Anisotropic elasticity

Abstract

This document treats anisotropic elasticity, used for the modelizations of continuums 3D and 2D (C_PLAN, D_PLAN, AXIS), or the layers of the composite shells.

The springy medium can be anisotropic according to the 3 directions (orthotropic elasticity is spoken), or in isotropic in two directions (one speaks about transverse isotropic elasticity).

Contents

1 Introduction

the purpose of this document is to give the form of the matrixes of flexibility and Hooke for elastic materials orthotropic, isotropic transverse and isotropic in 3D case, 2D-forced, 2D - plane strains and axisymetry.

We speak about "matrixes" of Hooke because, by preoccupation with a simplification, we did not adopt the notation of a tensor of order 4.

In any rigor, for the linear elastic materials, the stresses are linear functions of the strains.

One writes: $\sigma_{ij}=H_{ijkl}\varepsilon_{kl}$

The symmetric nature of $\{\sigma\}$ and $[\varepsilon]$ the adoption for these tensors of order 2 of a vectorial form make it possible to write:

$$\{\sigma\}=[H]\{\varepsilon\}$$

where $\{\sigma\}$ and $[\varepsilon]$ are the vectorial representation of the tensors of order 2 $\{\sigma\}$ and $[\varepsilon]$ where $[H]$ is a matrix 6×6 .

2 Topology of the matrixes of Hooke

2.1 the orthotropy

One can show the symmetry of the matrix of Hooke $[H]$.

We thus have twenty and one independent components in 3D case.

$$[H]=\begin{vmatrix} H_{11} & H_{12} & H_{13} & H_{14} & H_{15} & H_{16} \\ & H_{22} & H_{23} & H_{24} & H_{25} & H_{26} \\ & & H_{33} & H_{34} & H_{35} & H_{36} \\ SYM & & & H_{44} & H_{45} & H_{46} \\ & & & & H_{55} & H_{56} \\ & & & & & H_{66} \end{vmatrix}$$

An orthotropic material has two orthogonal planes of elastic symmetry.

This wants to say that if one calls $[H']$ the matrix $[H]$ after symmetry (S)
$[H']=[H]$.

The relations obtained between the coefficients make it possible to write that $[H]$ is defined by nine independent components.

In the axes of orthotropy:

$$[H]=\begin{vmatrix} H_{11} & H_{12} & H_{13} & 0 & 0 & 0 \\ & H_{22} & H_{23} & 0 & 0 & 0 \\ & & H_{33} & 0 & 0 & 0 \\ SYM & & & H_{44} & 0 & 0 \\ & & & & H_{55} & 0 \\ & & & & & H_{66} \end{vmatrix}$$

9 coefficients thus should be provided.

2.2 Transverse isotropy

the transverse isotropy is a restriction of the orthotropy in where one has the isotropy in one of the two orthogonal planes of elastic symmetry.

The matrix $[H]$ will have the same form as for the orthotropy but with additional relations between the components.
Five components are enough to determine $[H]$.

2.3 Isotropy

the material is isotropic if $[H]$ remains invariant in any change of reference.

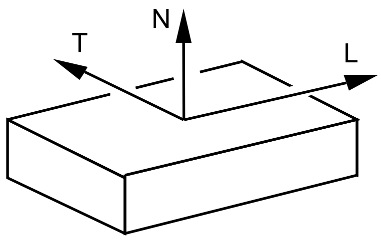
Two coefficients are enough to determine $[H]$.

3 Stamp of Hooke and from flexibility

3.1 Notations

Instead of using indices 1,2 and 3 to locate the axes, one will use the corresponding indices L , T and N :

1. L for longitudinal
2. T for transverse
3. N for normal



the coefficients which intervene are the following:

Key word	Notation	meaning
`E_L`	E_L	longitudinal Modulus Young
`E_T`	E_T	transverse Modulus Young
`E_N`	E_N	normal Modulus Young
`G_LT`	G_{LT}	Shear modulus in plane (L,T)
`G_TN`	G_{TN}	Shear modulus in plane (T,N)
`G_LN`	G_{LN}	Shear modulus in plane (L,N)
`NU_LT`	ν_{LT}	Poisson's ratio in plane (L,T)
`NU_TN`	ν_{TN}	Poisson's ratio in plane (T,N)
`NU_LN`	ν_{LN}	Poisson's ratio in the plane (L,N)

Notices very important:

> ν_{LT} *is different from* ν_{TL} *:*
>
> *If one applies a tension according to* L
>
> $\epsilon_{LL}=\frac{\overline{\sigma_{LL}}}{E_L}$ *(Hooke's law according to a direction).*

This tension is accompanied, proportionally, of a contraction according to $T,-\nu_{LT}.\frac{\sigma_{LL}}{E_L}$

and of a contraction according to $N,-\nu_{LN}.\frac{\sigma_{LL}}{E_L}$.

The first index indicates the axis where the effect of the loading is exerted and the second index indicates the direction of the loading.

Then one exerts a tension according to T, then a tension according to N; one obtains:

$$\left.\begin{array}{l}\varepsilon_{LL}=\frac{\sigma_{LL}}{E_L}-\nu_{TL}\frac{\sigma_{TT}}{E_T}-\nu_{NL}\frac{\sigma_{NN}}{E_N}\\ \varepsilon_{TT}=-\nu_{LT}\frac{\sigma_{LL}}{E_L}+\frac{\sigma_{TT}}{E_T}-\nu_{NT}\frac{\sigma_{NN}}{E_N}\\ \varepsilon_{NN}=-\nu_{LN}\frac{\sigma_{LL}}{E_L}-\nu_{TN}\frac{\sigma_{TT}}{E_T}+\frac{\sigma_{NN}}{E_N}\end{array}\right\}(S)$$

The matrix of flexibility $[H]^{-1}$ being symmetric; one from of deduced:

$$\frac{\nu_{LT}}{E_L}=\frac{\nu_{TL}}{E_T}$$

$$\frac{\nu_{LN}}{E_L}=\frac{\nu_{NL}}{E_N}$$

$$\frac{\nu_{TN}}{E_T}=\frac{\nu_{NT}}{E_N}$$

3.2 Case 3D

3.2.1 0rthotropie

3.2.1.1 Matrix of flexibility

$$\begin{bmatrix}\varepsilon_{LL}\\ \varepsilon_{TT}\\ \varepsilon_{NN}\\ 2\varepsilon_{LT}\\ 2\varepsilon_{LN}\\ 2\varepsilon_{TN}\end{bmatrix}=\begin{bmatrix}\frac{1}{E_L} & \frac{-\nu_{TL}}{E_T} & \frac{-\nu_{NL}}{E_N} & 0 & 0 & 0\\ \frac{-\nu_{LT}}{E_L} & \frac{1}{E_T} & \frac{-\nu_{NT}}{E_N} & 0 & 0 & 0\\ \frac{-\nu_{LN}}{E_L} & \frac{-\nu_{TN}}{E_T} & \frac{1}{E_N} & 0 & 0 & 0\\ & & & \frac{1}{G_{LT}} & 0 & 0\\ & SYM & & & \frac{1}{G_{LN}} & 0\\ & & & & & \frac{1}{G_{TN}}\end{bmatrix}\begin{bmatrix}\sigma_{LL}\\ \sigma_{TT}\\ \sigma_{NN}\\ \sigma_{LT}\\ \sigma_{LN}\\ \sigma_{TN}\end{bmatrix}$$

$[H]^{-1}$ – Orthotropy

3.2.1.2 Stamps of Hooke

$$\begin{bmatrix}\sigma_{LL}\\ \sigma_{LL}\\ \sigma_{NN}\\ \sigma_{LT}\\ \sigma_{LN}\\ \sigma_{TN}\end{bmatrix}=\frac{1}{\Delta}\begin{bmatrix}\frac{(1-\nu_{TN}\nu_{NT})}{E_T E_N} & \frac{(\nu_{TL}+\nu_{NL}\nu_{TN})}{E_T.E_N} & \frac{(\nu_{NL}+\nu_{TL}\nu_{NT})}{E_T.E_N} & 0 & 0 & 0\\ \frac{(\nu_{LT}+\nu_{LN}\nu_{NT})}{E_L E_N} & \frac{(1-\nu_{NL}\nu_{LN})}{E_L.E_N} & \frac{(\nu_{NT}+\nu_{NL}.\nu_{LT})}{E_L.E_N} & 0 & 0 & 0\\ \frac{(\nu_{LN}+\nu_{LT}.\nu_{TN})}{E_L.E_T} & \frac{(\nu_{TN}+\nu_{TL}.\nu_{LN})}{E_L.E_T} & \frac{(1-\nu_{LT}.\nu_{TL})}{E_L.E_T} & 0 & 0 & 0\\ & & & GLT*\Delta & 0 & 0\\ & SYM & & & GLN*\Delta & 0\\ & & & & & GTN*\Delta\end{bmatrix}\begin{bmatrix}\varepsilon_{LL}\\ \varepsilon_{TT}\\ \varepsilon_{NN}\\ 2\varepsilon_{LT}\\ 2\varepsilon_{LN}\\ 2\varepsilon_{TN}\end{bmatrix}$$

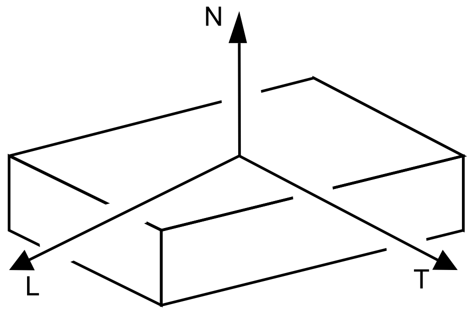
$[H]$ – Orthotropy with:

$$\frac{\nu_{TL}}{E_T}=\frac{\nu_{LT}}{E_L};\frac{\nu_{NL}}{E_N}=\frac{\nu_{LN}}{E_L};\frac{\nu_{NT}}{E_N}=\frac{\nu_{TN}}{E_T}$$

$$\frac{1}{\Delta}=\frac{E_L E_T E_N}{\left(\begin{array}{c}1-\nu_{TN}\nu_{NT}\\-\nu_{NL}\nu_{LN}\\-\nu_{LT}\nu_{TL}\\-2\nu_{TN}\nu_{NL}\nu_{LT}\end{array}\right)}$$

3.2.2 Transverse isotropy

3.2.2.1 Stamps flexibility

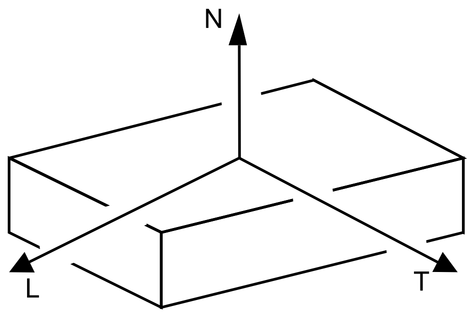


the matrix $\left[H\right]^{-1}$ can be deduced directly from the matrix $\left[H\right]^{-1}$ - Orthotropy by means of the properties of the transverse isotropy. In the plane (L,T) :

$$E_L=E_T$$
$$\nu_{TL}=\nu_{LT}$$
$$G_{LT}=\frac{E_L}{2(1+\nu_{LT})}$$

In the planes (L,N) and (T,N) :

$$\nu_{NT}=\nu_{NL}$$
$$\nu_{LN}=\nu_{TN}$$
$$G_{TN}=G_{LN}$$



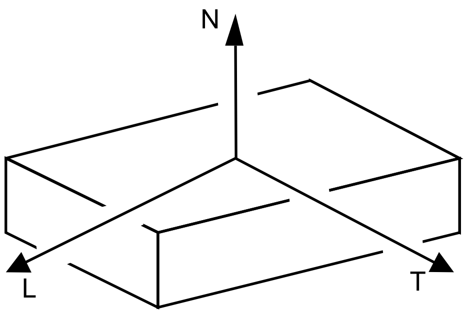
$$E_L = E_T$$
$$\nu_{LT} = \nu_{TL}$$
$$G_{LT} = \frac{E_L}{2(1+\nu_{LT})}$$
$$\nu_{NT} = \nu_{NL}$$
$$\nu_{LN} = \nu_{TN}$$
$$G_{TN} = G_{LN}$$
$$\frac{\nu_{NT}}{E_N} = \frac{\nu_{LN}}{E_L}$$

$$\begin{bmatrix} \varepsilon_{LL} \\ \varepsilon_{TT} \\ \varepsilon_{NN} \\ 2\varepsilon_{LT} \\ 2\varepsilon_{LN} \\ 2\varepsilon_{TN} \end{bmatrix} = \begin{bmatrix} \frac{1}{E_L} & \frac{-\nu_{LT}}{E_L} & \frac{-\nu_{NL}}{E_N} & 0 & 0 & 0 \\ \frac{-\nu_{TL}}{E_L} & \frac{1}{E_L} & \frac{-\nu_{NT}}{E_N} & 0 & 0 & 0 \\ \frac{-\nu_{LN}}{E_L} & \frac{-\nu_{TN}}{E_L} & \frac{1}{E_N} & 0 & 0 & 0 \\ & & & \frac{2(1+\nu_{LT})}{E_L} & 0 & 0 \\ & SYM & & & \frac{1}{G_{LN}} & 0 \\ & & & & & \frac{1}{G_{TN}} \end{bmatrix} \begin{bmatrix} \sigma_{LL} \\ \sigma_{TT} \\ \sigma_{NN} \\ \sigma_{LT} \\ \sigma_{LN} \\ \sigma_{TN} \end{bmatrix}$$

$[H]^{-1}$ - Transverse Isotropy

3.2.2.2 Stamps of Hooke

the matrix $[H]$ has same symmetries as $[H]^{-1}$.



$$\begin{bmatrix}\sigma_{LL}\\ \sigma_{TT}\\ \sigma_{NN}\\ \sigma_{LT}\\ \sigma_{LN}\\ \sigma_{TN}\end{bmatrix}=\frac{1}{\Delta'}\begin{bmatrix}\frac{1-\nu_{NL}.\nu_{LN}}{E_L.E_N} & \frac{\nu_{LT}+\nu_{NL}\nu_{LN}}{E_L.E_N} & \frac{\nu_{NL}+\nu_{LT}\nu_{NL}}{E_L.E_N} & 0 & 0 & 0\\ \frac{\nu_{TL}+\nu_{NL}\nu_{LN}}{E_L.E_N} & \frac{1-\nu_{NL}.\nu_{LN}}{E_L.E_N} & \frac{\nu_{LN}+\nu_{LT}\nu_{LN}}{E_L.E_N} & 0 & 0 & 0\\ \frac{\nu_{LN}+\nu_{LT}.\nu_{LN}}{E_L^2} & \frac{\nu_{TN}+\nu_{LT}.\nu_{TN}}{E_L^2} & \frac{1-\nu_{LT}^2}{E_L^2} & 0 & 0 & 0\\ & & & \frac{E_L.\Delta'}{2(1+\nu_{LT})} & & \\ & & & & G_{LN}.\Delta' & \\ & & & & & G_{LN}.\Delta'\end{bmatrix}\begin{bmatrix}\varepsilon_{LL}\\ \varepsilon_{TT}\\ \varepsilon_{NN}\\ 2\varepsilon_{LT}\\ 2\varepsilon_{LN}\\ 2\varepsilon_{TN}\end{bmatrix}$$

$[H]$ – Transverse Isotropy

$$\frac{1}{\Delta'}=\frac{E_L^2.E_N}{\begin{bmatrix}1-2\nu_{NL}.\nu_{LN}-\nu_{LT}^2\\ -2\nu_{NL}\nu_{LN}\nu_{LT}\end{bmatrix}}$$

3.2.3 cubic Elasticity

cubic elasticity corresponds to a matrix of elasticity of the form :

$$\begin{bmatrix}y_{1111} & y_{1122} & y_{1122} & & & \\ y_{1122} & y_{1111} & y_{1122} & & & \\ y_{1122} & y_{1122} & y_{1111} & & & \\ & & & y_{1212} & & \\ & & & & y_{1212} & \\ & & & & & y_{1212}\end{bmatrix}$$

Being given cubic symmetry, it remains to determine 3 coefficients:

$$E_L=E_N=E_T=E\,,\,G_{LT}=G_{LN}=G_{TN}\;=G\,,\,\nu_{LN}=\nu_{LT}=\nu_{LN}=\nu$$

To reproduce cubic elasticity with `ELAS_ORTH`, it is enough to calculate the coefficients of the orthotropy such that the matrix of elasticity obtained is form above:

$$y_{1111}=\frac{E(1-\nu^2)}{(1-3\nu^2-2\nu^3)}$$
$$y_{1122}=\frac{E\,\nu(1+\nu)}{(1-3\nu^2-2\nu^3)}$$
$$y_{1212}=G_{LT}=G_{LN}=G_{TN}$$

therefore, as long as $(1-3\nu^2-2\nu^3)\neq 0$ (i.e. ν different from 0.5).

$\frac{y_{1122}}{y_{1111}}=\frac{\nu}{1-\nu}$ what provides $\nu=\frac{1}{1+\frac{y_{1111}}{y_{1122}}}$ then $E=y_{1111}\frac{(1-3\nu^2-2\nu^3)}{(1-\nu^2)}$

3.2.4 Isotropy

3.2.4.1 Stamps flexibility according to E and ν

$$\begin{bmatrix}\varepsilon_{LL}\\ \varepsilon_{TT}\\ \varepsilon_{NN}\\ 2\varepsilon_{LT}\\ 2\varepsilon_{LN}\\ 2\varepsilon_{TN}\end{bmatrix}=\begin{bmatrix}\frac{1}{E} & \frac{-\nu}{E} & \frac{-\nu}{E} & 0 & 0 & 0\\ & \frac{1}{E} & \frac{-\nu}{E} & 0 & 0 & 0\\ & & \frac{1}{E} & 0 & 0 & 0\\ & & & \frac{1}{G}=\frac{2(1+\nu)}{E} & 0 & 0\\ & SYM & & & \frac{1}{G}=\frac{2(1+\nu)}{E} & 0\\ & & & & & \frac{1}{G}=\frac{2(1+\nu)}{E}\end{bmatrix}\begin{bmatrix}\sigma_{LL}\\ \sigma_{TT}\\ \sigma_{NN}\\ \sigma_{LT}\\ \sigma_{LN}\\ \sigma_{TN}\end{bmatrix}$$

$[H]^{-1}$ – complete Isotropy

3.2.4.2 Stamps of Hooke according to E and ν

$$\begin{bmatrix}\sigma_{LL}\\ \sigma_{TT}\\ \sigma_{NN}\\ \sigma_{LT}\\ \sigma_{LN}\\ \sigma_{TN}\end{bmatrix}=\frac{E}{(1+\nu)(1-2\nu)}\begin{bmatrix}1-\nu & \nu & \nu & 0 & 0 & 0\\ & 1-\nu & \nu & 0 & 0 & 0\\ & & 1-\nu & 0 & 0 & 0\\ & SYM & & \frac{1-2\nu}{2} & 0 & 0\\ & & & & \frac{1-2\nu}{2} & 0\\ & & & & & \frac{1-2\nu}{2}\end{bmatrix}\begin{bmatrix}\varepsilon_{LL}\\ \varepsilon_{TT}\\ \varepsilon_{NN}\\ 2\varepsilon_{LT}\\ 2\varepsilon_{LN}\\ 2\varepsilon_{TN}\end{bmatrix}$$

$[H]$ – complete Isotropy

3.2.4.3 Stamps flexibility according to the coefficients of Lamé λ and μ

the Hooke's law takes the following shape with the coefficients of Lamé λ and μ .

$$\sigma_{ij}=\lambda\,\varepsilon_{kk}\,\delta_{ij}+2\,\mu\,\varepsilon_{ij}$$

By means of the system of equations (S), one obtains:

$$\begin{bmatrix}\sigma_{LL}\\ \sigma_{TT}\\ \sigma_{NN}\\ \sigma_{LT}\end{bmatrix}=\frac{1}{1-\nu_{LT}.\nu_{TL}}\begin{bmatrix}E_L & \nu_{TL}.E_T & 0 & 0\\ \nu_{LT}.E_L & E_T & 0 & 0\\ 0 & 0 & 0 & 0\\ 0 & 0 & 0 & G_{LT}\end{bmatrix}\begin{bmatrix}\varepsilon_{LL}\\ \varepsilon_{TT}\\ \varepsilon_{NN}\\ 2\varepsilon_{LT}\end{bmatrix}$$

$[H]$ – Plane Orthotropy in plane stresses

3.2.4.4 Stamps of Hooke according to the coefficients of Lamé λ and μ

$$\begin{bmatrix}\sigma_{LL}\\ \sigma_{TT}\\ \sigma_{NN}\\ \sigma_{LN}\\ \sigma_{LT}\\ \sigma_{TN}\end{bmatrix}=\begin{bmatrix}\lambda+2\mu & \lambda & \lambda & 0 & 0 & 0\\ & \lambda+2\mu & \lambda & 0 & 0 & 0\\ & & \lambda+2\mu & 0 & 0 & 0\\ & SYM & & \mu & 0 & 0\\ & & & & \mu & 0\\ & & & & & \mu\end{bmatrix}\begin{bmatrix}\varepsilon_{LL}\\ \varepsilon_{TT}\\ \varepsilon_{NN}\\ 2\varepsilon_{LN}\\ 2\varepsilon_{LT}\\ 2\varepsilon_{TN}\end{bmatrix}$$

$[H]$ – complete Isotropy with the coefficients of Lamé

3.3 Case 2D orthotropic in plane strains and axisymmetric

3.3.1 Matrix of flexibility

$$\begin{bmatrix}\varepsilon_{LL}\\ \varepsilon_{TT}\\ 0\\ 2\varepsilon_{LT}\end{bmatrix}=\begin{bmatrix}\frac{1}{E_L} & -\frac{\nu_{TL}}{E_T} & -\frac{\nu_{NL}}{E_N} & 0\\ -\frac{\nu_{LT}}{E_L} & \frac{1}{E_T} & -\frac{\nu_{NL}}{E_N} & 0\\ 0 & 0 & 0 & 0\\ 0 & 0 & 0 & \frac{1}{G_{LT}}\end{bmatrix}\begin{bmatrix}\sigma_{LL}\\ \sigma_{TT}\\ \sigma_{NN}\\ \sigma_{LT}\end{bmatrix}$$

$[H]^{-1}$ – plane Orthotropy in plane strains and axisymetry

3.3.2 Stamps of Hooke

$$\begin{bmatrix}\sigma_{LL}\\ \sigma_{TT}\\ \sigma_{NN}\\ \sigma_{LT}\end{bmatrix}=\frac{1}{\Delta}\begin{bmatrix}\frac{(1-\nu_{TN}\nu_{NT})}{E_T E_N} & \frac{(\nu_{TL}+\nu_{NL}\nu_{TN})}{E_T.E_N} & \frac{(\nu_{NL}+\nu_{TL}\nu_{NT})}{E_T.E_N} & 0\\ \frac{(\nu_{LT}+\nu_{LN}\nu_{NT})}{E_L E_N} & \frac{(1-\nu_{NL}\nu_{LN})}{E_L.E_N} & \frac{(\nu_{NT}+\nu_{NL}.\nu_{LT})}{E_L.E_N} & 0\\ \frac{(\nu_{LN}+\nu_{LT}.\nu_{TN})}{E_L.E_T} & \frac{(\nu_{TN}+\nu_{TL}.\nu_{LN})}{E_L.E_T} & \frac{(1-\nu_{LT}.\nu_{TL})}{E_L.E_T} & 0\\ 0 & 0 & 0 & GLT*\Delta\end{bmatrix}\begin{bmatrix}\varepsilon_{LL}\\ \varepsilon_{TT}\\ 0\\ \varepsilon_{LT}\end{bmatrix}$$

$[H]$ – plane Orthotropy in plane strains and axisymetry

$$\frac{1}{\Delta}=\frac{E_L E_T E_N}{\begin{pmatrix}1-\nu_{TN}\nu_{NT}\\ -\nu_{NL}\nu_{LN}\\ -\nu_{LT}\nu_{TL}\\ -2\nu_{TN}\nu_{NL}\nu_{LT}\end{pmatrix}}$$

3.4 Case 2D orthotropic in plane stresses

3.4.1 Stamps flexibility

$$\begin{bmatrix}\varepsilon_{LL}\\ \varepsilon_{TT}\\ \varepsilon_{NN}\\ 2\varepsilon_{LT}\end{bmatrix}=\begin{bmatrix}\frac{1}{E_L} & -\frac{\nu_{TL}}{E_T} & 0 & 0\\ -\frac{\nu_{LT}}{E_L} & \frac{1}{E_T} & 0 & 0\\ 0 & 0 & 0 & 0\\ 0 & 0 & 0 & \frac{1}{G_{LT}}\end{bmatrix}\begin{bmatrix}\sigma_{LL}\\ \sigma_{TT}\\ \sigma_{NN}\\ \sigma_{LT}\end{bmatrix}$$

$[H]^{-1}$ – plane Orthotropy in plane stresses

3.4.2 Stamps of Hooke

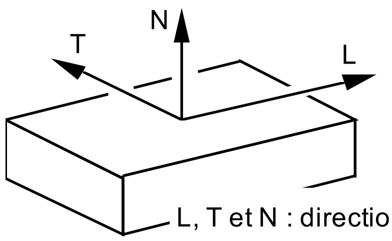
$$\begin{bmatrix}\sigma_{LL}\\ \sigma_{TT}\\ 0\\ \sigma_{LT}\end{bmatrix}=\frac{1}{1-\nu_{LT}.\nu_{TL}}\begin{bmatrix}E_L & \nu_{TL}E_T & 0 & 0\\ \nu_{LT}E_L & E_T & 0 & 0\\ 0 & 0 & 0 & 0\\ 0 & 0 & 0 & G_{LT}\end{bmatrix}\begin{bmatrix}\varepsilon_{LL}\\ \varepsilon_{TT}\\ \varepsilon_{NN}\\ 2\varepsilon_{LT}\end{bmatrix}$$

$[H]$ – Orthotropy in plane stresses

4 Use in *Code_Aster*

In *Aster* , the definition of the constant orthotropic elastic characteristics or functions of the temperature are carried out by the command DEFI_MATERIAU , key keys ELAS_ORTH, ELAS_ISTR, ELAS_ISTR_FO or ELAS_ORTH_FO for the isoparametric shell elements and the solid elements or layers constitutive of a composite (see command DEFI_COMPOSITE).

To define the orthotropic reference (L, T, N) related one to the elements, one can refer to documentations [U4.42.03] DEFI_COMPOSITE and [U4.42.01] AFFE_CARA_ELEM .



L, T et N : directions d'orthotropie longitudinale, transversale et normale

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/ELAS_ORTH     = _F   (  ♦  E_L = ygl
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♦	E_L = ygl	longitudinal Modulus Young.
♦	E_T = ygt	transverse Modulus Young.
◊	E_N = ygn	normal Modulus Young.
♦	GL_T = glt	Shear modulus in the plane LT .
◊	G_TN = gtn	Shear modulus in the plane TN .
◊	G_LN = gln	Shear modulus in the plane LN .
♦	NU_LT = nult	Poisson's ratio in the plane LT .
◊	NU_TN = nutn	Poisson's ratio in the plane TN .
◊	NU_LN = nuln	Poisson's ratio in the plane LN .

Notice important:

The talk of this note of reference is based on the convention of the books of J.L.Batoz and D.Gay. The documentation U of DEFI_MATERIAU describes *these choices, and coefficient NU_LT* is interpreted *in the following way in Aster: if one*

exerts a tension according to the axis which causes L *a strain according to this axis equalizes with, one has* $\varepsilon_L = \frac{\sigma_l}{\text{ygl}}$ *a strain according to the axis equalizes with* T *: .*

Bibliography $\varepsilon_t = -\text{nult} * \frac{\sigma_l}{\text{ygl}}$

5 J.C. MASSON

1) : Stamp of Hooke for the orthotropic materials, Ratio interns Applications in Mechanics, n °79-018, CiSi, 1979. D. GAY

2) : Composites, Hermes Edition, 1987 J.L. BATOZ

3) , G. DHATT: Modelization of structures by finite elements, Volume 1, Edition Hermes Description

6 of the versions of the document Version

Aster Author (S	**) Organization (S) Description**	**of the modifications 6.4 A. ASSIRE**
	, EDF-R&D/ AMA initial Text	8.4 A. ASSIRE
	, X. DESROCHES, J.M. PROIX EDF-R&D/ AMA Corrections	tiny