

Cast3M, a multiphysic Finite Element Program opened to the research community

Christian La Borderie

SIAME – University of Pau

Heat, Light and Wind simulation on an urban scale.
Anglet, 7th of February 2017

Short presentation

- Cast3M is a program developed by the French Alternative Energies and Atomic Energy Commission (CEA) whose object is to solve partial derivate equations by the way of finite elements.

Short presentation

- Cast3M is a program developed by the French Alternative Energies and Atomic Energy Commission (CEA) whose object is to solve partial derivate equations by the way of finite elements.
- Cast3M is free to download including sources.

Short presentation

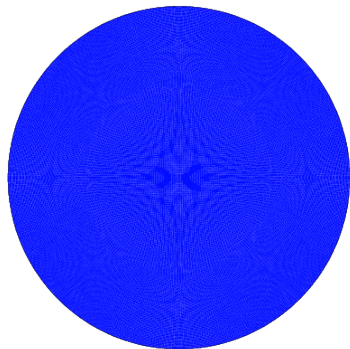
- Cast3M is a program developed by the French Alternative Energies and Atomic Energy Commission (CEA) whose object is to solve partial derivate equations by the way of finite elements.
- Cast3M is free to download including sources.
- The civil engineering research community (in particular in France) uses and develops Cast3M.

Short presentation

- Cast3M is a program developed by the French Alternative Energies and Atomic Energy Commission (CEA) whose object is to solve partial derivate equations by the way of finite elements.
- Cast3M is free to download including sources.
- The civil engineering research community (in particular in France) uses and develops Cast3M.
- A new version of the code that includes improvements by researchers is available annually

Examples of computation

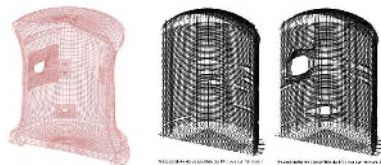
- Mechanics, damage, cracking, plasticity ...



damage during a splitting test

Examples of computation

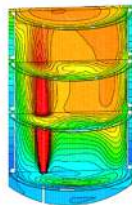
- Mechanics, damage, cracking, plasticity ...



Reinforced concrete nuclear
containment vessel

Examples of computation

- Mechanics, damage, cracking, plasticity . . .
- Fluid mechanics

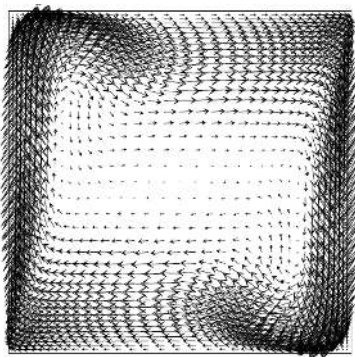


Convection naturelle dans une maquette d'enceinte (2005)

Natural convection into a vessel
mock-up

Examples of computation

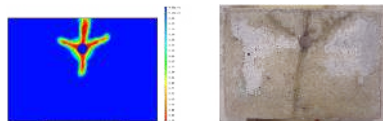
- Mechanics, damage, cracking, plasticity ...
- Fluid mechanics



Natural convection into a square cavity

Examples of computation

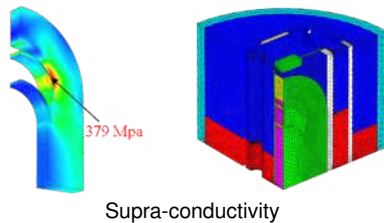
- Mechanics, damage, cracking, plasticity ...
- Fluid mechanics
- Couplings



THMC computation : oxydation of a Re bar

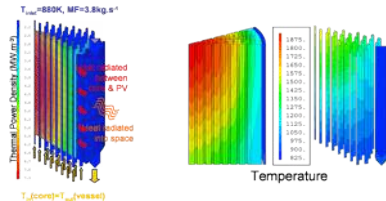
Examples of computation

- Mechanics, damage, cracking, plasticity ...
- Fluid mechanics
- Couplings
- Magnetostatic



Examples of computation

- Mechanics, damage, cracking, plasticity . . .
- Fluid mechanics
- Couplings
- Magnetostatic
- Heat exchange



Heat exchange in a reactor kernel

GIBIANE object oriented language

```
1  DEBPROC BUILDING L_X+FLOTTANT L_Y+FLOTTANT L_Z+FLOTTANT;  
2  *  
3  * DEFINITION OF A BUILDING OF DIMENSIONS L_X L_Y L_Z CENTERED AT 0 0 0;  
4  *  
5  DENSITE 0.3;  
6  P1=(-0.5*L_X) 0. 0.;  
7  VECX=L_X 0. 0.;  
8  VECY=0. L_Y 0.;  
9  ...  
10 BUILD.4=WALL3;  
11 BUILD.5=WALL4;  
12 BUILD.6=ROOF;  
13 FINP BUILD;  
14 ...  
15   BUILD1 =BUILDING 10 6 8;  
16 ...
```

Fortran like *esope* language

```
1  C RAYEN      SOURCE      CHAT      12/06/07      21:15:58      7389
2      SUBROUTINE RAYEN(modl , mchel1 , mchel2 , mchel3 , errj , mchel4)
3
4  C .....
5  C ****          OPERATEUR RAYE          ****
6
7  ....
8      KABS=0
9      KMATR=1
10     IF (IIMPI.GE.4) WRITE(6,*) 'DEBUT_DE_RAYT.ESO'
11     if (mchel3.ne.0) then
12         segact mchel2
13         kabs=0
14         kmatr=0
15         do io=1,mchel2.imache(/1)
16             mchaml=mchel2.ichaml(io)
17             segact mchaml
18             do ia=1,nomche(/2)
19                 if ( nomche(ia).eq.'TABS' ) then
20     ....
```

Heat exchange

- Conduction
 - Linear
 - Non linear
 - Steady state
 - Transient

- $\rho C_p \frac{\partial T}{\partial t} - q - \text{div}(\lambda \overrightarrow{\text{grad}}(T)) = 0$

Heat exchange

- Conduction
 - Linear
 - Non linear
 - Steady state
 - Transient
- Convection

- $\rho C_p \frac{\partial T}{\partial t} - q - \text{div}(\lambda \overrightarrow{\text{grad}}(T)) = 0$
- $\varphi_c = H(T - T_\infty)$

Heat exchange

- Conduction
 - Linear
 - Non linear
 - Steady state
 - Transient
- Convection
- Radiation

$$\bullet \rho C_p \frac{\partial T}{\partial t} - q - \operatorname{div}(\lambda \overrightarrow{\operatorname{grad}}(T)) = 0$$

$$\bullet \varphi_c = H(T - T_\infty)$$

$$\bullet \varphi_r = \frac{\sigma \varepsilon_1 \varepsilon_2}{1 - (1 - \varepsilon_1)(1 - \varepsilon_2)} (T_1^4 - T_2^4)$$

Heat exchange

- Conduction
 - Linear
 - Non linear
 - Steady state
 - Transient
- Convection
- Radiation
- Phase change, advection

$$\bullet \rho C_p \frac{\partial T}{\partial t} - q - \operatorname{div}(\lambda \overrightarrow{\operatorname{grad}}(T)) = 0$$

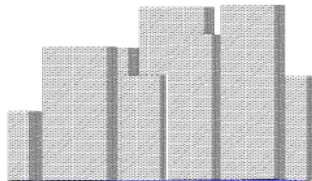
$$\bullet \varphi_c = H(T - T_\infty)$$

$$\bullet \varphi_r = \frac{\sigma \varepsilon_1 \varepsilon_2}{1 - (1 - \varepsilon_1)(1 - \varepsilon_2)} (T_1^4 - T_2^4)$$

Sun heating of a set of buildings

Geometry

- North-South street
- 15 cm of concrete + insulating material
 - $\lambda = 0.2 \text{ W}/(\text{m}\cdot\text{K})$
 - $\rho = 2500 \text{ kg}/\text{m}^3$
 - $C_p = 1000 \text{ J}/(\text{kg}\cdot\text{K})$
 - $H_v = 10 \text{ J}/(\text{m}^2\cdot\text{K})$
 - $H_h = 2 \text{ J}/(\text{m}^2\cdot\text{K})$



GENE FRANCIS

Sun view of the street

Heating of a set of buildings

hypothesis

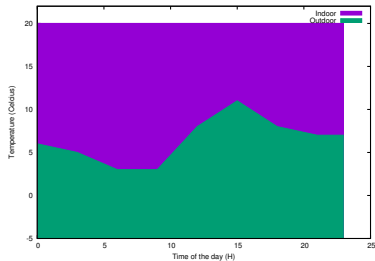
- position of the sun at Anglet on 4th of February 2017^a
- sunny day (was unreal)
- Irradiance of solar radiation^b $S_{pb} = S_{p0}\tau^m$
($S_{p0} = 1.367 \text{ W/m}^2$, $\tau \approx 0.6$)
- $m = m_0 P_a / P_0 \approx m_0$
- $m_0 = \sqrt{1229 + 614 \sin^2 \psi} - 614 \sin \psi$ with ψ : zenith angle

^a[Sunearthtool](#). *Calcul de la position du soleil dans le ciel pour chaque emplacement à importe quel moment.* [Web](#).

^b[Benoit Beckers, ed.](#) *Solar energy at urban scale.* 2012.

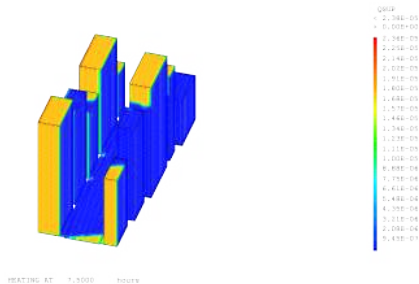
Boundary conditions

- Temperature

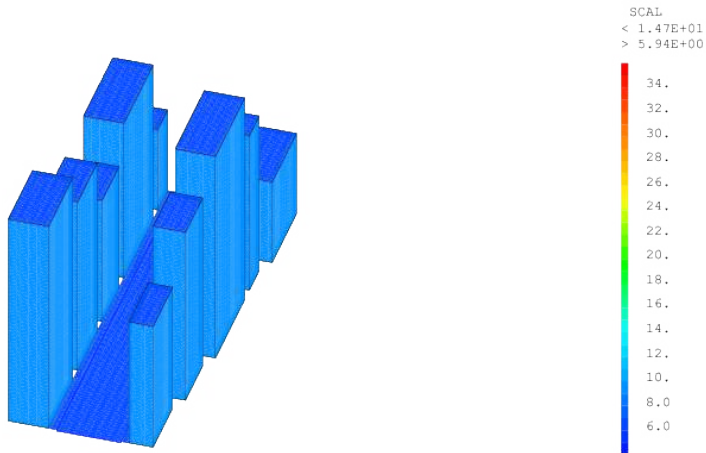


Boundary conditions

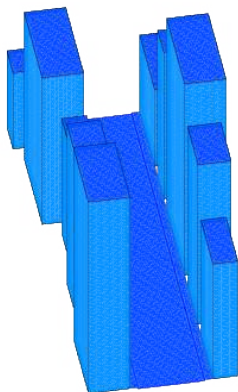
- Temperature
- Sun heating



Temperature of external faces of buildings



Temperature of external faces of buildings



SCAL
< 1.47E+01
> 5.94E+00

34.
32.
30.
28.
26.
24.
22.
20.
18.
16.
14.
12.
10.
8.0
6.0

temperature at 0.16696 h



Conclusions and perspectives

- Multiphysics Finite Element code
- Numerous possibilities of geometrical modeling
- Oriented towards research and innovation
- Opened to users