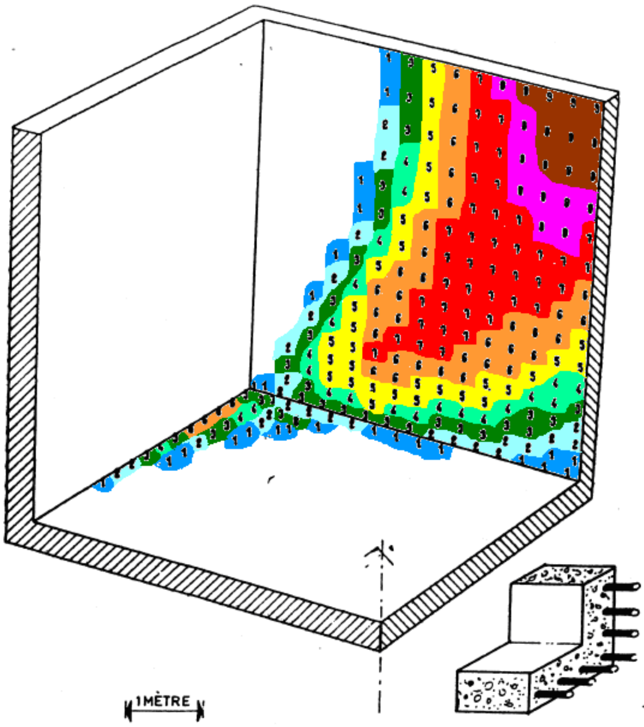

Fig. 16. — Cuve carrée en béton armé. Carte de ferraillage des aciers X extérieurs (en cm² par mètre).

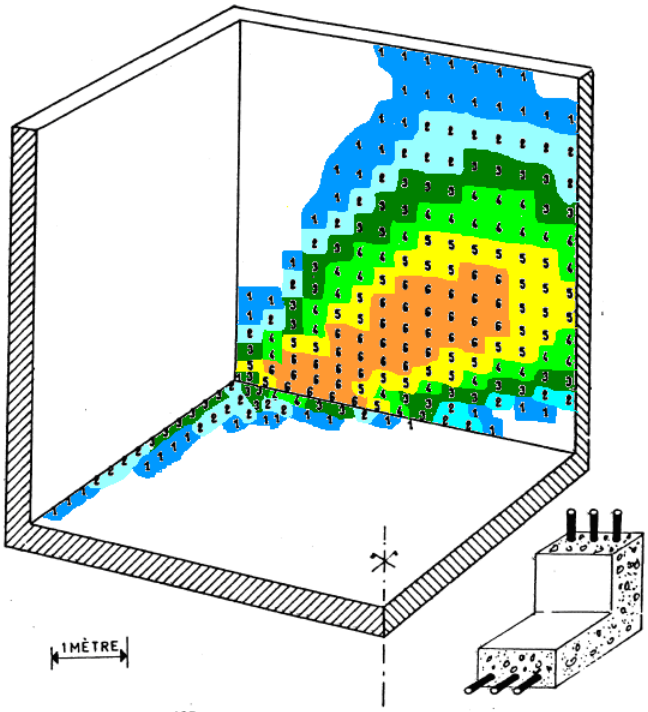

Fig. 17. — Cuve carrée en béton armé. Carte de ferraillage des aciers Y extérieurs (en cm² par mètre).

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Fig. 18. — Cuve carrée en béton armé. Carte de ferraillage des aciers X intérieurs (en cm² par mètre).

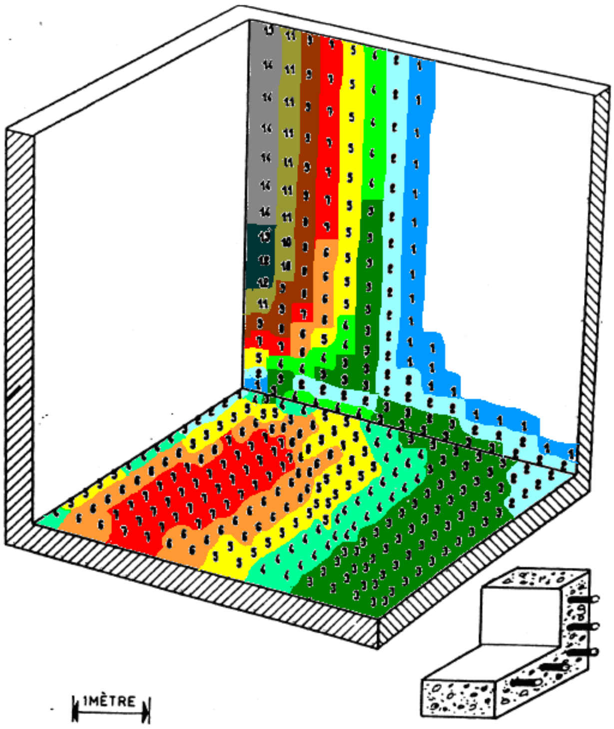
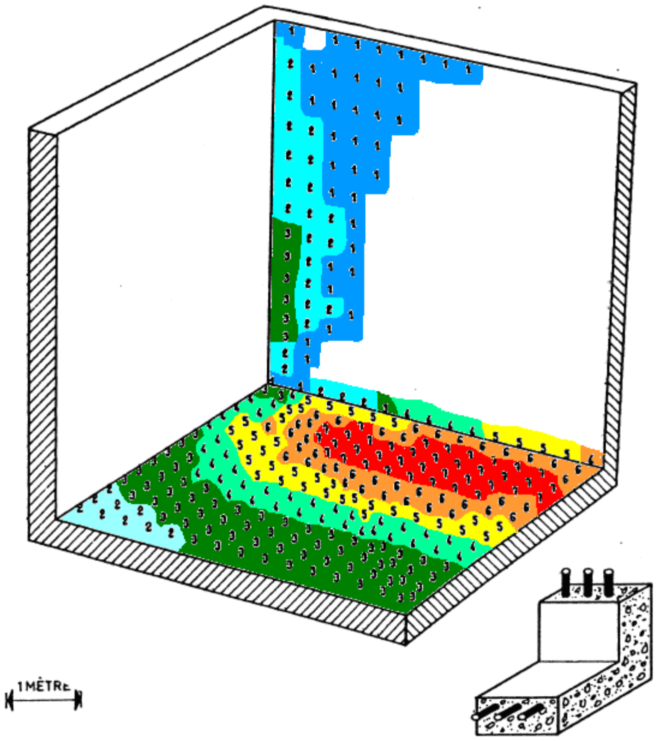


Fig. 19. — Cuve carrée en béton armé. Carte de ferraillage des aciers Y intérieurs (en cm² par mètre).



2.3 Bibliographical references

[1] Yearly of the Technical Institute of the Building industry and Public works N° 367 December 1978 – Series: Computer applications – Article entitled "automatic Calculation of the optimal reinforcement of the plates or reinforced concrete hulls" by Alain CAPRA and Jean-Francis MAURY.

3 Modeling A

3.1 Characteristics of modeling

A modeling is used DKT.

3.2 Characteristics of the grid

The elements are quadrangles. The length of maximum edge is of 0.5. Elements DKT are directed towards X positive, respectively towards Y positive, respectively towards Z positive for the elements perpendicular to X, respectively with Y and respectively with Z. Moreover, for the elements of the base, horizontal, the elementary axis X is identical to the total axis X. For the other elements, vertical, the elementary axis Y is identical to the total axis Z.

3.3 Other parameters of calculation

The acceleration of gravity is of $9.81\,m/s^2$.
The distance between the axis of steels and the surface of an element (coating) is of $0.04\,m$.
The coefficient of equivalence is of 15.0.
The acceptable maximum constraint of steel is of $2.3\,10^8\,Pa$.
The acceptable maximum constraint of the concrete is of $3.5\,10^7\,Pa$.
Calculation is carried out with the Absolute limit of Service (ELS).
The pivots are worth respectively $PIVA=1.0\,10^3$ and $PIVB=3.5\,10^{-3}$

3.4 Sizes tested and results

The values tested correspond to a certain number of elements "characteristic" of the model.
To facilitate the reading, the results were converted into cm^2/m and the values observers in the publication of reference were readjusted on the frame of reference used in the model Aster.

The analysis is led on the quarter of the tank presented in the publication (quarter of the model). 10 items were discussed:

Base tank
- BC : center
- BSO : south-west
- BSE : south-east
- BNO : the North-West
- BNE : the North-East

Veil "is" tank
- VC : center
- VBN : low north
- VBS : low-south
- VHN : high-north
- VHS : high-south

Not	density	Type of reference	Value of reference (in cm^2/m)
BC	DNSXI	'SOURCE_EXTERNE'	0
BC	DNSXS	'SOURCE_EXTERNE'	6
BC	DNSYI	'SOURCE_EXTERNE'	0
BC	DNSYS	'SOURCE_EXTERNE'	5
BSO	DNSXI	'SOURCE_EXTERNE'	0
BSO	DNSXS	'SOURCE_EXTERNE'	3
BSO	DNSYI	'SOURCE_EXTERNE'	0
BSO	DNSYS	'SOURCE_EXTERNE'	3
BSE	DNSXI	'SOURCE_EXTERNE'	0
BSE	DNSXS	'SOURCE_EXTERNE'	6
BSE	DNSYI	'SOURCE_EXTERNE'	1
BSE	DNSYS	'SOURCE_EXTERNE'	2
BNO	DNSXI	'SOURCE_EXTERNE'	1
BNO	DNSXS	'SOURCE_EXTERNE'	2
BNO	DNSYI	'SOURCE_EXTERNE'	0
BNO	DNSYS	'SOURCE_EXTERNE'	4
BNE	DNSXI	'SOURCE_EXTERNE'	3
BNE	DNSXS	'SOURCE_EXTERNE'	1
BNE	DNSYI	'SOURCE_EXTERNE'	2
BNE	DNSYS	'SOURCE_EXTERNE'	2
VC	DNSXI	'SOURCE_EXTERNE'	1
VC	DNSXS	'SOURCE_EXTERNE'	6
VC	DNSYI	'SOURCE_EXTERNE'	0
VC	DNSYS	'SOURCE_EXTERNE'	4
VBN	DNSXI	'SOURCE_EXTERNE'	2
VBN	DNSXS	'SOURCE_EXTERNE'	1
VBN	DNSYI	'SOURCE_EXTERNE'	2
VBN	DNSYS	'SOURCE_EXTERNE'	3
VBS	DNSXI	'SOURCE_EXTERNE'	1
VBS	DNSXS	'SOURCE_EXTERNE'	1
VBS	DNSYI	'SOURCE_EXTERNE'	0
VBS	DNSYS	'SOURCE_EXTERNE'	0
VHN	DNSXI	'SOURCE_EXTERNE'	15
VHN	DNSXS	'SOURCE_EXTERNE'	0
VHN	DNSYI	'SOURCE_EXTERNE'	1
VHN	DNSYS	'SOURCE_EXTERNE'	0
VHS	DNSXI	'SOURCE_EXTERNE'	0
VHS	DNSXS	'SOURCE_EXTERNE'	9
VHS	DNSYI	'SOURCE_EXTERNE'	0
VHS	DNSYS	'SOURCE_EXTERNE'	0

Identification	Component	Type of Reference	Reference	% tolerance
UT01_ELEM - Maximum	$X1$	'NON_REGRESSION'	–	–
UT01_ELEM - Minimum	$X1$	'NON_REGRESSION'	–	–
$ferMax$ - Maximum	$X1$	'AUTRE_ASTER'	0.000515023673871	0.10
$ferMax$ - Minimum	$X1$	'AUTRE_ASTER'	5.67845794742E-05	0.10

4 Summary of the results

This test makes it possible to highlight the validity of calculations of density of reinforcement. The got results are indeed very close to those appearing in the reference document of the authors of the method. The validation is however limited by the absence of precise data of certain parameters used (value of coating for example) and the small quantity of useable results provided by the publication of origin.