

SOFTWARE

Orthotropic materials in Sesam GeniE

Tutorial

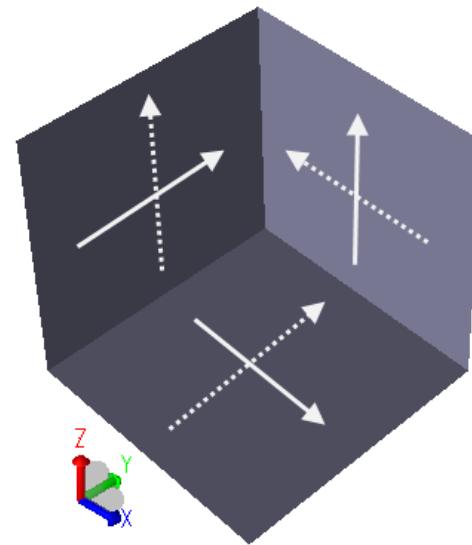
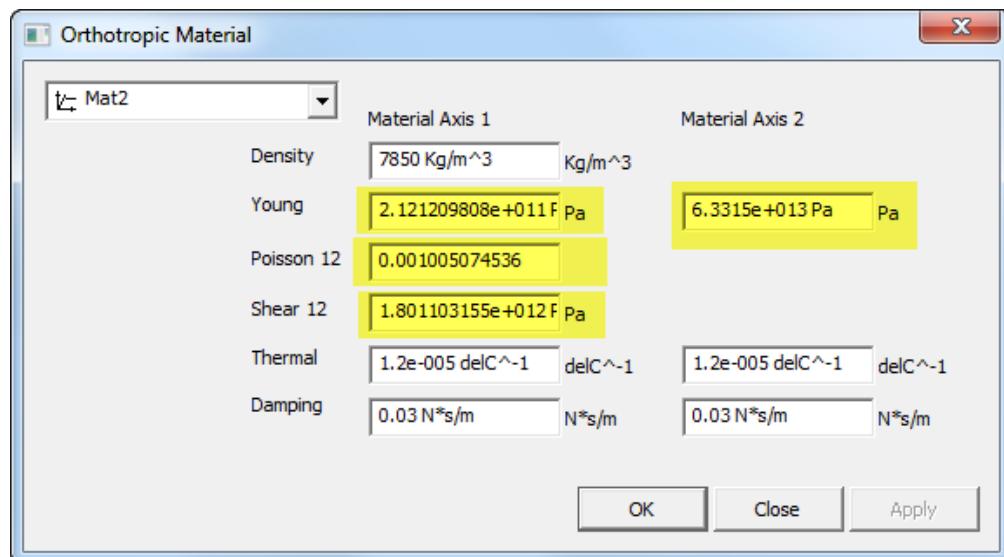
9 September 2014

Purpose

- This tutorial will explain
 - The difference between orthotropic and isotropic material
 - How to calculate the material coefficients in a orthotropic material
 - How to use scripts to generate the material coefficients
 - See also GeniE SnackPack:
https://projects.dnv.com/sesam/Genie_utils/index.html
 - How to use it in GeniE (from version 6.7 and onwards)
 - Limitations
 - How to make a corrugated bulkhead in GeniE (including mesh settings)
- Note: These are simplified methods from literature. The validity of the calculations will depend upon boundary conditions and loads.

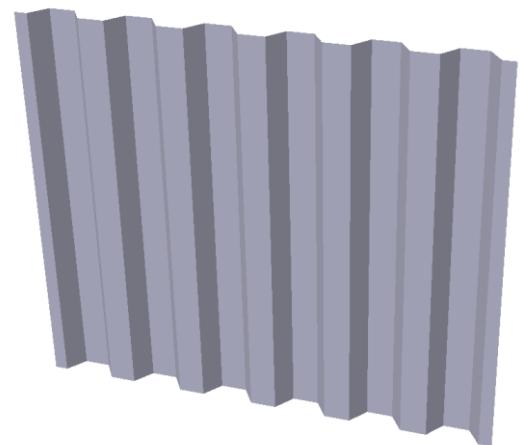
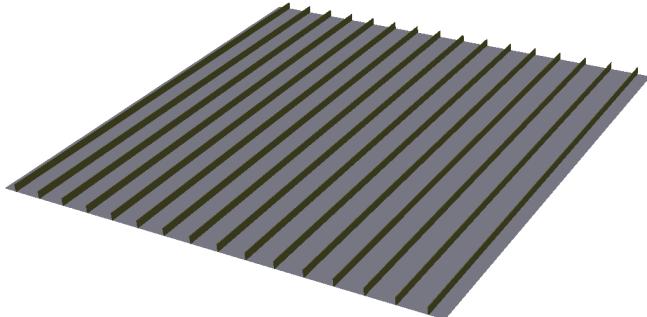
Orthotropic material

- Material properties may be different for material main axis 1 and 2
 - As compared to isotropic material, there are different material constants for E-modulus (Young factor in direction 1 and 2), the Shear modulus G12 (the shear modulus in direction 2 on the plane whose normal is in direction 1) and the Poisson ratio V12 (corresponds to a contraction in direction 2 when an extension is applied in direction 1).



Where to use it?

- In global models to make simple plates from structures like:
 - Plates with equidistant stiffeners
 - Corrugated plates (e.g. corrugated bulkhead),
- Defining composites



Limitations

- Applies for planar plates
- The values for Young modulus E1 and E2 are defined by the users
- The Poisson ration V12 is defined by the user. The Poisson ration V21 is computed by GeniE to be $V21 = (E2/E1) * V12$
- The Shear modulus is defined by the user. For an orthotropic plate it may be approximated as

$$G_{12} = \frac{\sqrt{E_1 E_2}}{(2(1 + \sqrt{\nu_{12} \nu_{21}}))}$$

	Material Axis 1	Material Axis 2
Density	7850 Kg/m ³	Kg/m ³
Young	2.121209808e+011 F Pa	6.3315e+013 Pa
Poisson 12	0.001005074536	
Shear 12	1.801103155e+012 F Pa	
Thermal	1.2e-005 delC^-1	delC^-1
Damping	0.03 N*s/m	N*s/m

- To avoid negative values on the matrix describing the material the Poisson ratio V12 and V21 should be within the following limits
 $0.0 < V12 < 0.5$
 $0.0 < V21 < 0.5$
 $(1 - V12 * V21) > 0.0$

Flat plates with stiffeners in equal distance

Purpose of this section:

- How to compute substitution modulus
- JS example

Flat plates with stiffeners in equal distance

- To simplify plates with stiffeners you need to compute equivalent Young modulus in direction X and Y.

t – plate thickness

t_1 – plate thickness + beam height

h – stiffener thickness

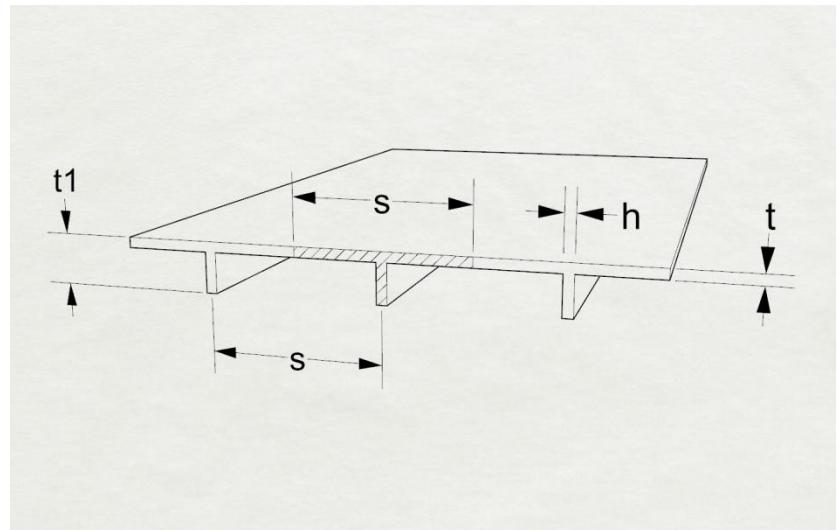
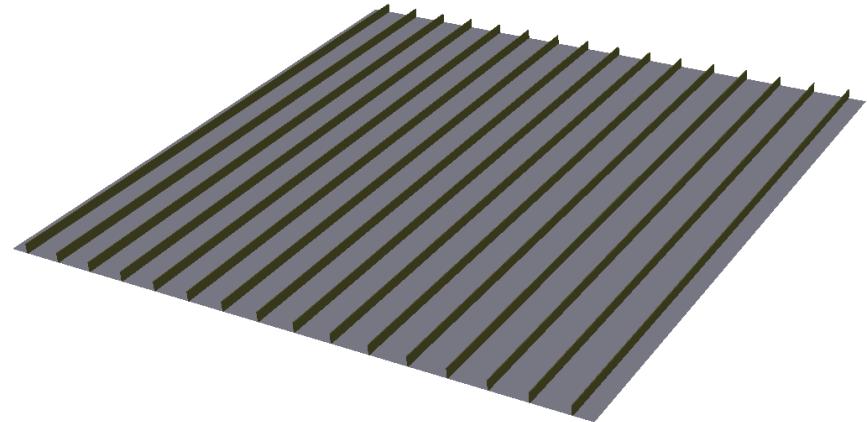
E – original's material Young modulus

ν – Poisson's ratio

I – Moment of inertia about neutral axis of a T-section of width s (shown as dashed)

E_x - equivalent Young modulus in local X axis

E_y - equivalent Young modulus in local Y direction



Recalculating Young modulus

- First we need to calculate moment of inertia

$$A_1 = st$$

$$A_2 = hb$$

$$\bar{I}_1 = \frac{st^3}{12}$$

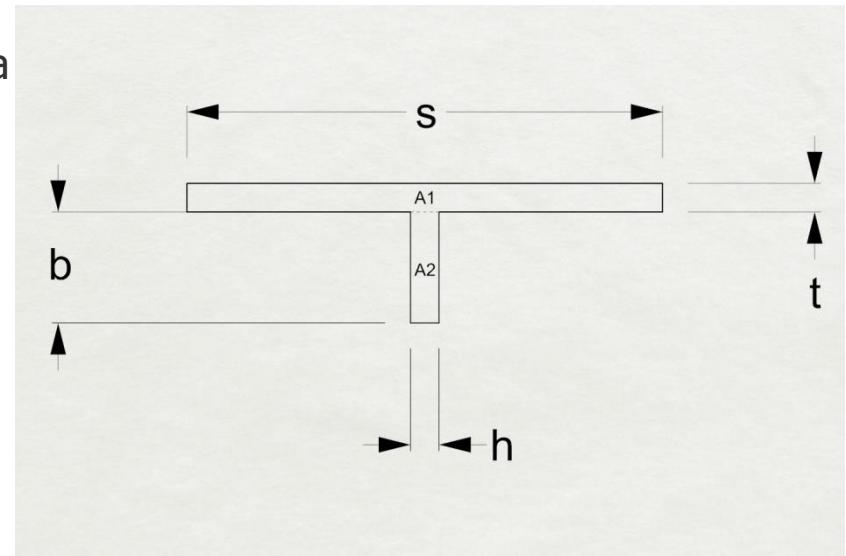
$$\bar{I}_2 = \frac{hb^3}{12}$$

$$\bar{y}_1 = \frac{t}{2}$$

$$\bar{y}_2 = t + \frac{b}{2}$$

$$\bar{y} = \frac{A_1\bar{y}_1 + A_2\bar{y}_2}{A_1 + A_2}$$

$$I = [\bar{I}_1 + A_1(\bar{y} - \bar{y}_1)^2] + [\bar{I}_2 + A_2(\bar{y} - \bar{y}_2)^2]$$



- If we want use different type of stiffener we need to know it's y dimension of neutral axis and moment of inertia. Inertia has to be correctly included to a plate due to the effect of the Steiner theorem.

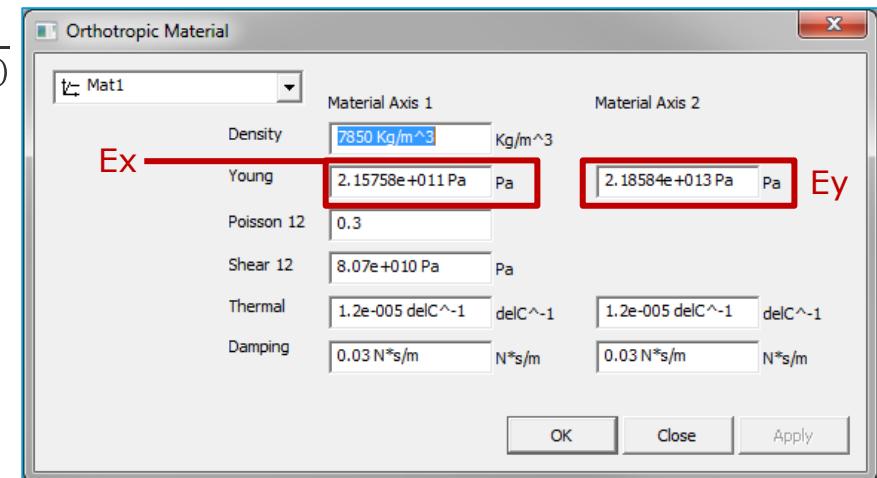
Recalculating Young modulus

- Computing equivalent Young modulus

$$E_x = \frac{Es}{s-h+h\left(\frac{t}{t_1}\right)^3}$$

$$E_y = \frac{12EI}{t^3s}$$

- If plate is stiffed in X direction $v_{12} = v_{original}$
- If plate is stiffed in Y direction $v_{12} = \frac{E_x}{E_y} v_{21}$ $v_{21} = v_{original}$
- Computing shear modulus $G_{12} = \frac{\sqrt{E_x E_y}}{2(1+\sqrt{v_{12} v_{21}})}$



Flat plates with stiffeners in equal distance JS example

- We can make calculation much more faster using JS
- Example for plate with stiffeners:

```
// Before start create new materials
// E.g.:
Mat1 = MaterialLinear(285 MPa, 7850 Kg/m^3, 2.1e+011 Pa, 0.3, 1.2e-005 delC^-1, 0.03 N*s/m);
Mat2 = MaterialOrthotropic(7850 Kg/m^3, 2.1E+11 Pa, 2.1E+11 Pa, 0.3, 8.07e+010 Pa, 1.2e-005 delC^-1, 1.2e-005 delC^-1, 0.03 N*s/m, 0.03 N*s/m);
Mat3 = MaterialOrthotropic(7850 Kg/m^3, 2.1E+11 Pa, 2.1E+11 Pa, 0.3, 8.07e+010 Pa, 1.2e-005 delC^-1, 1.2e-005 delC^-1, 0.03 N*s/m, 0.03 N*s/m);

s = 0.75;
t = 0.02;
h = 0.02;
b = 0.2;
t1 = t + b;

// Material constants
// Use your basis material name
E = Mat1.young;
poisson = Mat1.poisson;

// Moment of inertia about neutral axis of a T-section of width s

A1 = s * t;
I1 = (s * (Math.pow(t, 3)))/12;
y1 = t / 2;

A2 = h * b;
I2 = (h * (Math.pow(b, 3)))/12;
y2 = t + (b / 2);

yc = ((A1 * y1) + (A2 * y2))/(A1 + A2);

I = I1 + (A1 * (Math.pow((yc - y1), 2))) + I2 + (A2 * (Math.pow((yc - y2), 2)));

// Substitute Young modulus
Ex = (E * s) / (s - h + (h * (Math.pow((t / t1), 3))));
Ey = (12 * E * I) / (Math.pow(t, 3) * s);
```

Flat plates with stiffeners in equal distance JS example (cont'd)

```
////////////////// Case 1 : stiffeners in Y-direction use Mat2
// Assign new Young modulus values

Mat2.young1 = Ex;
Mat2.young2 = Ey;

// Assign derived values

poisson21 = poisson;
poisson12 = Ex / Ey *poisson21;

Mat2.poisson12 = poisson12;
Mat2.shear = Math.sqrt( Ex.toDouble()*Ey.toDouble() ) / ( 2.0 * ( 1.0 + Math.sqrt( poisson12*poisson21 ) ) );
```

```
////////////////// Case 2 : stiffeners in X-direction use Mat3
```

```
// Assign new Young modulus values

Mat3.young1 = Ey;
Mat3.young2 = Ex;

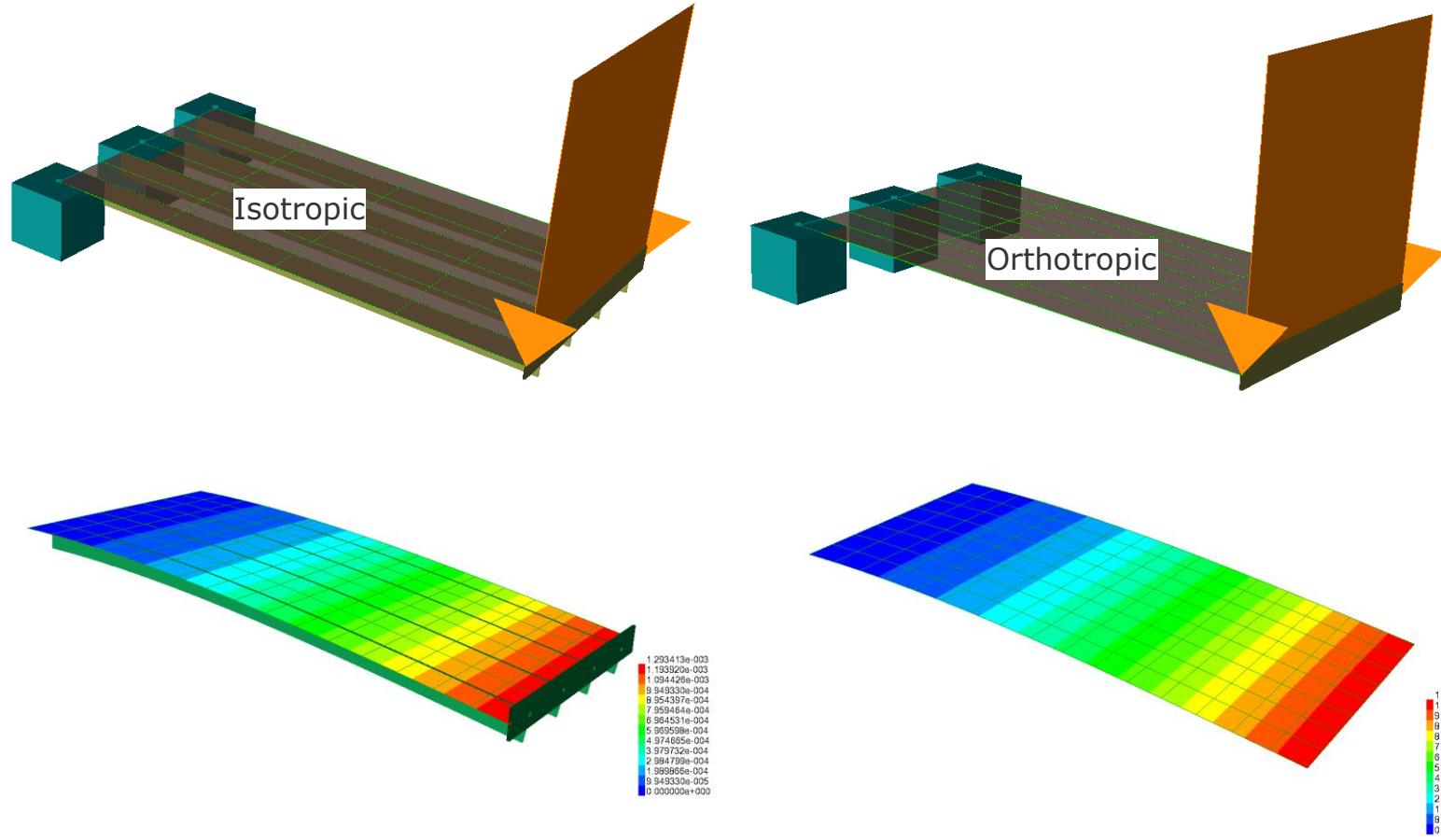
// Assign derived values

poisson12 = poisson;
poisson21 = Ey / Ex *poisson12;

Mat3.poisson12 = poisson12;
Mat3.shear = Math.sqrt( Ex.toDouble()*Ey.toDouble() ) / ( 2.0 * ( 1.0 + Math.sqrt( poisson12*poisson21 ) ) );
```

Flat plates with stiffeners in equal distance

- Stiffened flat plate



Corrugated plates

Purpose of this section:

- How to compute substitution modulus
- JS example

Corrugated plates

- Calculating inertia moment

$$I = \frac{1}{2} h^2 t \left[1 - \frac{0.81}{1 + 2.5 \left(\frac{h}{2s} \right)^2} \right]$$

- Calculating λ

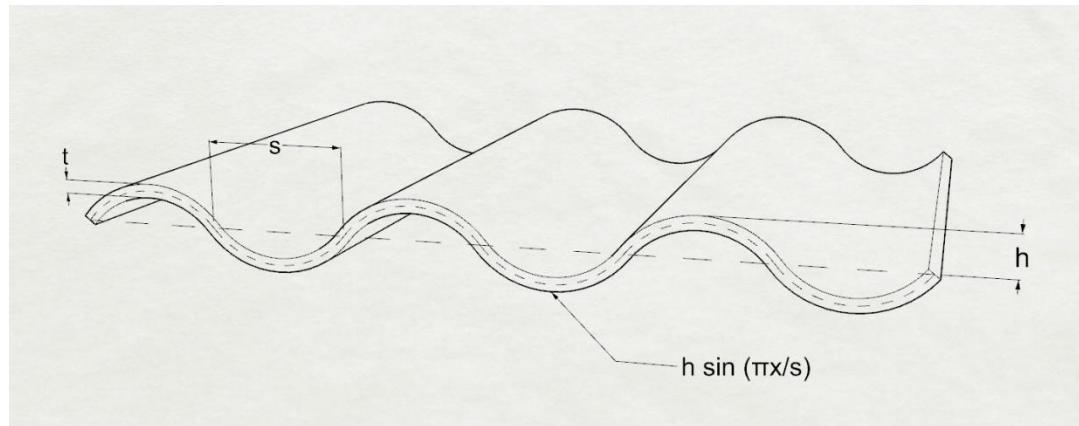
$$\lambda = s \left(1 + \frac{\pi^2 h^2}{4s^2} \right)$$

- Equivalent Young modulus

$$E_x = \frac{sE}{\lambda(1-\nu^2)}$$

$$E_y = \frac{12EI}{t^3}$$

- If plate is stiffed in X direction $\nu_{12} = \nu_{original}$
- If plate is stiffed in Y direction $\nu_{12} = \frac{E_x}{E_y} \nu_{21} \quad \nu_{21} = \nu_{original}$
- Computing shear modulus $G_{12} = \frac{\sqrt{E_x E_y}}{2(1+\sqrt{\nu_{12} \nu_{21}})}$



Corrugated plates JS Example

```
//////////  
// Corrugated plate  
//  
// Before start create new orthotropic material  
// E.g.:  
// Mat3 = MaterialOrthotropic(7850 Kg/m^3, 2.1+11, 2.1E+11, 0.3, 8.07e+010 Pa, 1.2e-005 delC^-1, 1.2e-005 delC^-1, 0.03 N*s/m, 0.03 N*s/m);  
  
h = 0.1875;  
s = 0.375;  
t = 0.01;  
  
// Material constants  
// Use your basis material name  
E = Mat1.young;  
poisson = Mat1.poisson;  
  
// Moment of inertia and gama  
gama = s * (1 + ((Math.pow(Math.PI, 2) * Math.pow(h, 2))/(4 * Math.pow(s, 2))));  
I = 0.5 * Math.pow(h, 2) * t * (1 - (0.81 / (1 + (2.5 * Math.pow((h / (2*s)), 2)))));  
  
// Substitute Young modulus  
Ex = (s * E) / (gama * (1 - Math.pow(poisson, 2)));  
Ey = (12 * E * I) / Math.pow(t, 3);
```

Corrugated plates JS Example (continued)

```
////////////////// Case 1 : corrugations in Y-direction use Mat2

// Assign new Young modulus values

Mat2.young1 = Ex;
Mat2.young2 = Ey;

// Assign derived values

poisson21 = poisson;
poisson12 = Ex / Ey *poisson21;

Mat2.poisson12 = poisson12;
Mat2.shear = Math.sqrt( Ex.toDouble()*Ey.toDouble() ) / ( 2.0 * ( 1.0 + Math.sqrt( poisson12*poisson21) ) );

////////////////// Case 2 : corrugations in X-direction use Mat3

// Assign new Young modulus values

Mat3.young1 = Ey;
Mat3.young2 = Ex;

// Assign derived values

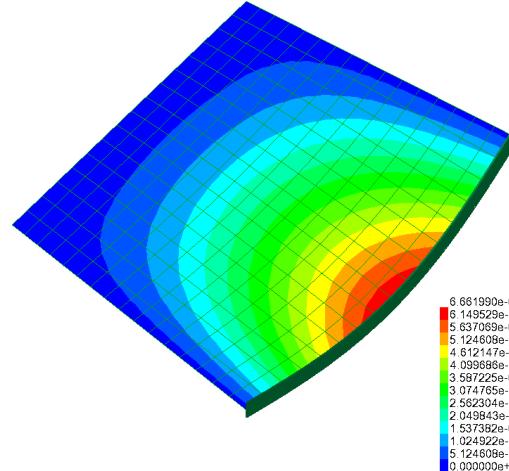
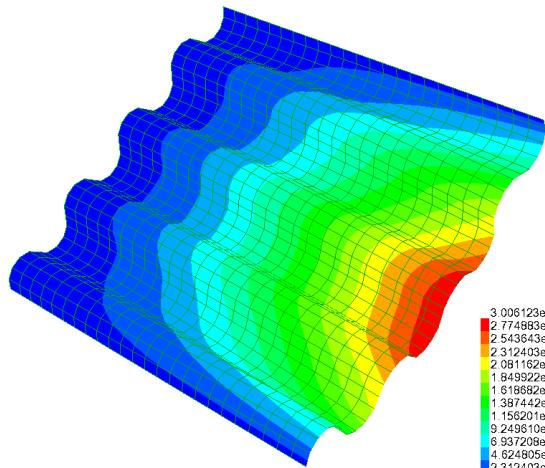
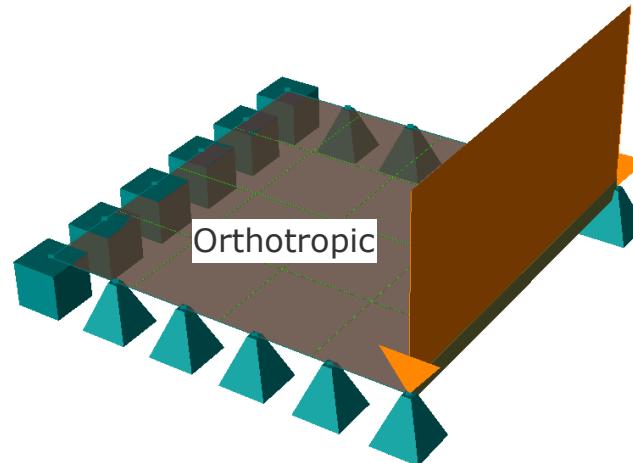
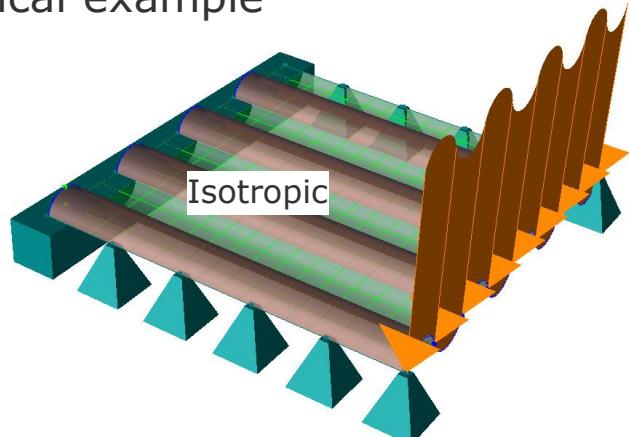
poisson12 = poisson;
poisson21 = Ey / Ex *poisson12;

Mat3.poisson12 = poisson12;
Mat3.shear = Math.sqrt( Ex.toDouble()*Ey.toDouble() ) / ( 2.0 * ( 1.0 + Math.sqrt( poisson12*poisson21) ) );

///////////////////////////////
```

Corrugated plates

- Typical example



Corrugated non-continuous plate

Purpose of this section:

- How to compute substitution modulus
- JS example

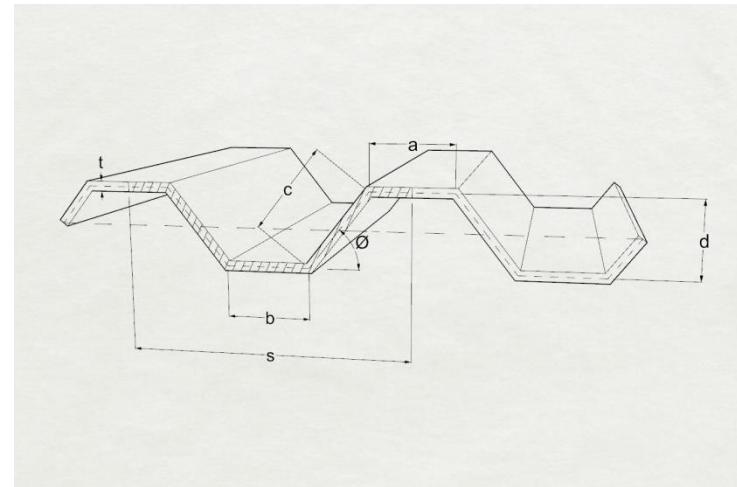
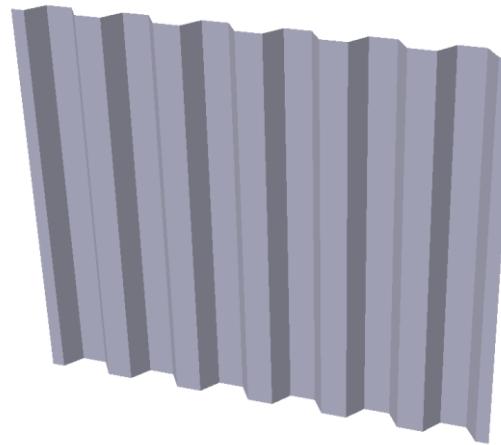
Corrugated non-continuous plate

- Equivalent Young modulus

$$E_x = \frac{sE}{(a+b+2c)(1-v^2)}$$

$$E_y = \frac{12EI}{st^3}$$

- I – moment of inertia about neutral axis
of a dashed area.



Corrugated non-continuous plate

- Calculating moment of inertia

$$t' = \frac{t}{\sin\phi}$$

$$c = \frac{d}{\sin\phi}$$

$$A_1 = at$$

$$A_2 = bt$$

$$A_3 = 2dt'$$

$$\bar{I}_1 = \frac{at^3}{12}$$

$$\bar{I}_2 = \frac{bt^3}{12}$$

$$\bar{I}_3 = 2 \cdot \left(\frac{t'd^3}{12} \right)$$

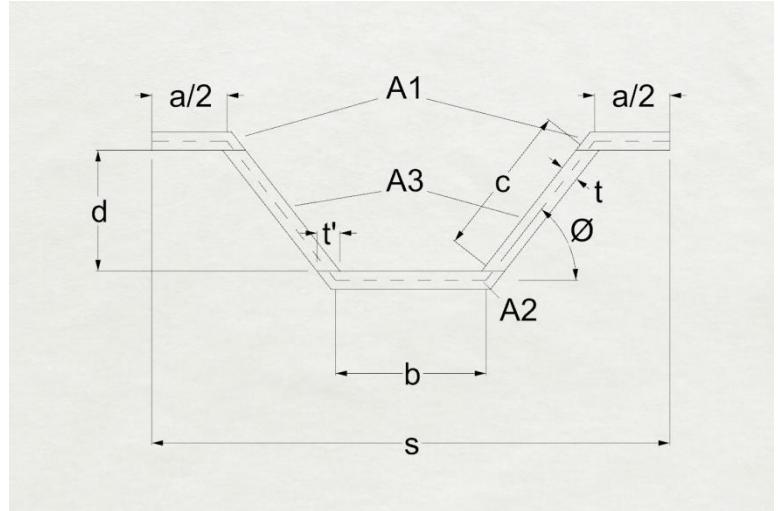
$$\bar{y}_1 = t/2$$

$$\bar{y}_2 = t + d + t/2$$

$$\bar{y}_3 = t + d/2$$

$$\bar{y} = \frac{A_1\bar{y}_1 + A_2\bar{y}_2 + A_3\bar{y}_3}{A_1 + A_2 + A_3}$$

$$I = [\bar{I}_1 + A_1(\bar{y} - \bar{y}_1)^2] + [\bar{I}_2 + A_2(\bar{y} - \bar{y}_2)^2] + [\bar{I}_3 + A_3(\bar{y} - \bar{y}_3)^2]$$



Corrugated non-continuous plate

- If plate is stiffed in X direction $v_{12} = v_{original}$
- If plate is stiffed in Y direction $v_{12} = \frac{E_x}{E_y} v_{21}$ $v_{21} = v_{original}$
- Computing shear modulus $G_{12} = \frac{\sqrt{E_x E_y}}{2(1 + \sqrt{v_{12} v_{21}})}$

Corrugated non-continuous plate JS example

```
///////////////////////////////
// Corrugated non-continuous plate
//
// Before start create new orthotropic material
// E.g.:

Mat1 = MaterialLinear(285 MPa, 7850 Kg/m^3, 2.1e+011 Pa, 0.3, 1.2e-005 delC^-1, 0.03 N*s/m);
Mat2 = MaterialOrthotropic(7850 Kg/m^3, 2.1E+11 Pa, 2.1E+11 Pa, 0.3, 8.07e+010 Pa, 1.2e-005 delC^-1, 1.2e-005 delC^-1, 0.03 N*s/m, 0.03 N*s/m);
Mat3 = MaterialOrthotropic(7850 Kg/m^3, 2.1E+11 Pa, 2.1E+11 Pa, 0.3, 8.07e+010 Pa, 1.2e-005 delC^-1, 1.2e-005 delC^-1, 0.03 N*s/m, 0.03 N*s/m);

a = 0.3;
b = 0.3;
d = 0.25;

fiangle = 60;
firadians = (2*Math.Pi()*fiangle)/360;

c = d / Math.sin(firadians);
t = 0.01;
tprim = t / Math.sin(firadians);
s = 0.85;

// Material constants
// Use your basis material name

E = Mat1.young;
poisson = Mat1.poisson;

A1 = a*t;
I1 = (a * Math.Pow(t, 3))/12;
y1 = t / 2;

A2 = b * t;
I2 = (b * Math.Pow(t, 3))/12;
y2 = t + d + (t/2);

A3 = 2 * d * tprim;
I3 = 2 * ((tprim * Math.Pow(d, 3))/12);
y3 = t + (d/2);
```

Corrugated non-continuous plate JS example (continued)

```
y = ((A1*y1) + (A2*y2) + (A3*y3))/(A1 + A2 + A3);
I = (I1 + A1*Math.Pow((y - y1), 2)) + (I2 + A2*Math.Pow((y - y2),2)) + (I3 + A3*Math.Pow((y - y3), 2));

Ex = (s * E)/((a + b + (2*c)) * (1 - Math.Pow(poisson, 2)));
Ey = (12 * E * I)/(s * Math.Pow(t, 3));
////////////////// Case 1 : corrugations in Y-direction use Mat2

// Assign new Young modulus values

Mat2.young1 = Ex;
Mat2.young2 = Ey;

// Assign derived values

poisson21 = poisson;
poisson12 = Ex / Ey *poisson21;

Mat2.poisson12 = poisson12;
Mat2.shear = Math.sqrt( Ex.toDouble()*Ey.toDouble() ) / ( 2.0 * ( 1.0 + Math.sqrt( poisson12*poisson21 ) ) );

////////////////// Case 2 : corrugations in X-direction use Mat3

// Assign new Young modulus values

Mat3.young1 = Ey;
Mat3.young2 = Ex;

// Assign derived values

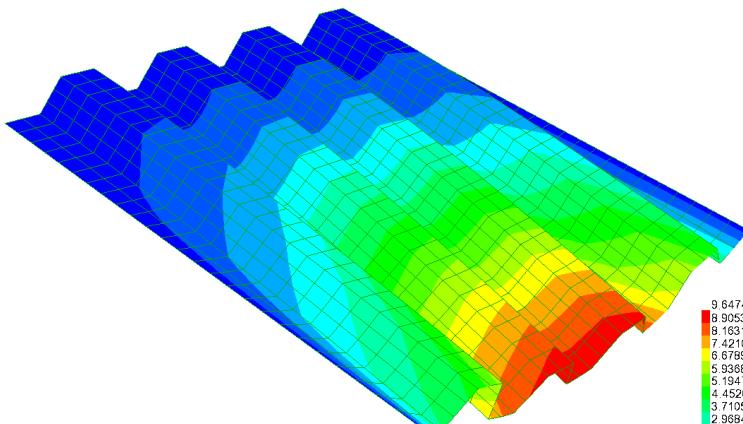
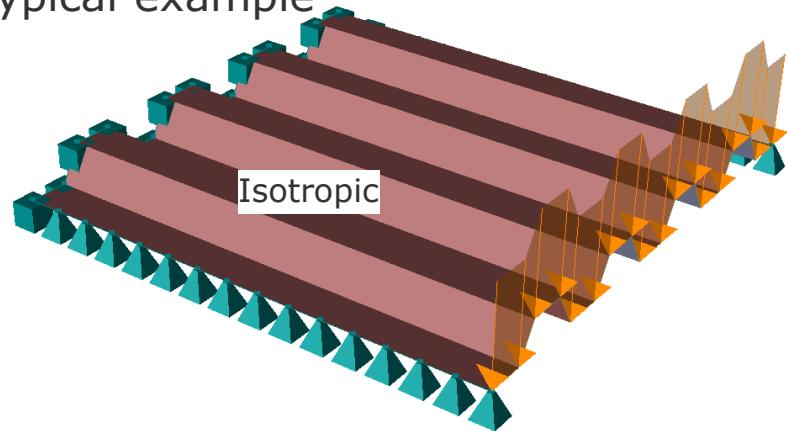
poisson12 = poisson;
poisson21 = Ey / Ex *poisson12;

Mat3.poisson12 = poisson12;
Mat3.shear = Math.sqrt( Ex.toDouble()*Ey.toDouble() ) / ( 2.0 * ( 1.0 + Math.sqrt( poisson12*poisson21 ) ) );

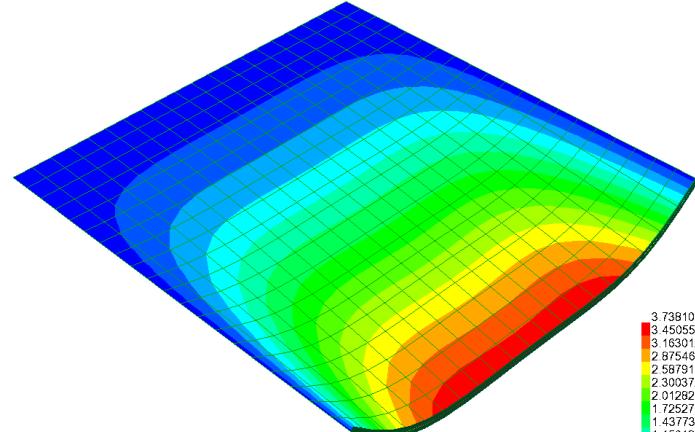
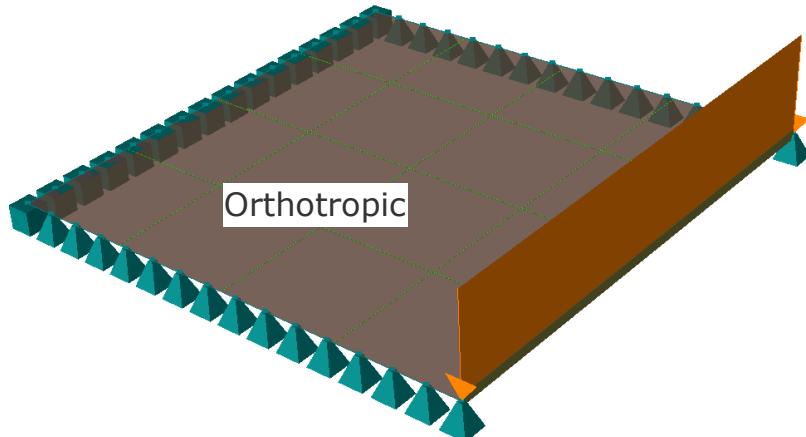
//////////////////
```

Corrugated non-continuous plate

- Typical example



9.647414e-003
8.905205e-003
8.163196e-003
7.421097e-003
6.678979e-003
5.936870e-003
5.194761e-003
4.452652e-003
3.710544e-003
2.968435e-003
2.226328e-003
1.484221e-003
7.421097e-004
0.000000e+000

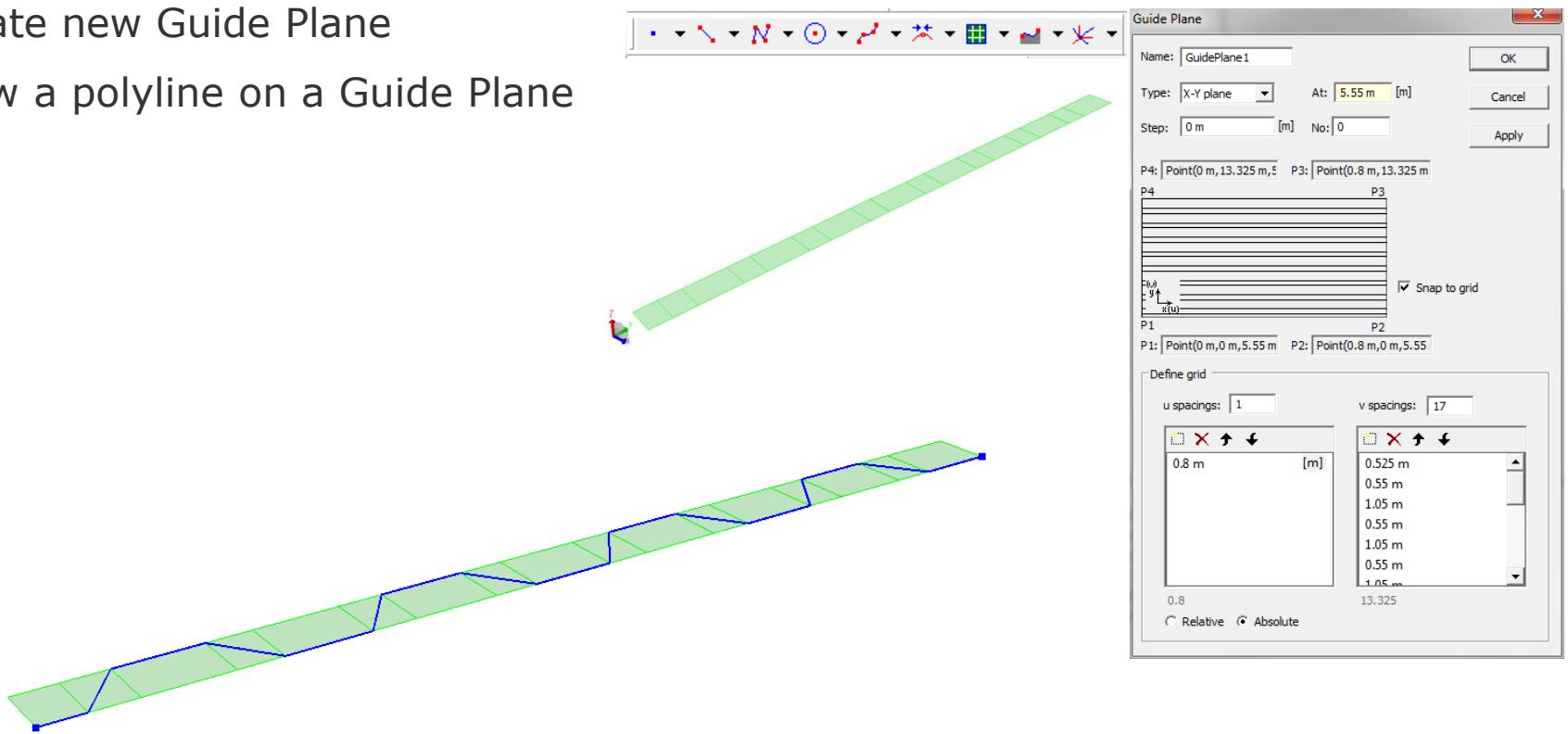


3.738105e-003
3.450559e-003
3.163012e-003
2.875485e-003
2.587919e-003
2.300452e-003
2.012922e-003
1.725278e-003
1.437733e-003
1.150196e-003
8.626395e-004
5.750930e-004
2.875485e-004
0.000000e+000

Modelling continuous corrugated plate

Modelling typical non-continuous plate

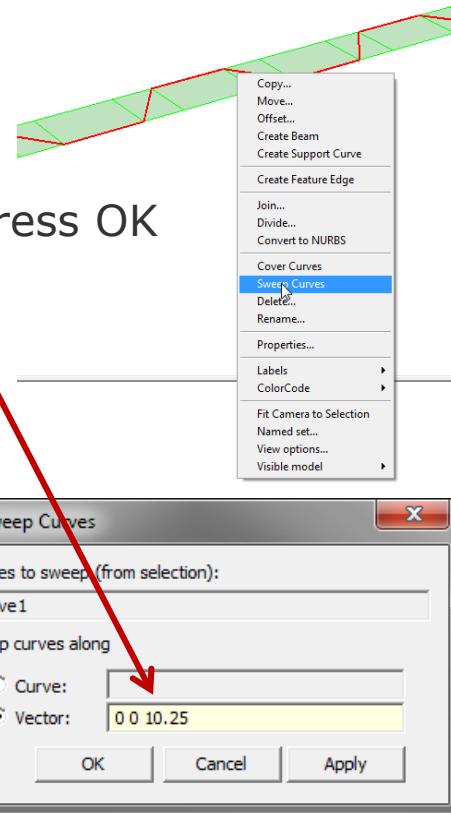
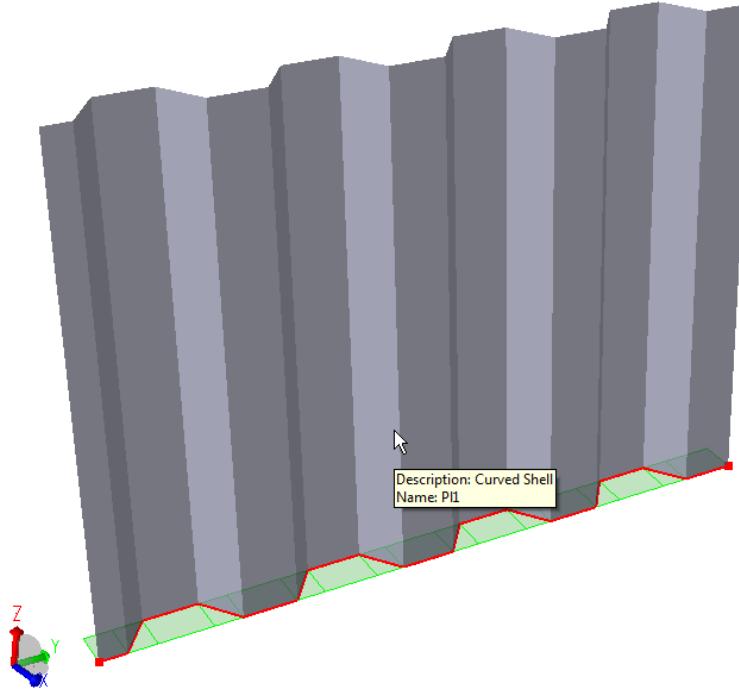
- Create new Guide Plane
- Draw a polyline on a Guide Plane



Modelling typical non-continuous plate

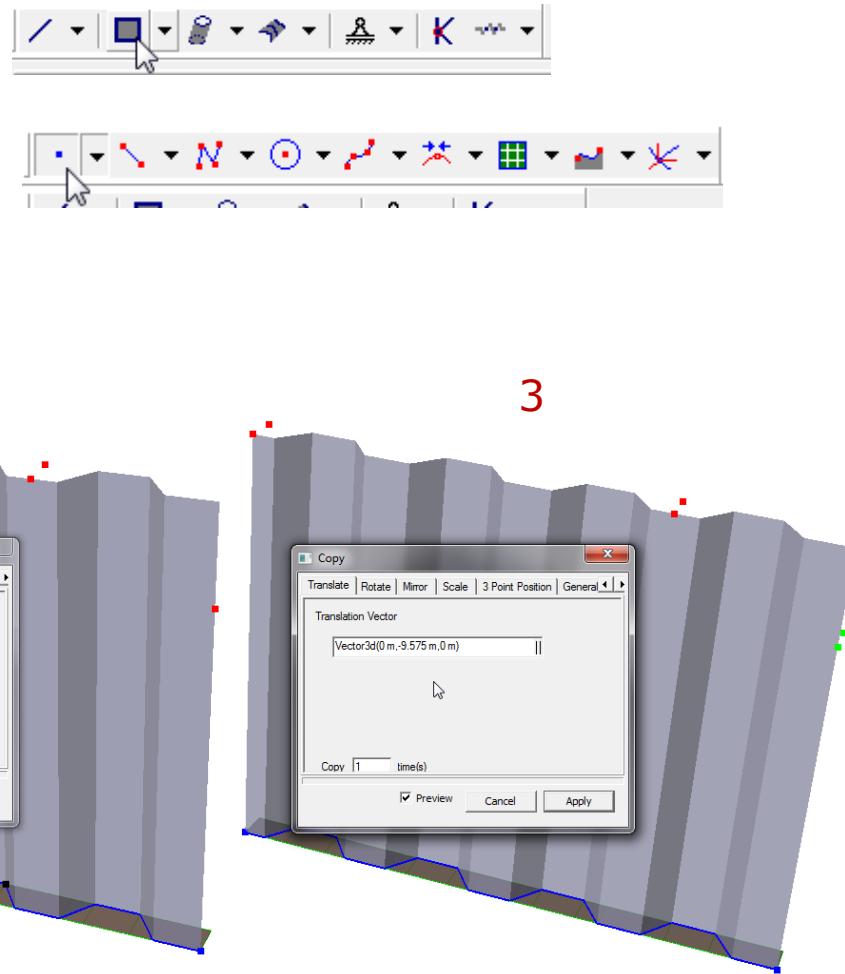
Sweeping polyline

- Right click on polyline and click Sweep Curves
- Type vector value in Sweep Curves dialog and press OK



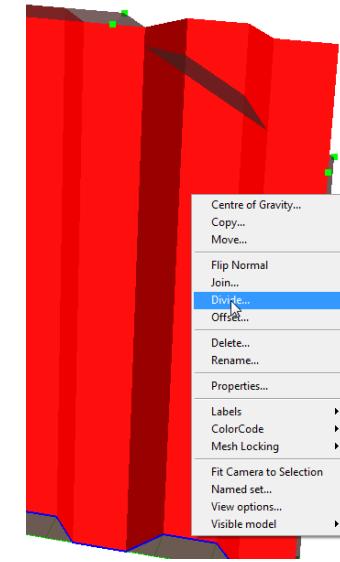
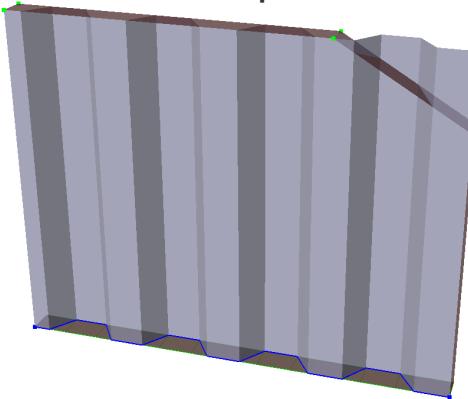
Modelling typical non-continuous plate

- Create plate using Flat Plate feature on the bottom part of corrugated plate
- Create two points on the outside corners of bottom plate
- Copy those points like in pictures below

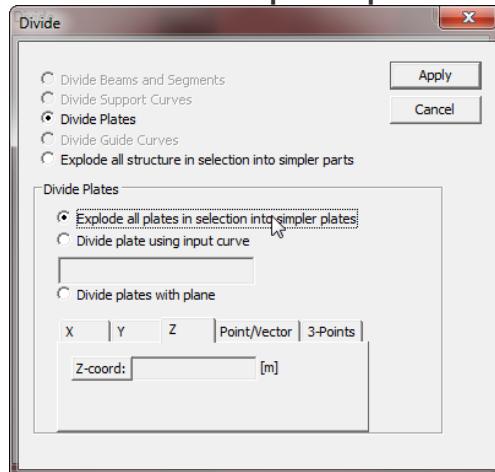


Modelling typical non-continuous plate

- Create plates on side and on the top of corrugated plate

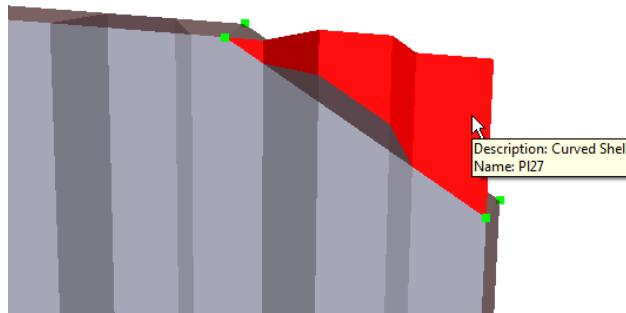


- Select corrugated plate and right click, select Divide
- Choose „Explode all plates into simpler parts“ and click „Apply“

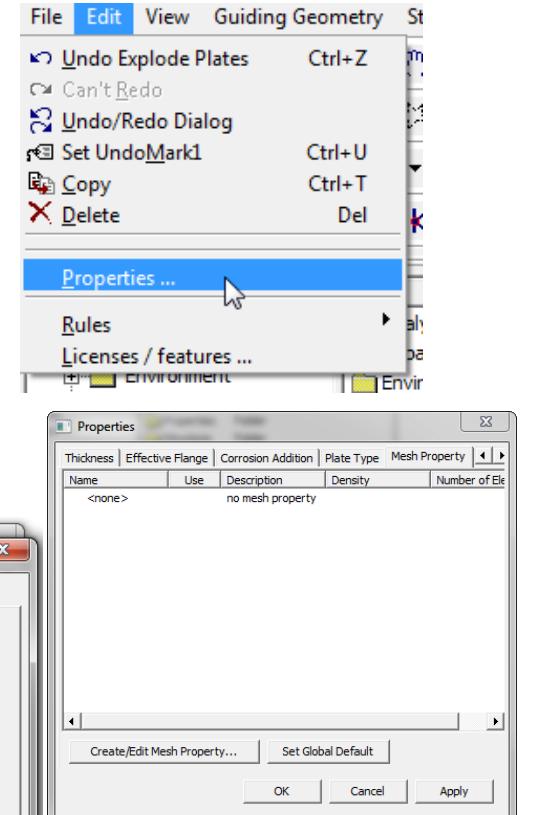


Modelling typical non-continuous plate

- Remove unnecessary plates from bulkhead like in picture

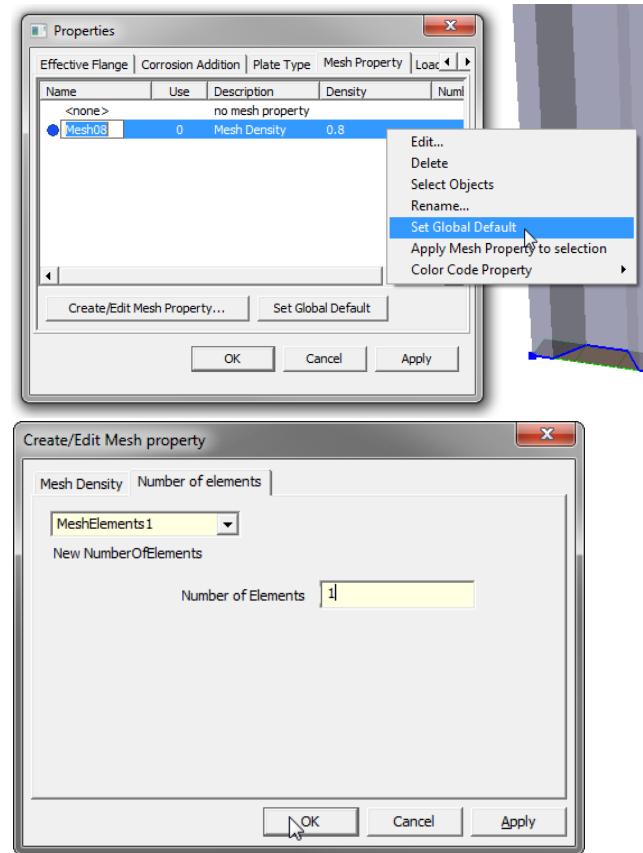
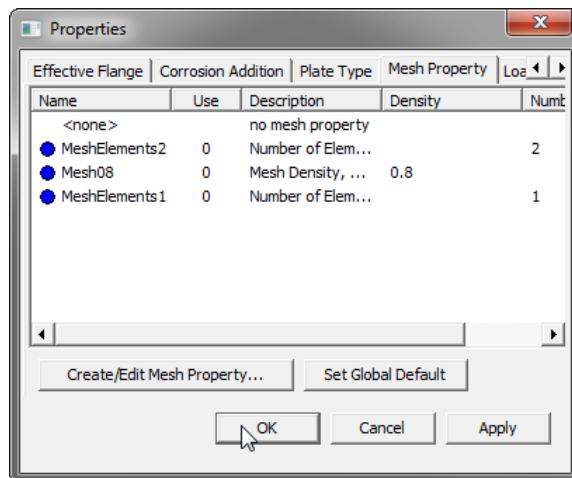


- Select Edit -> Properties from menu bar
- Go to „Mesh property tab“ and Click „Create/Edit Mesh Property...“
- Fill dialog like on picture to create main mesh density property.



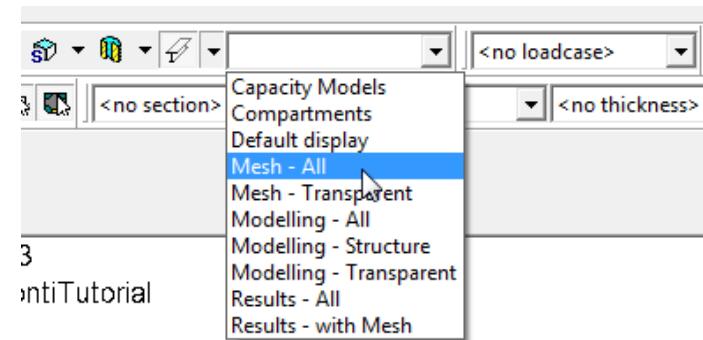
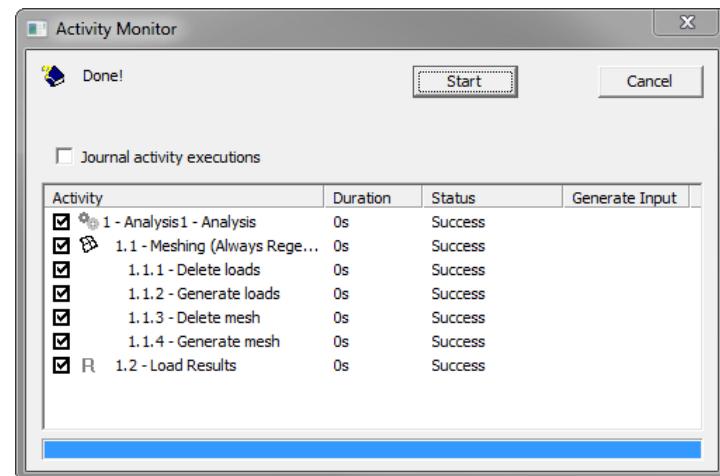
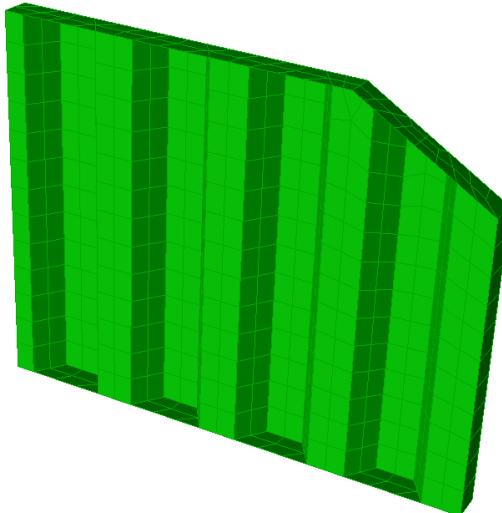
Modelling typical non-continuous plate

- Right click on new mesh property and select „Set global default”
- Click again on „Create/Edit Mesh Property” and move to „Number elements” tab
- Fill dialog box with value 1, click Apply and do the same with value 2



Modelling typical non-continuous plate

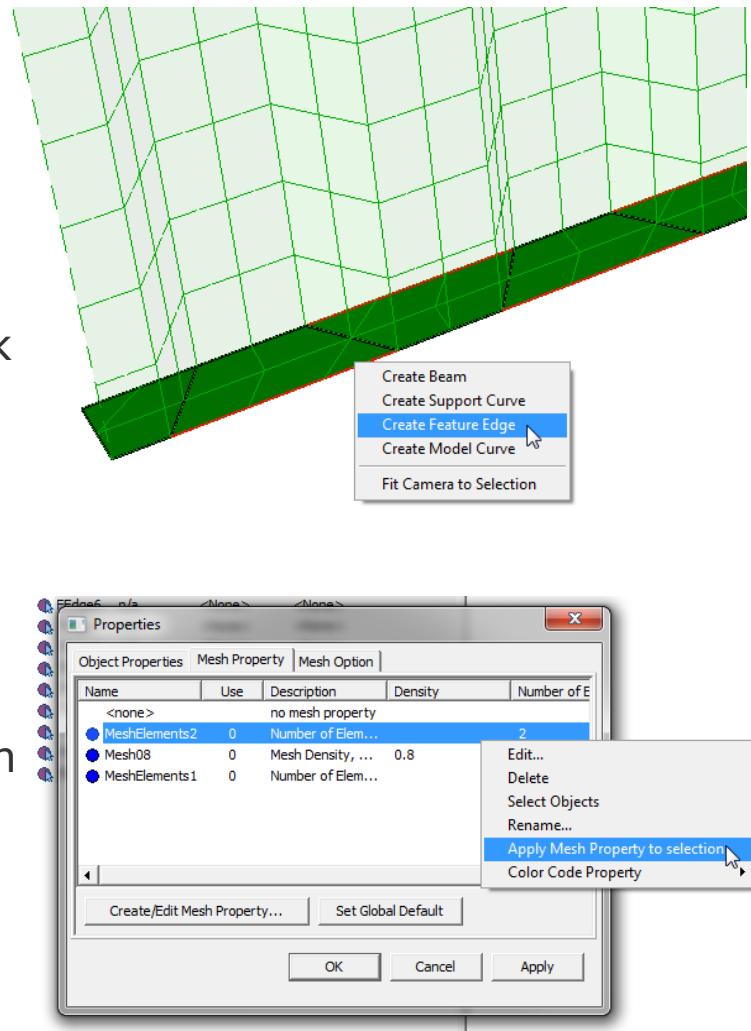
- Press „Alt + D“ to create new analysis
- Unselect „Linear Structural Analysis“ and press „OK“
- Click „Start in Activity monitor“. GeniE will mesh model. When all points has status Success you can close „Activity Monitor“ dialog
- Select „Mesh – All“ view



Modelling typical non-continuous plate

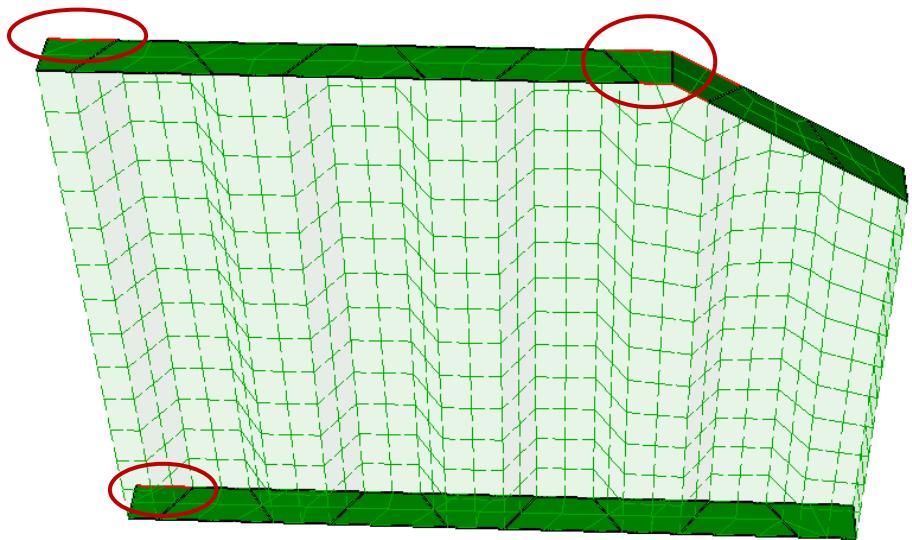
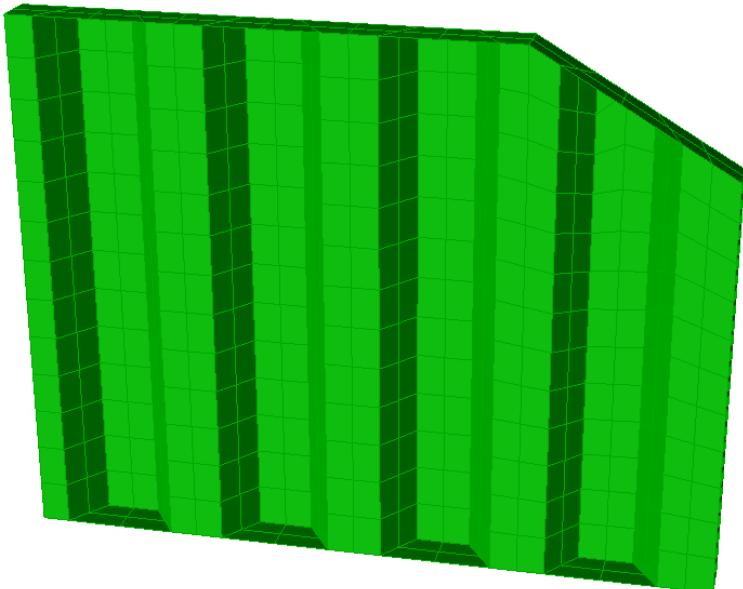
- Double click on bottom plate and select all edges that has more than two elements.
- Right click and select „Create Feature Edge”
- Do the same for top surfaces
- Select all Feature Edges from tree, right click and select „Properties” from menu
- Move to „Mesh Property” tab
- Right click on MeshElements2 and select „Apply Mesh Property to selection”

Feature edges are additional properties that can be used to specify exactly the number of elements along an edge.



Modelling typical non-continuous plate

- Create new feature edges on places marked on picture and assign MeshElement1 property like in previous slide
- Press „Alt + D” and click „Start”
- In result we should have good regular mesh



References

- Sestra_UM.pdf Chapter B6.5 – you can find it in e.g. \Program Files\DNVS\Sestra V8.7-00\Doc
- Ansel Ugural - „Stresses In Plates and Shells” – Second Edition, McGraw-Hill, 1999
- Hai-Hong Sun, Jack Spencer - Buckling strength assessment of corrugated panels in offshore structures - American Bureau of Shipping, Houston, 2005

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