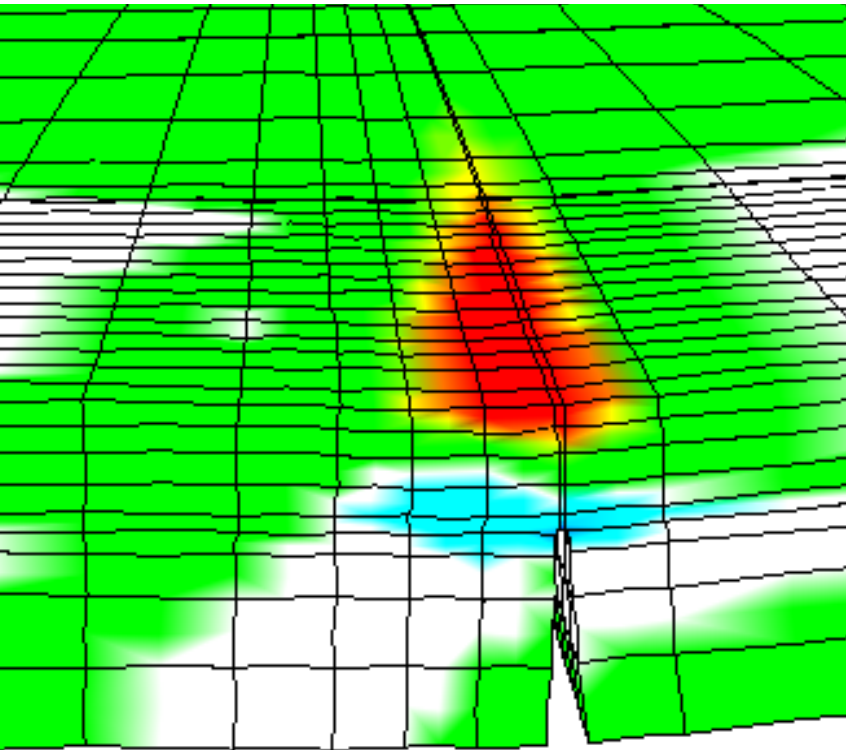


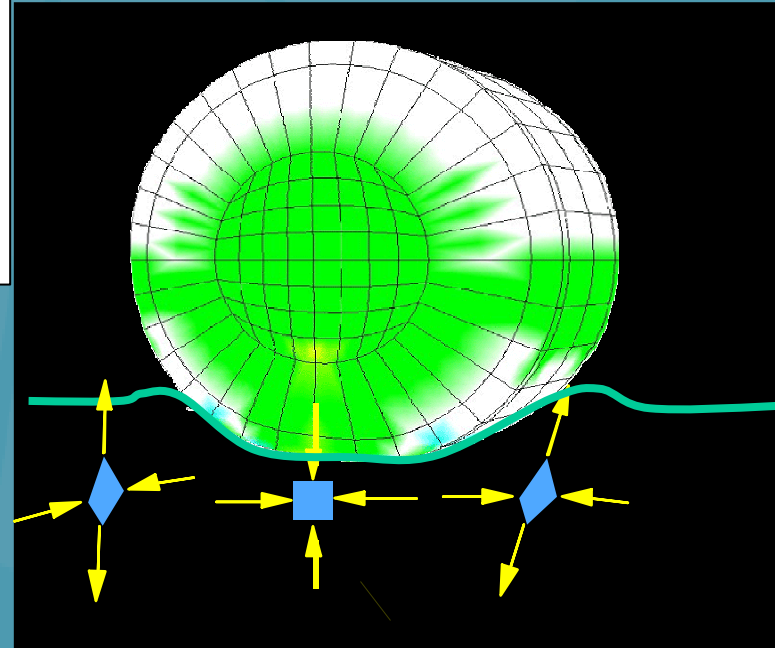
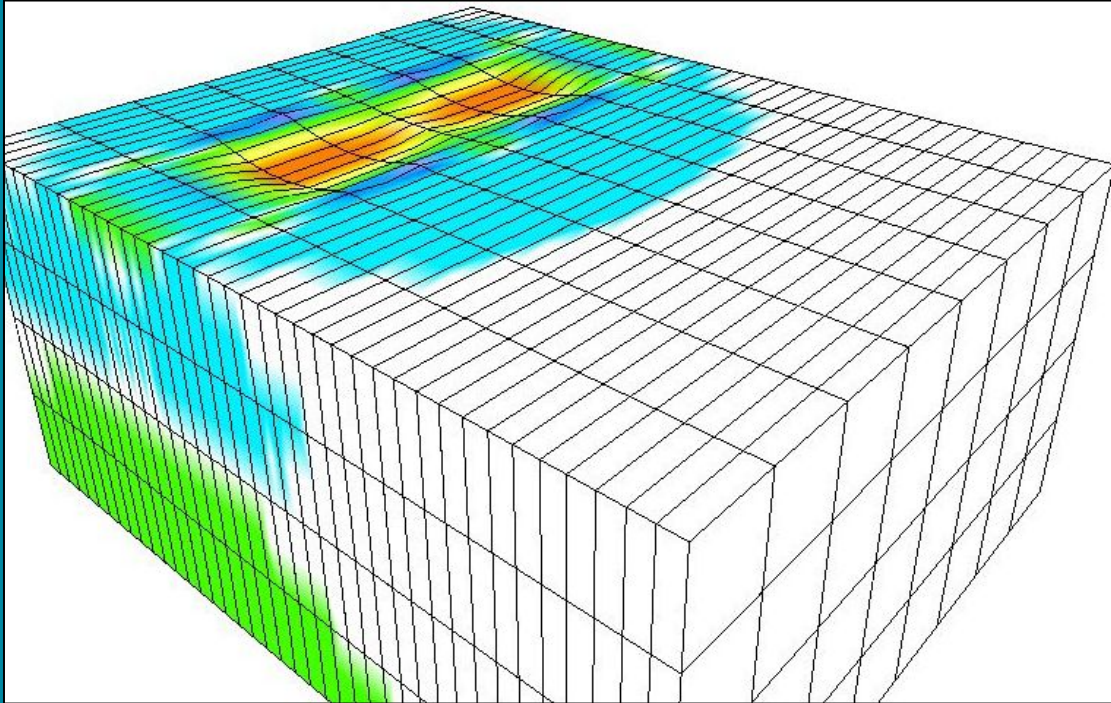
TRB Workshop 110: Validation of Advanced Flexible Pavement Modeling with Accelerated Pavement Testing Data



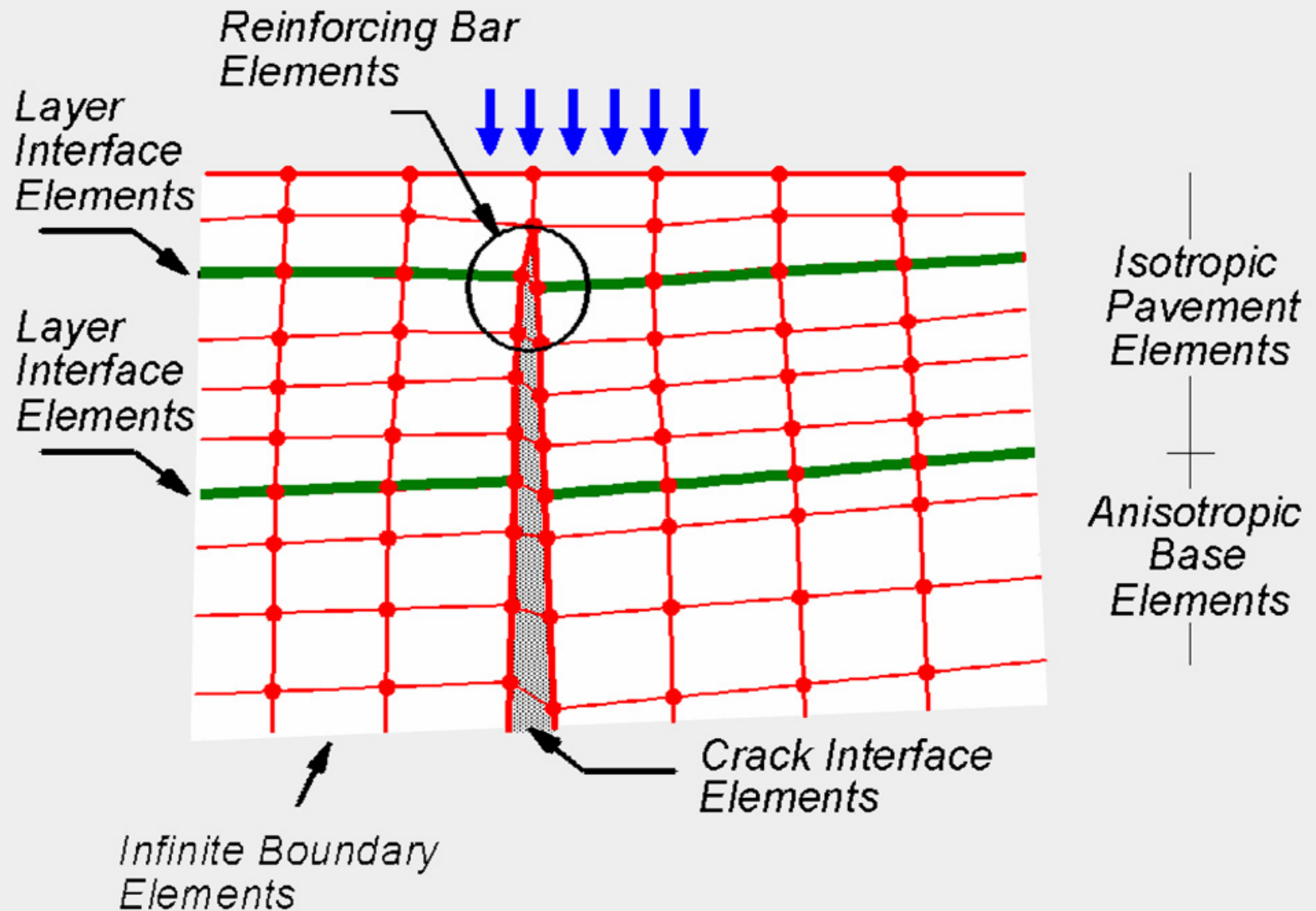
Needs for Accurate Pavement Modeling

Tom Scarpas, Xueyan Liu, Cor Kasbergen
Section of Structural Mechanics
TU Delft

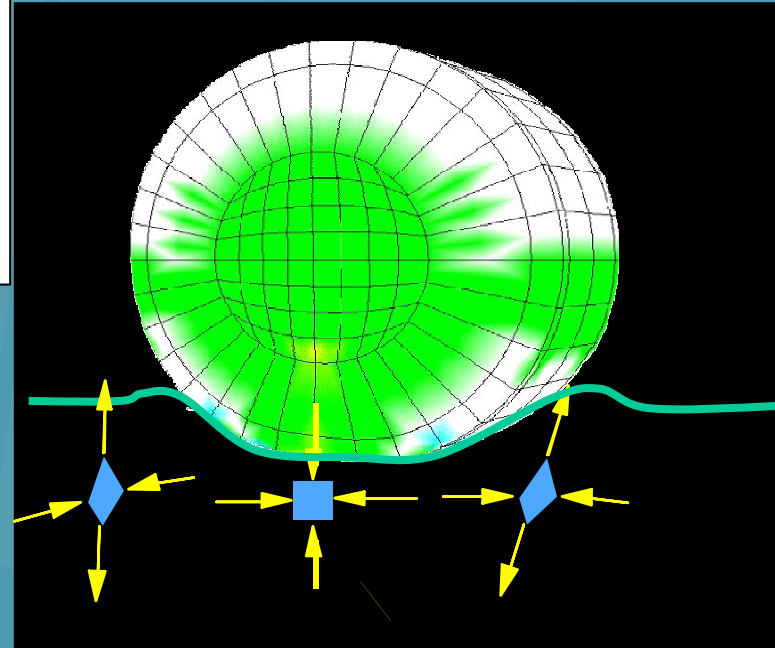
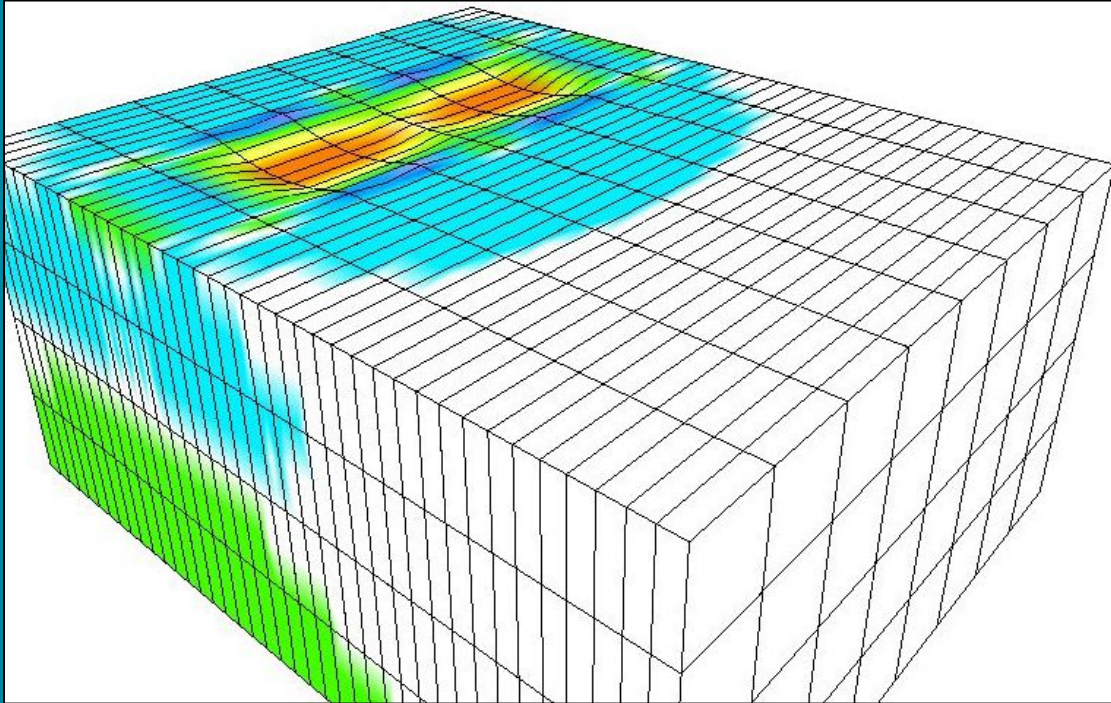
- Wheel induced state of stress



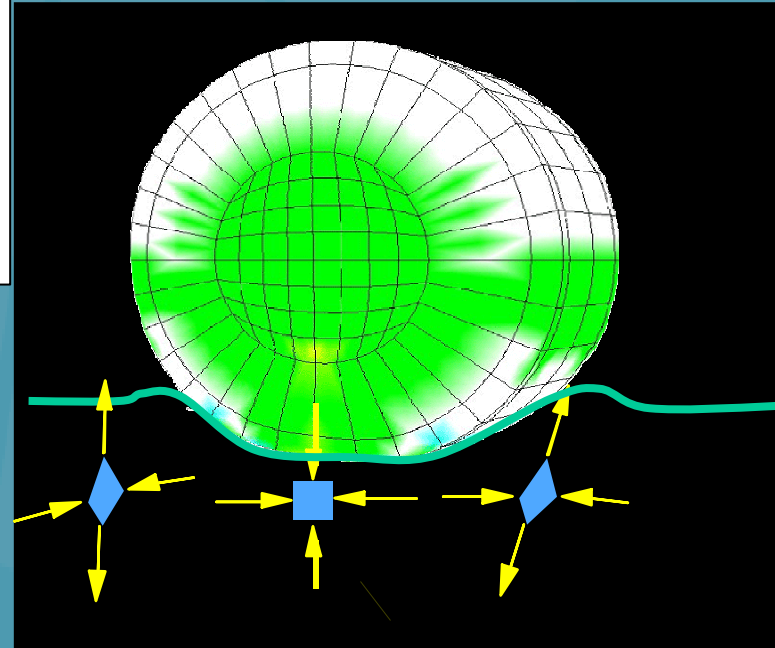
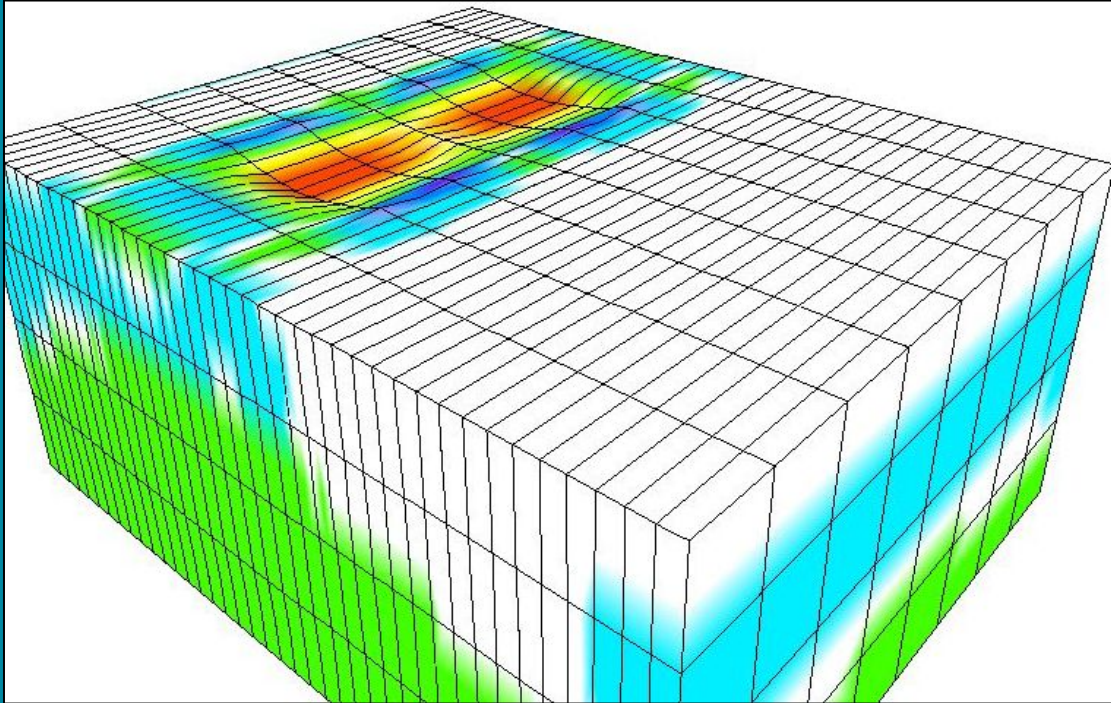
- the simulation problem



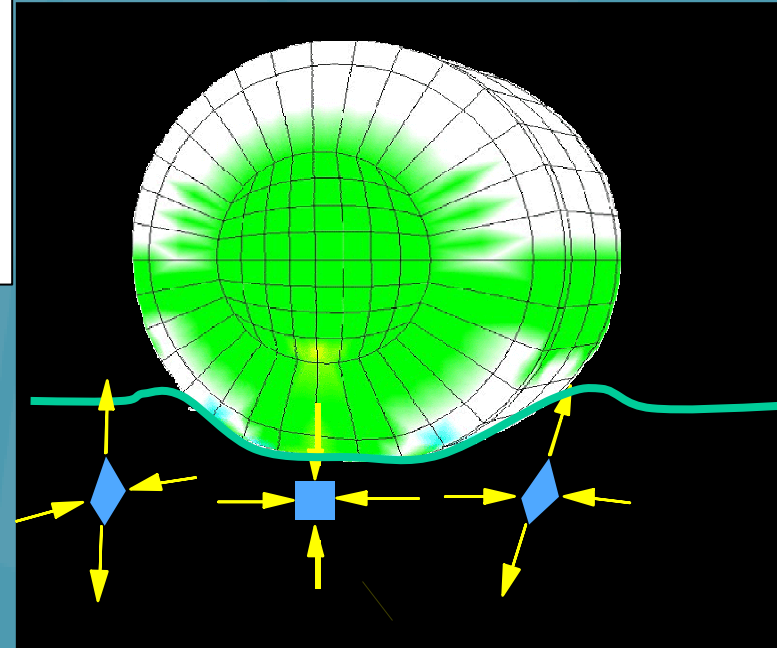
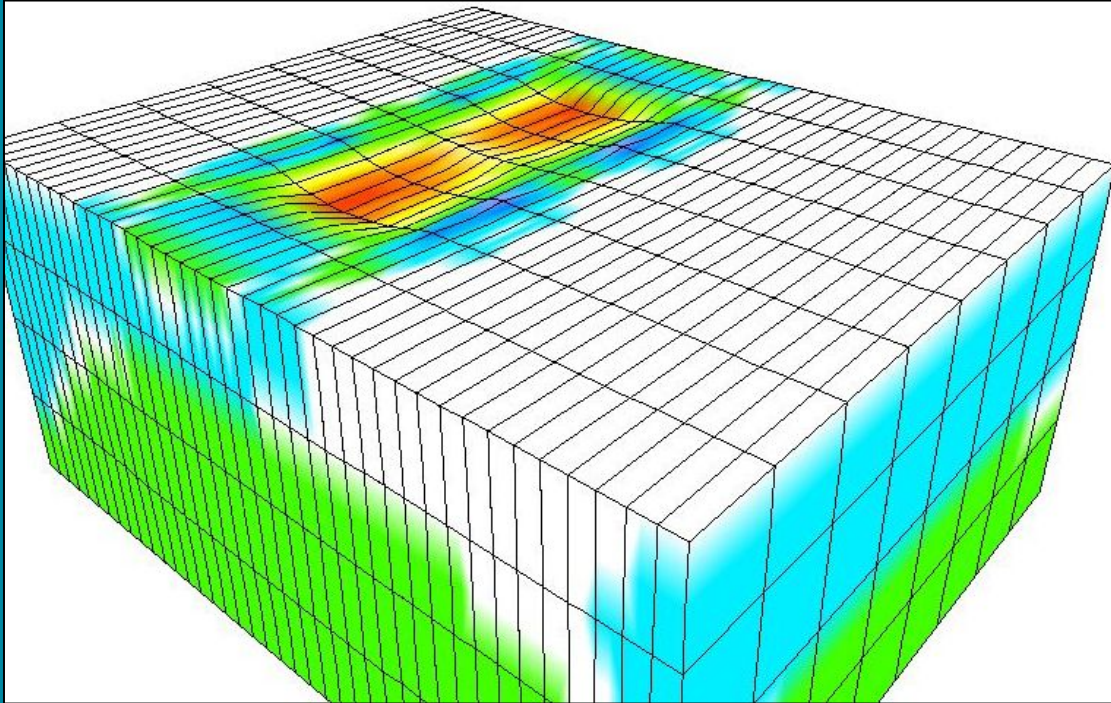
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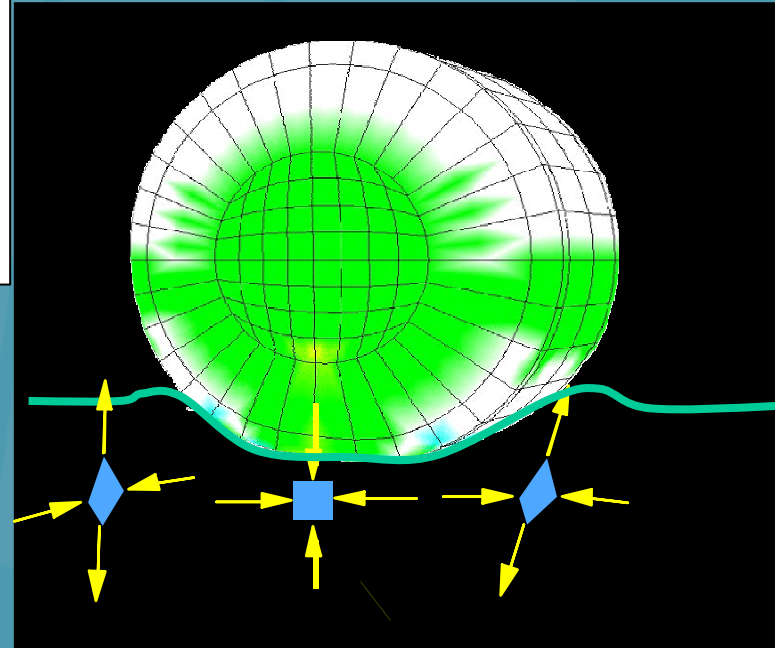
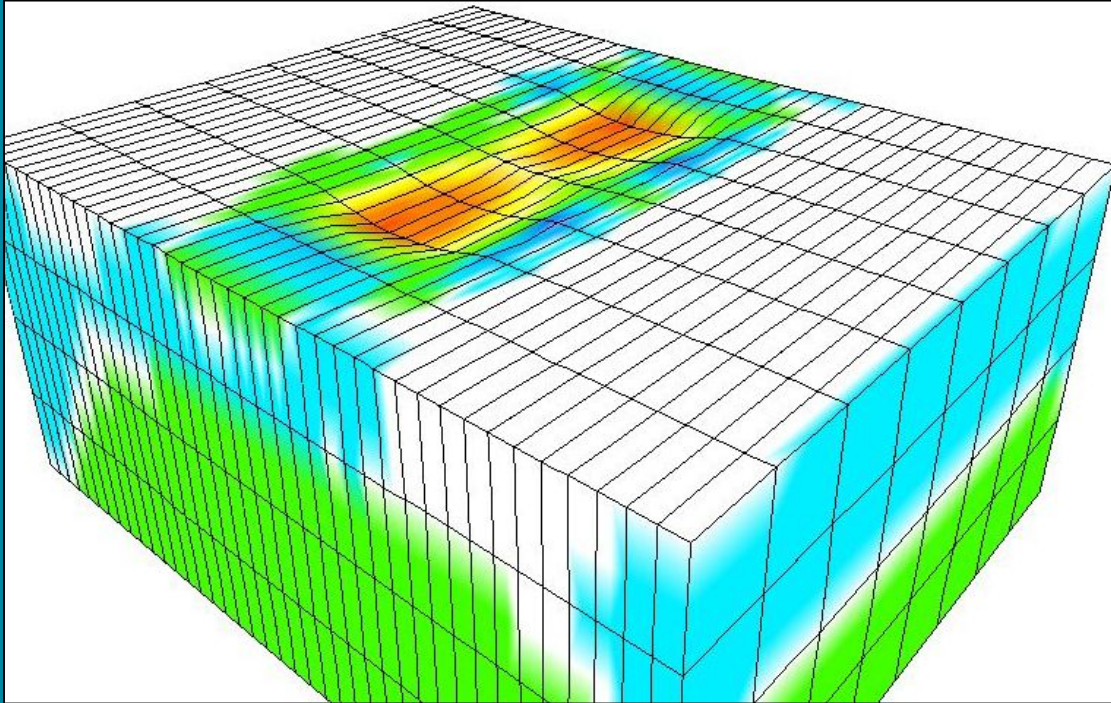
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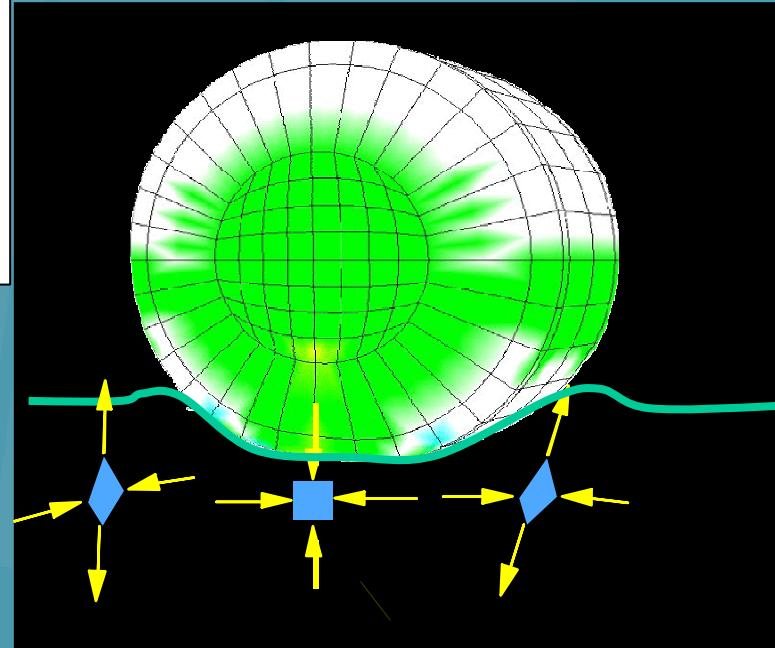
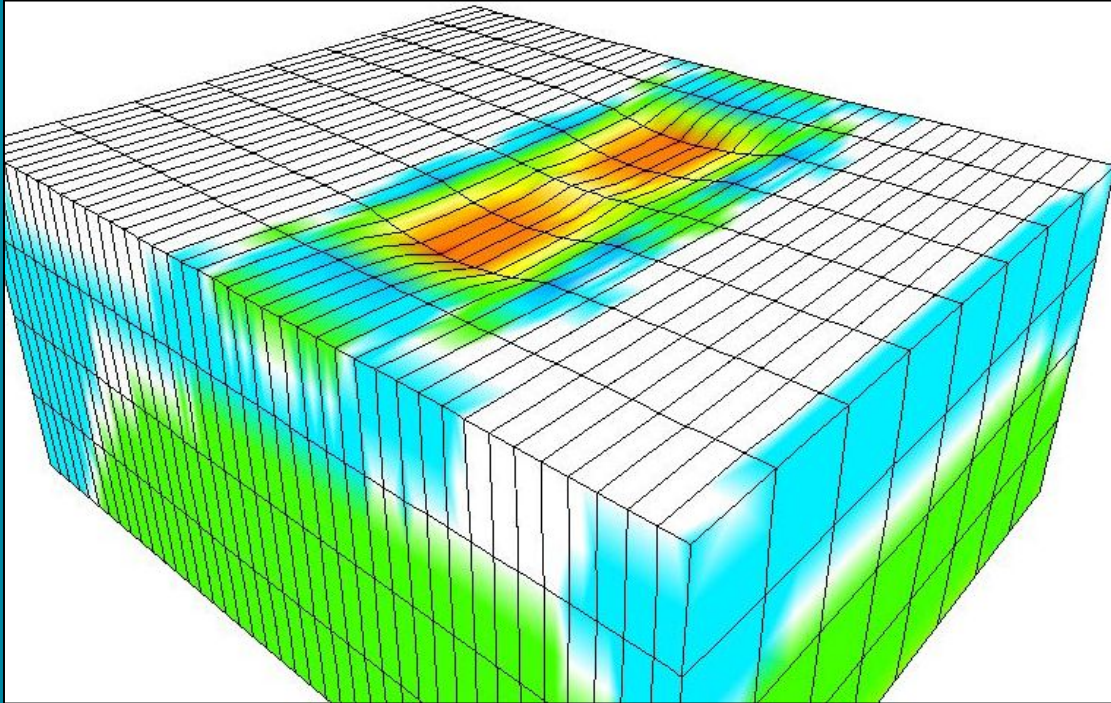
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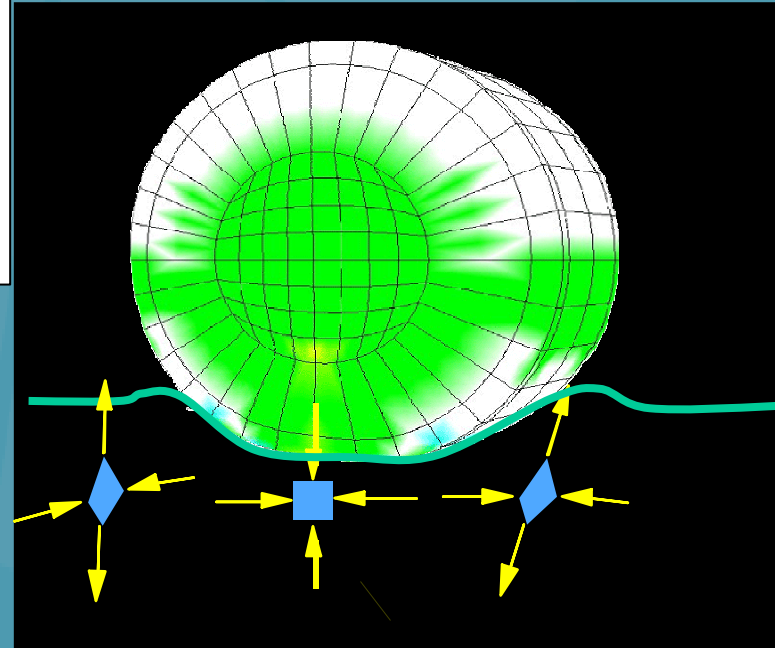
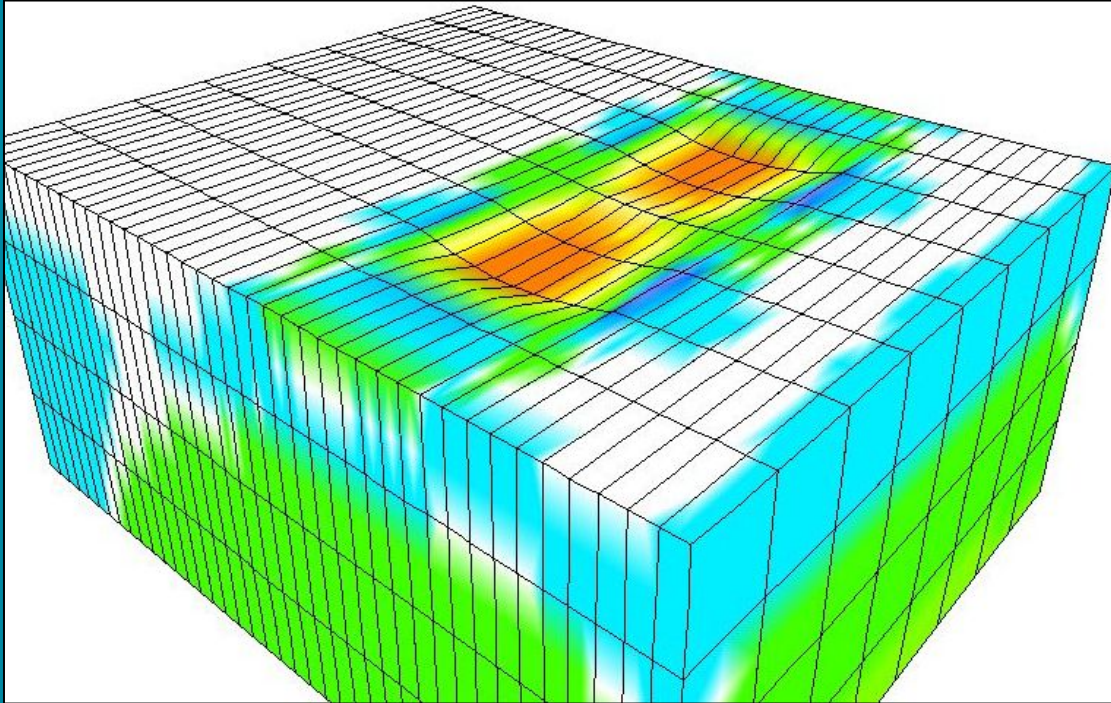
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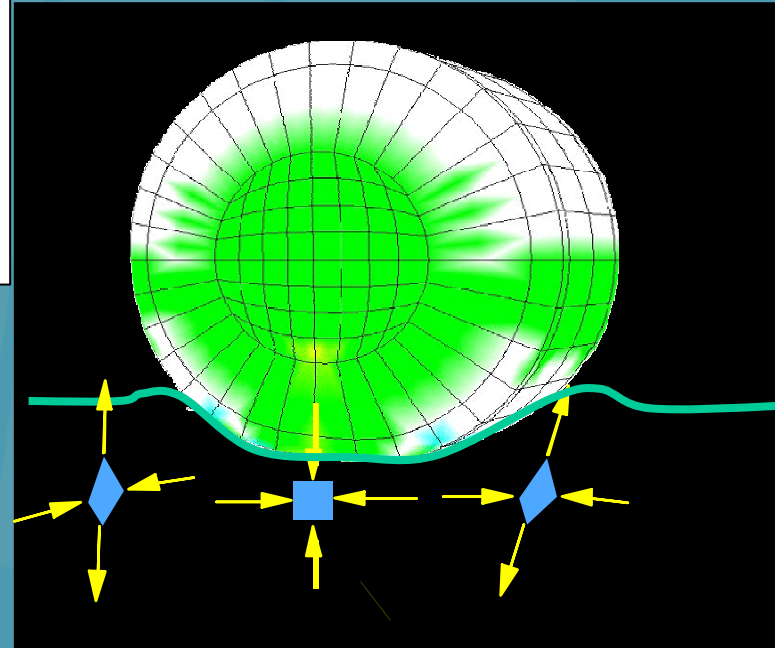
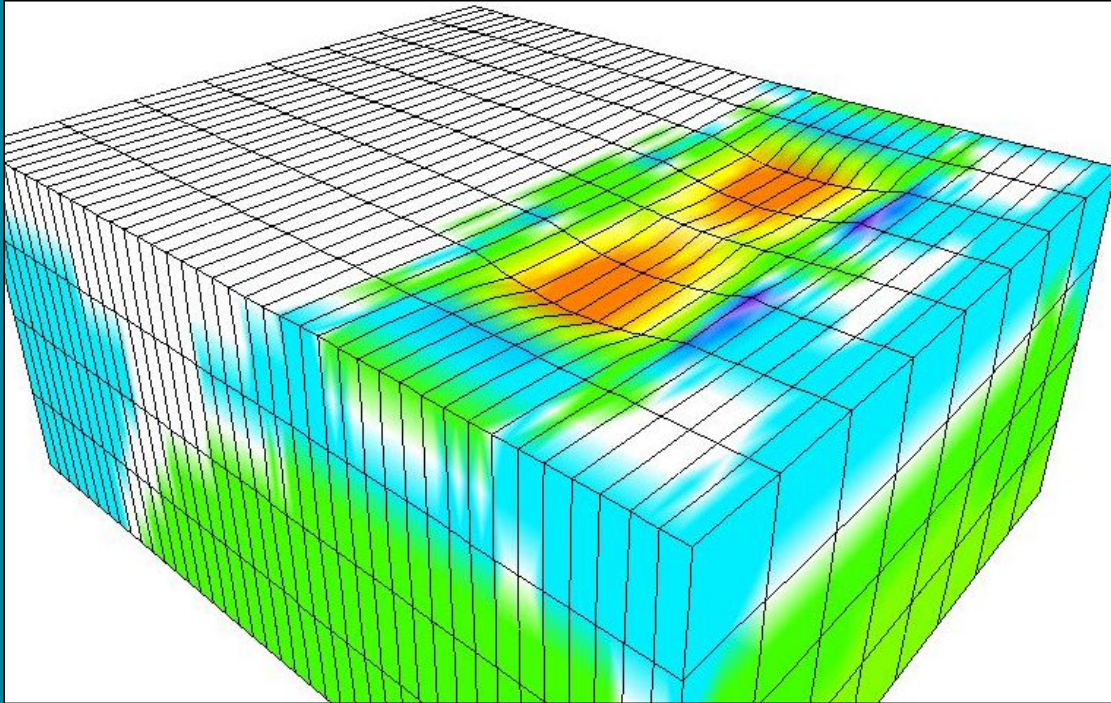
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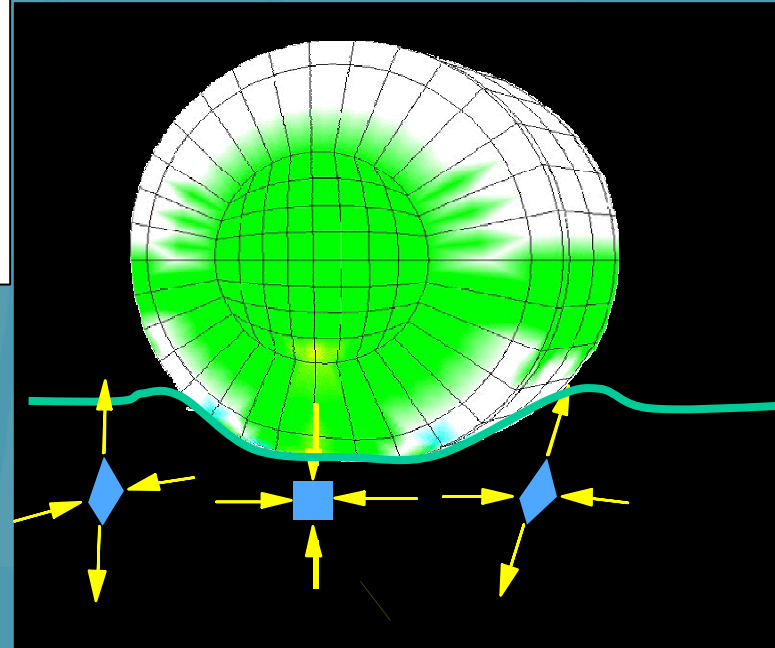
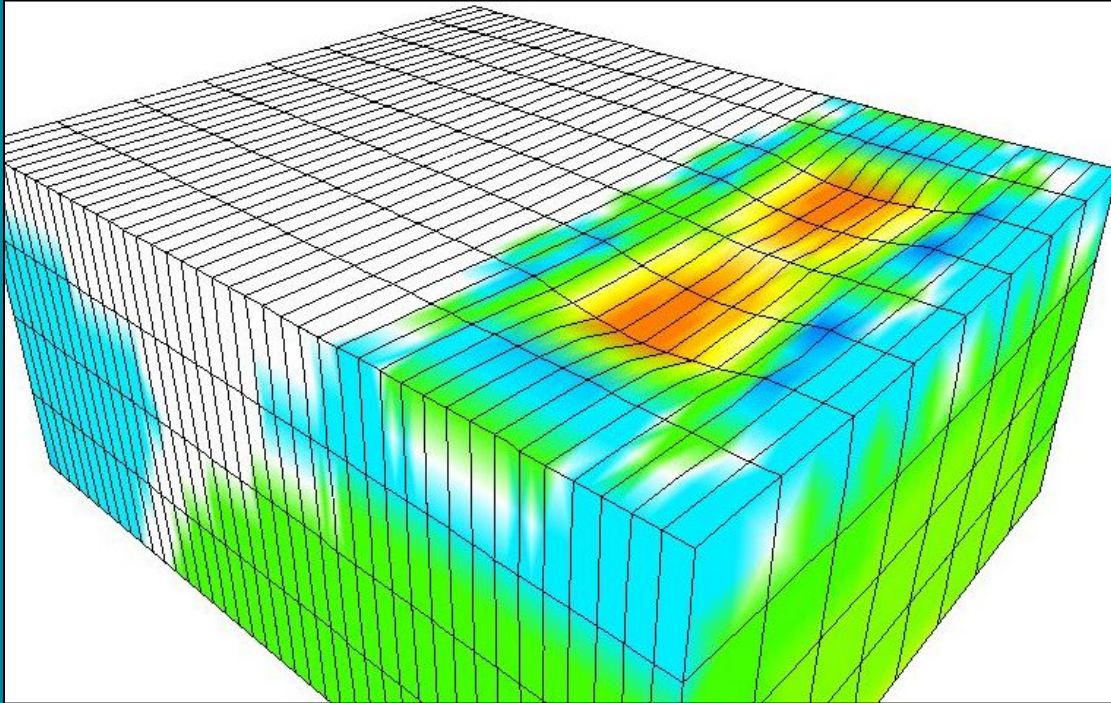
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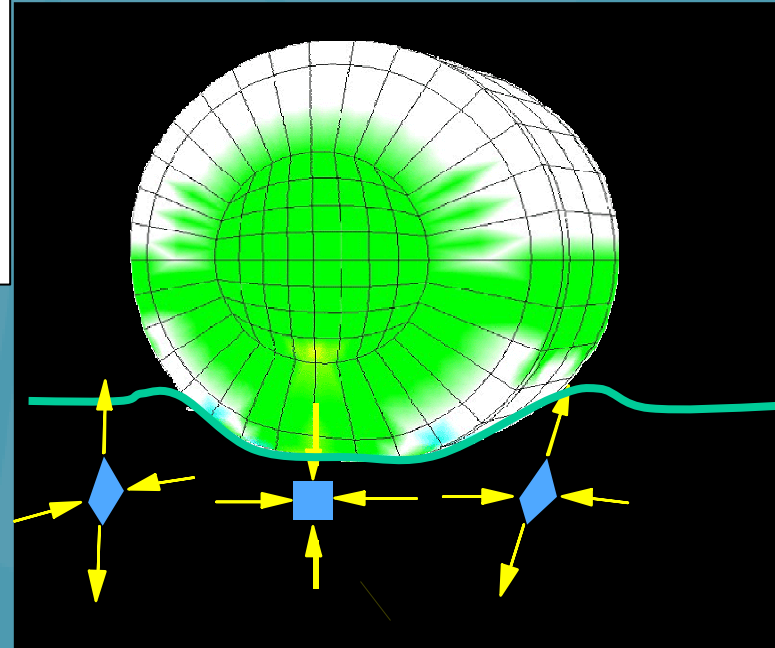
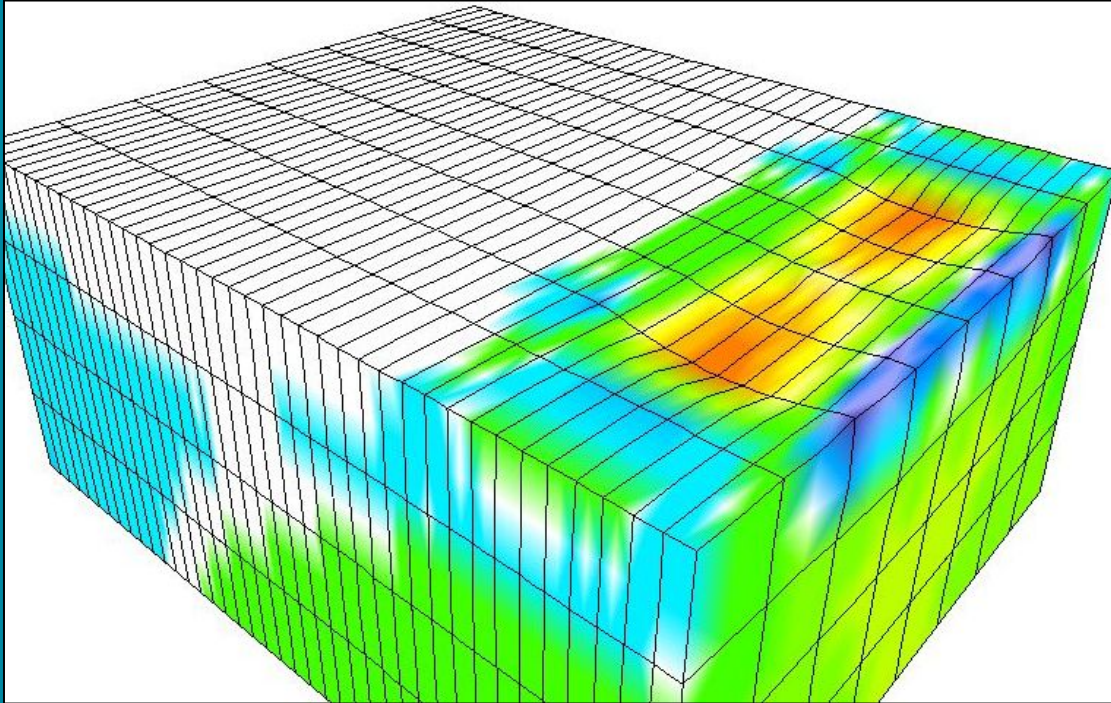
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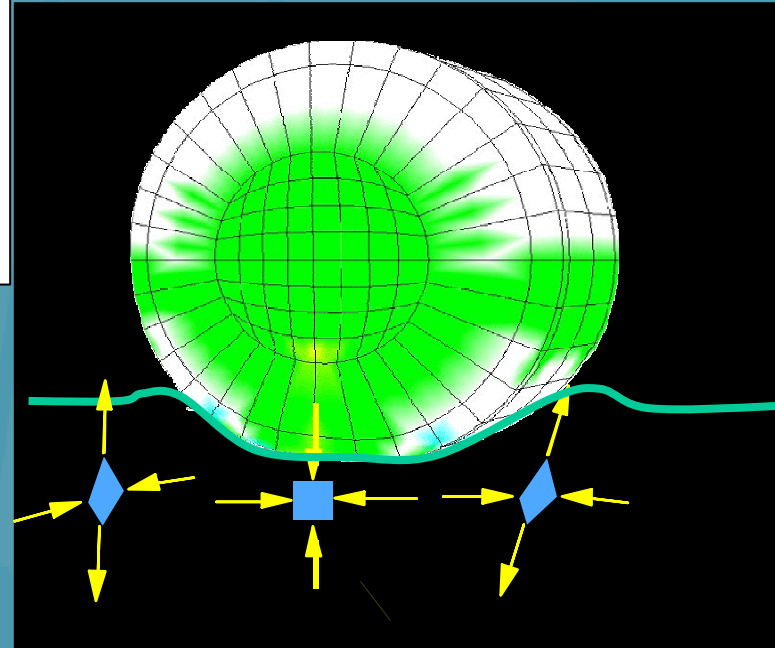
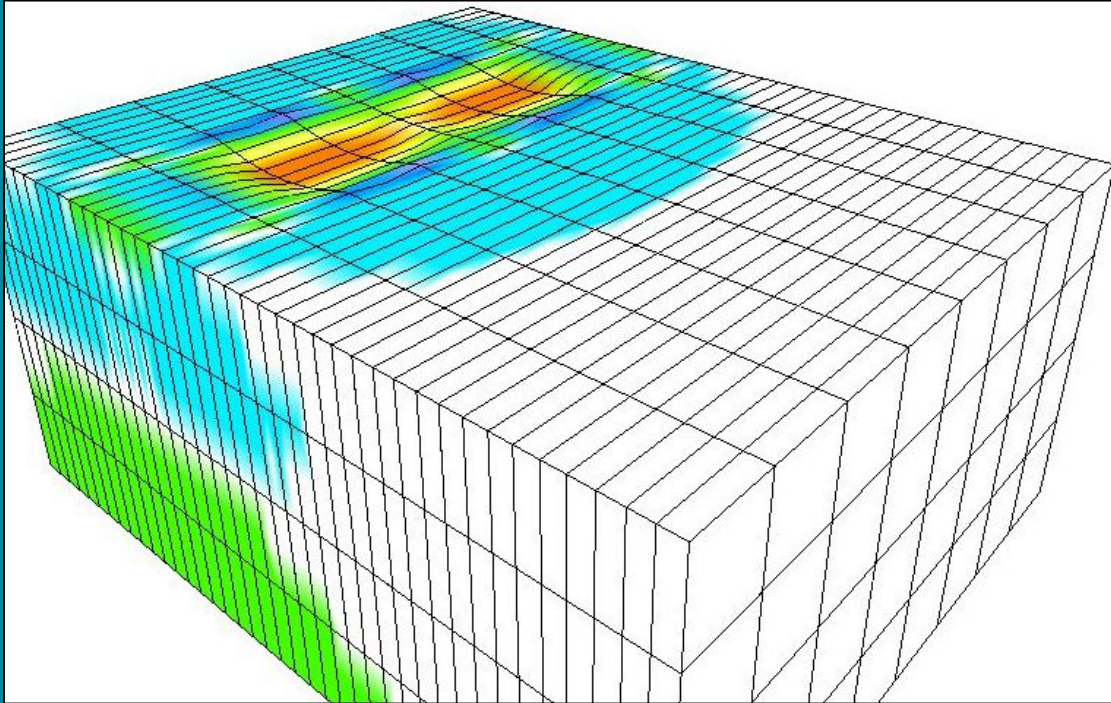
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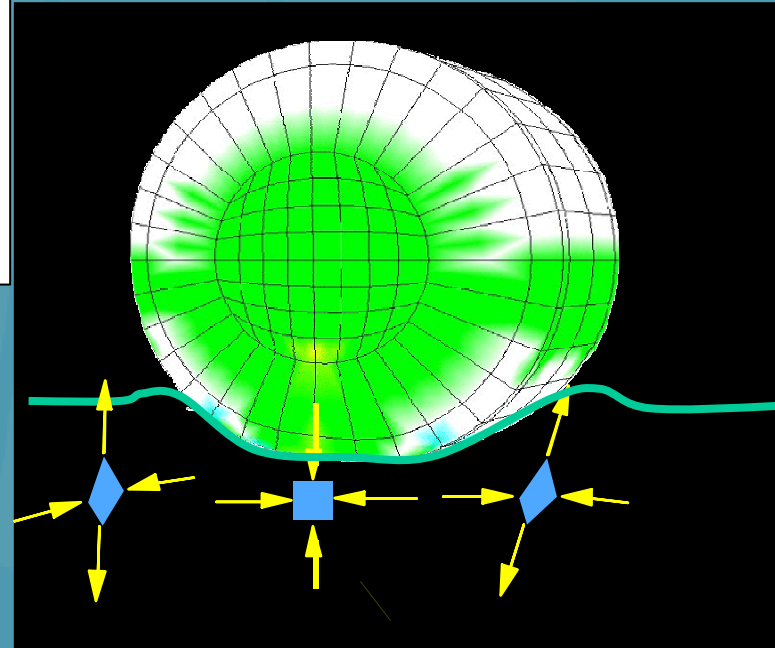
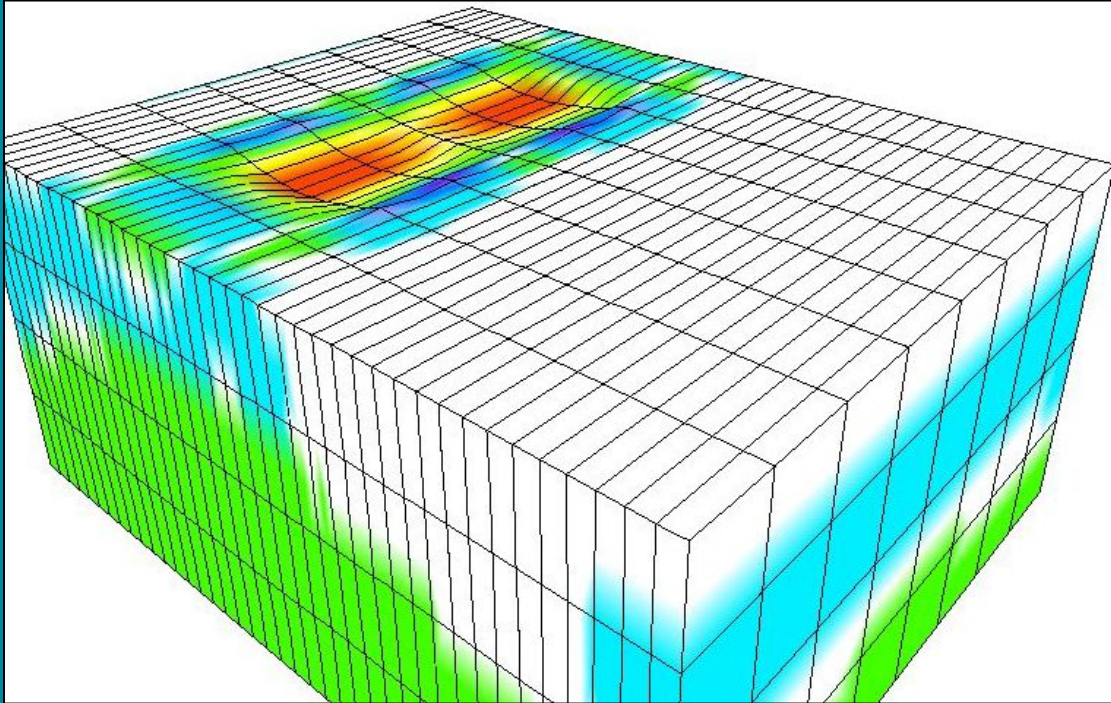
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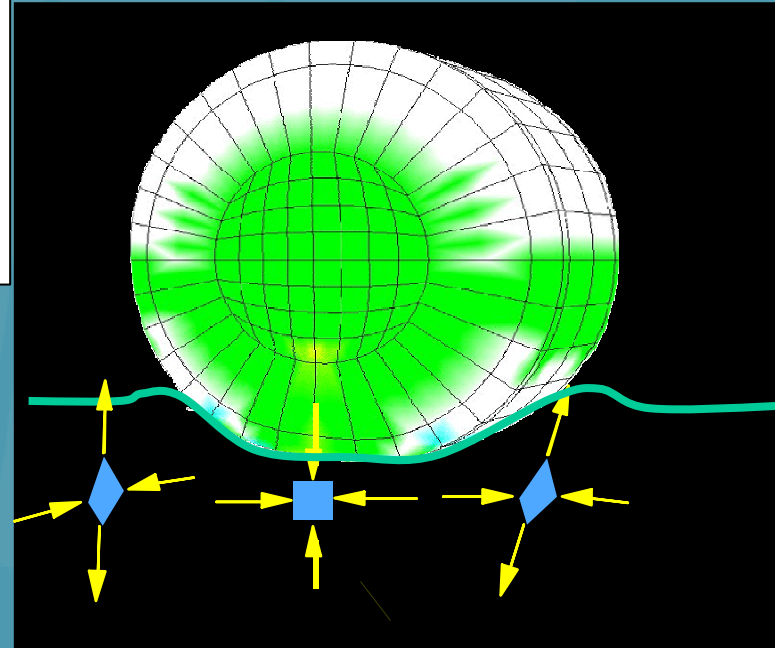
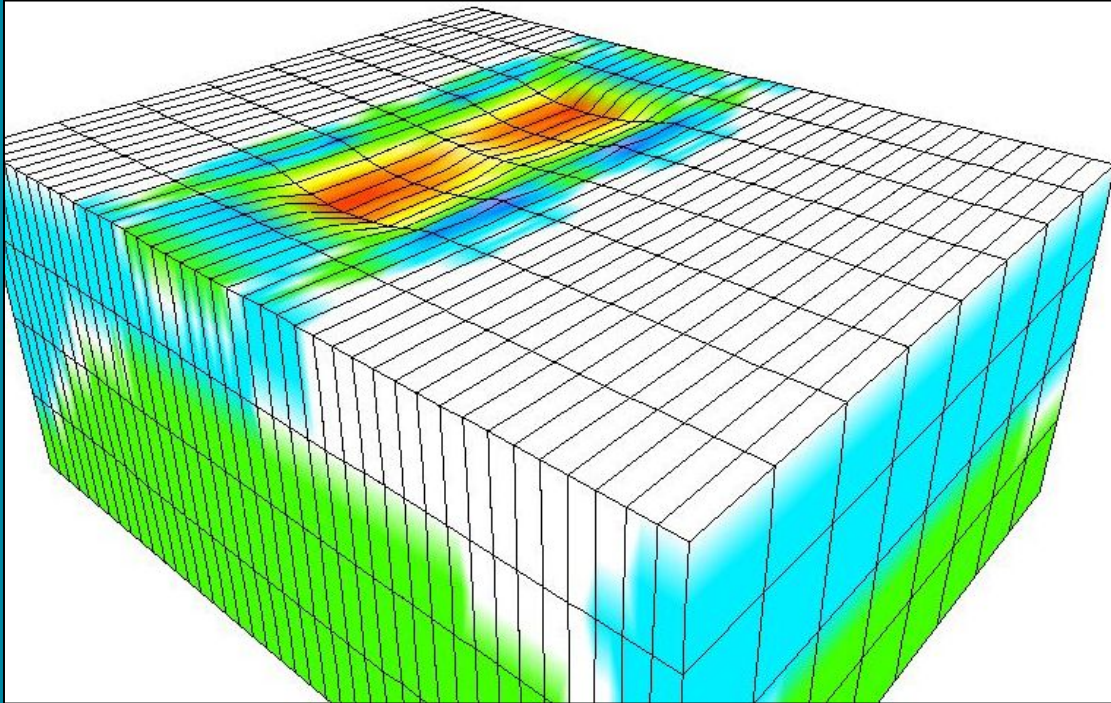
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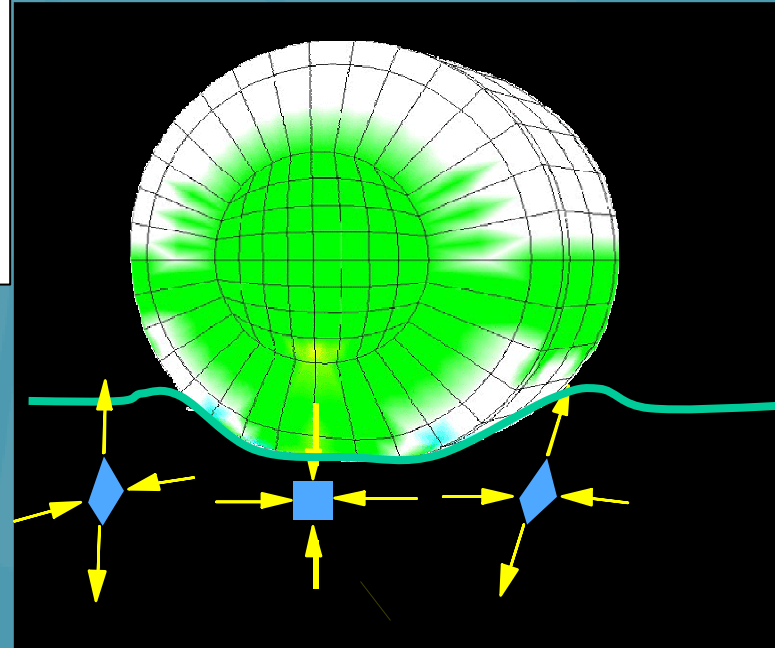
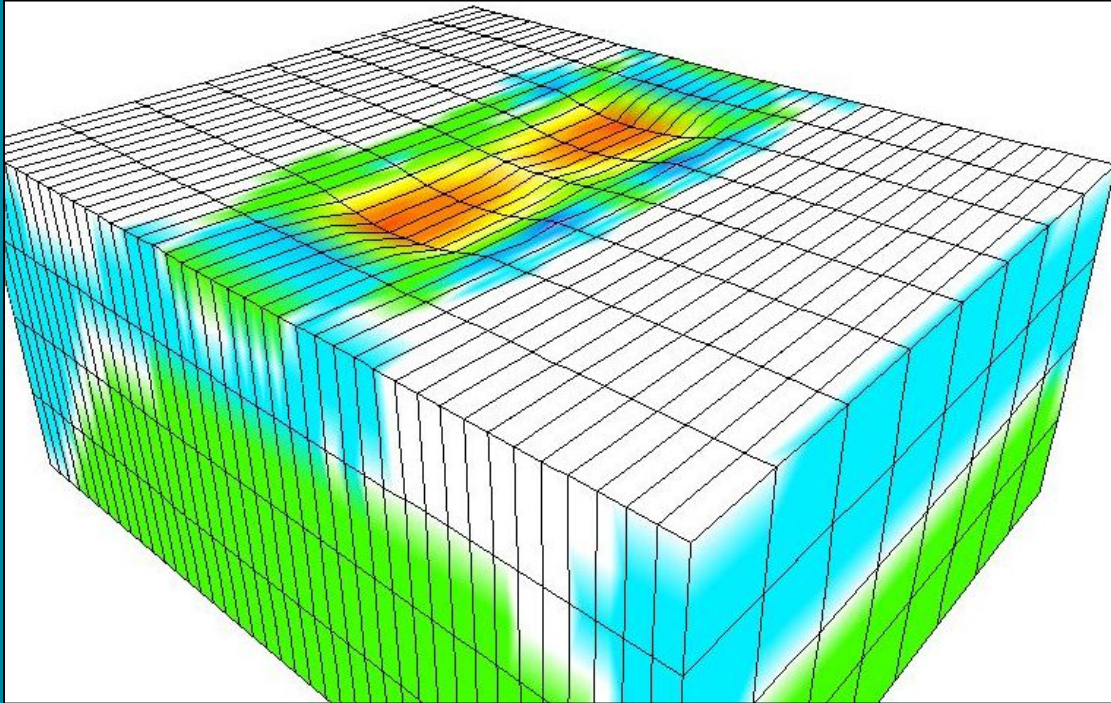
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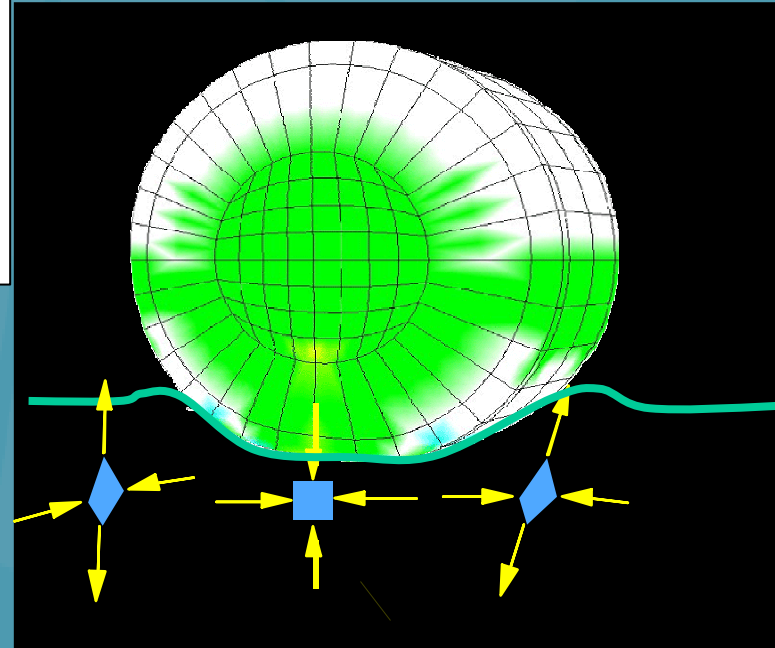
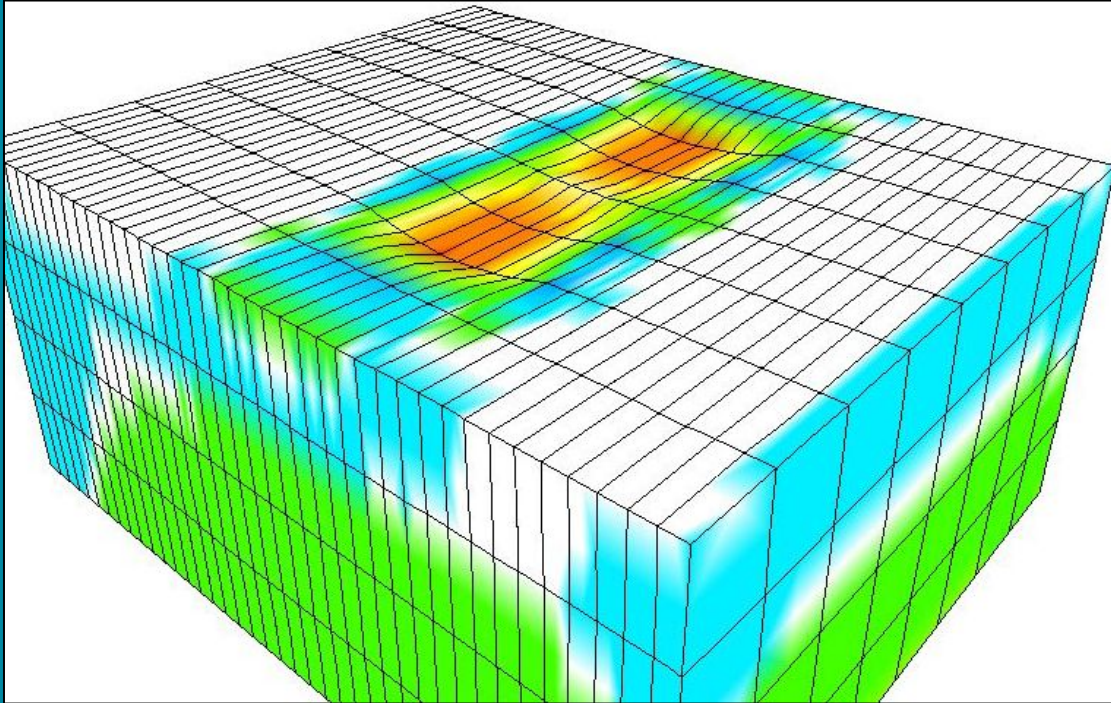
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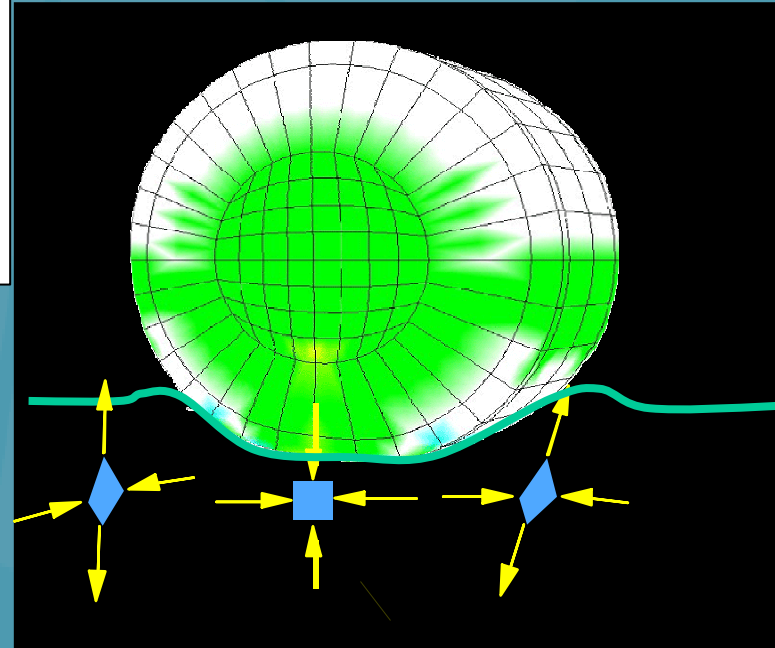
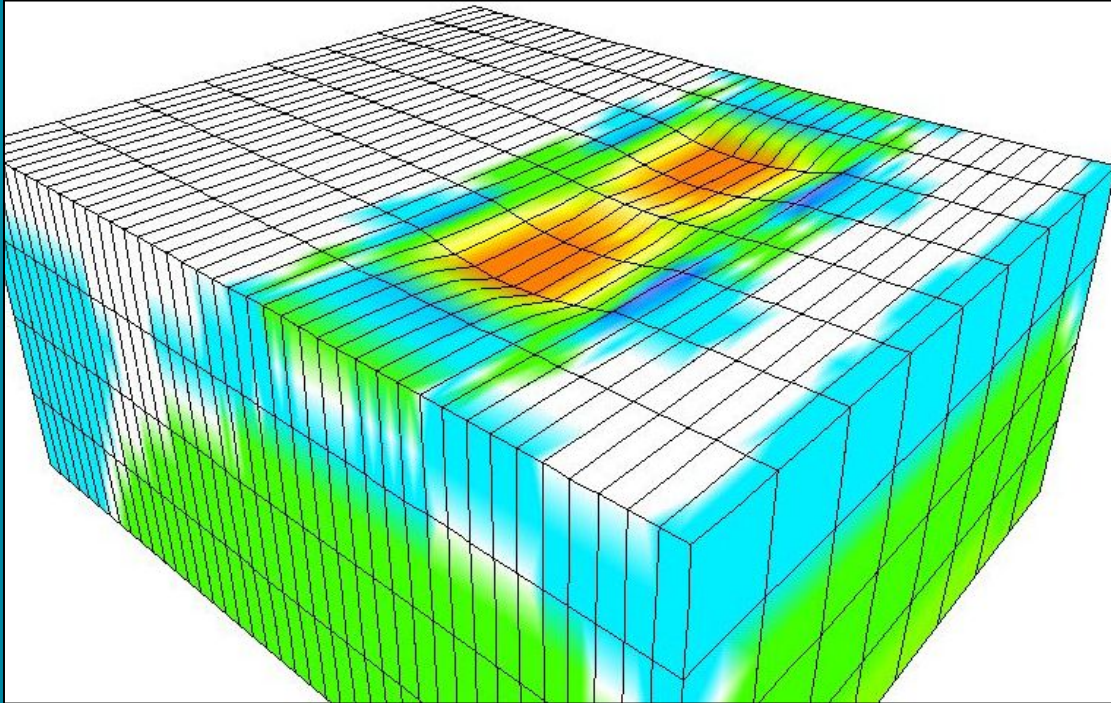
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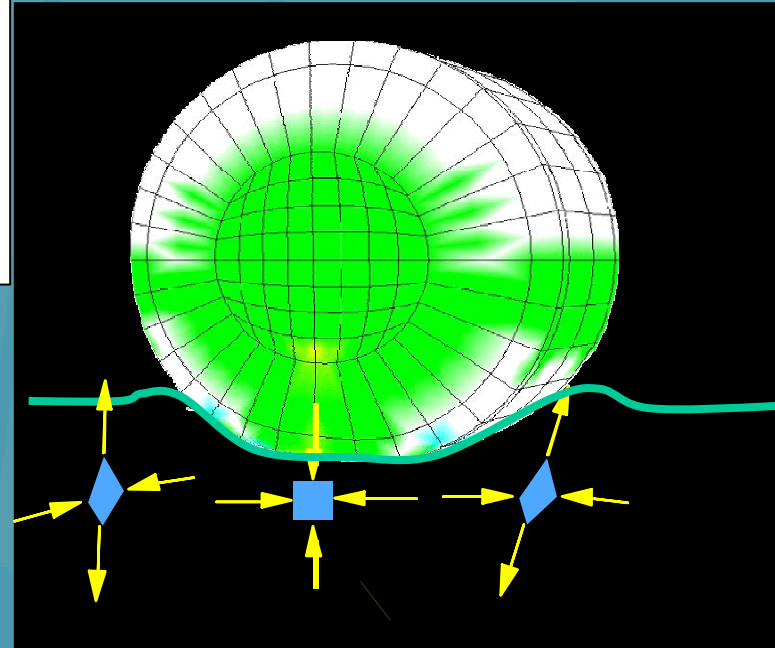
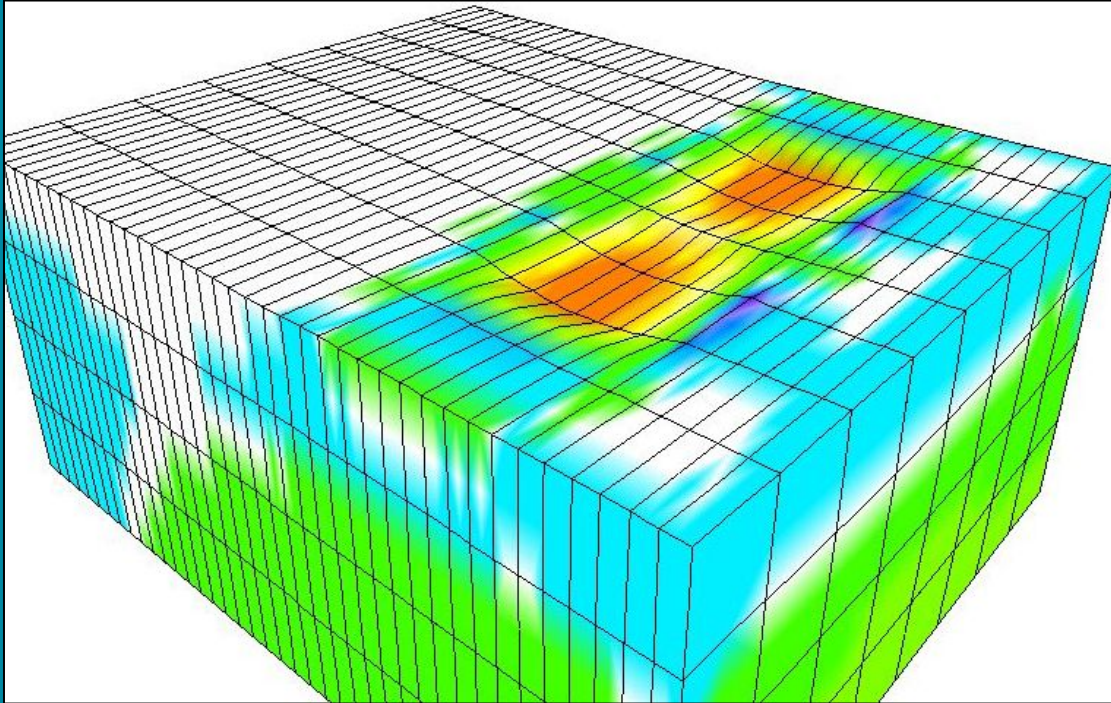
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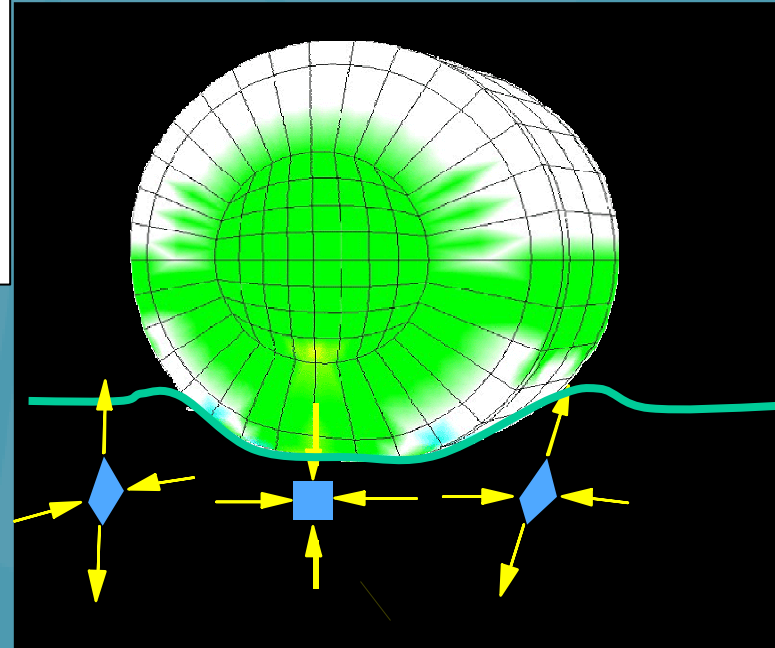
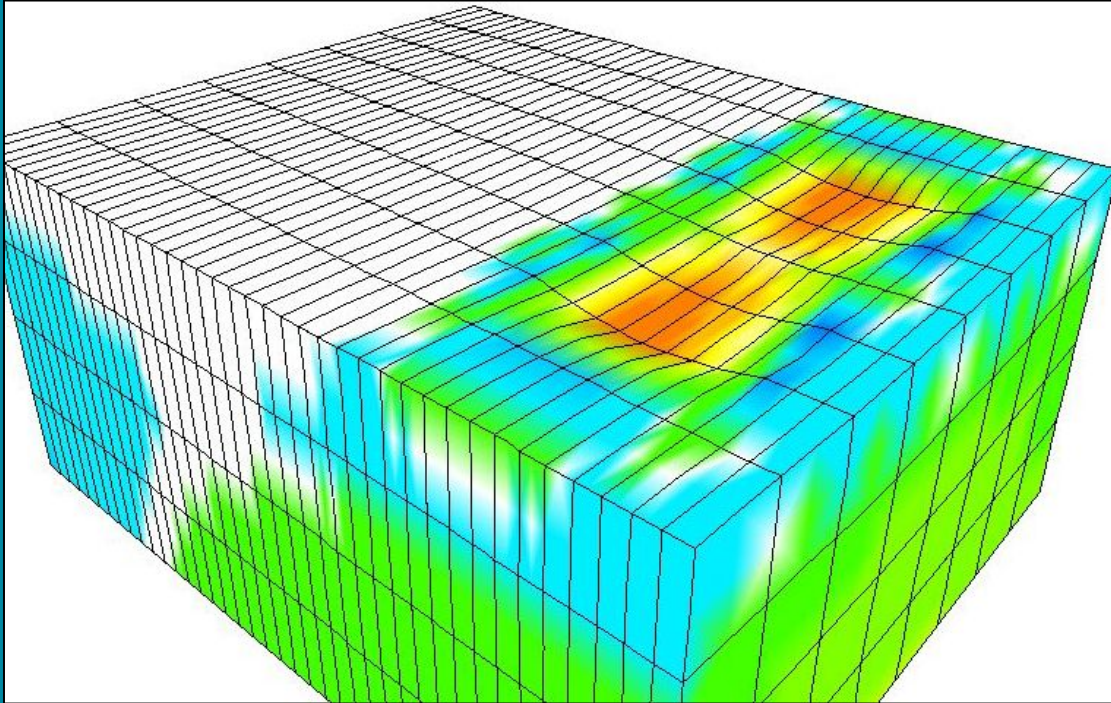
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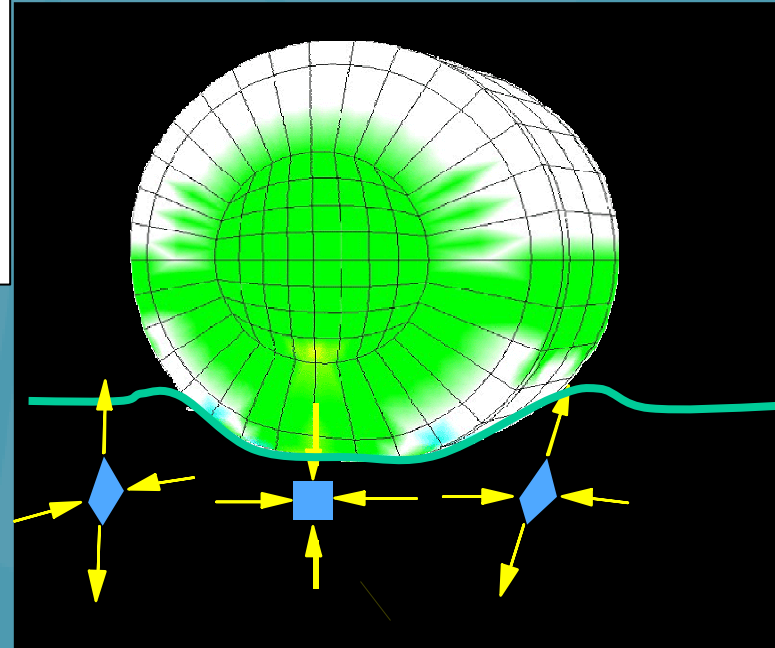
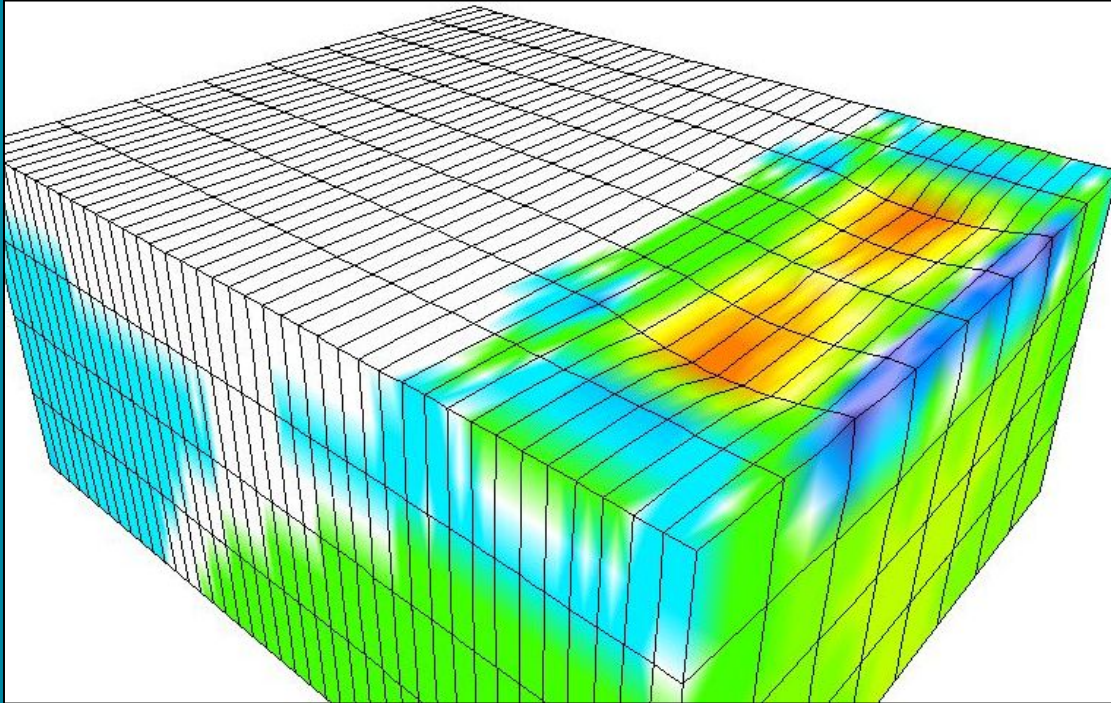
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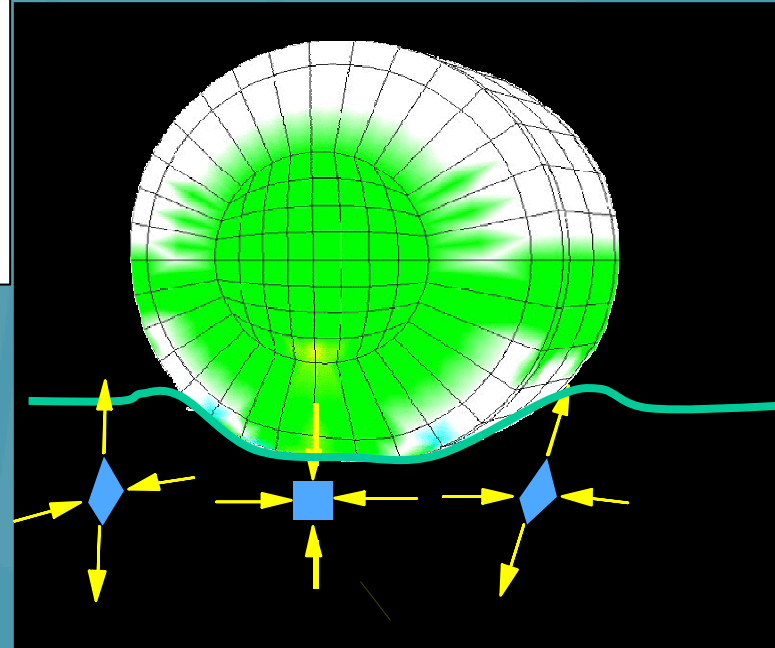
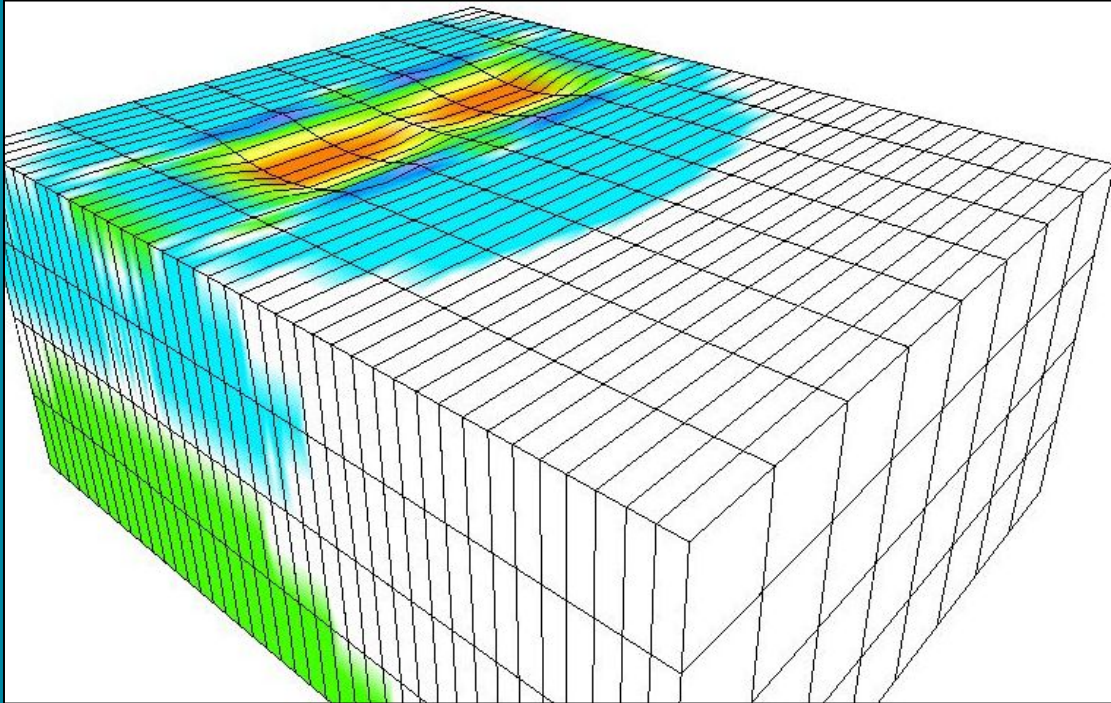
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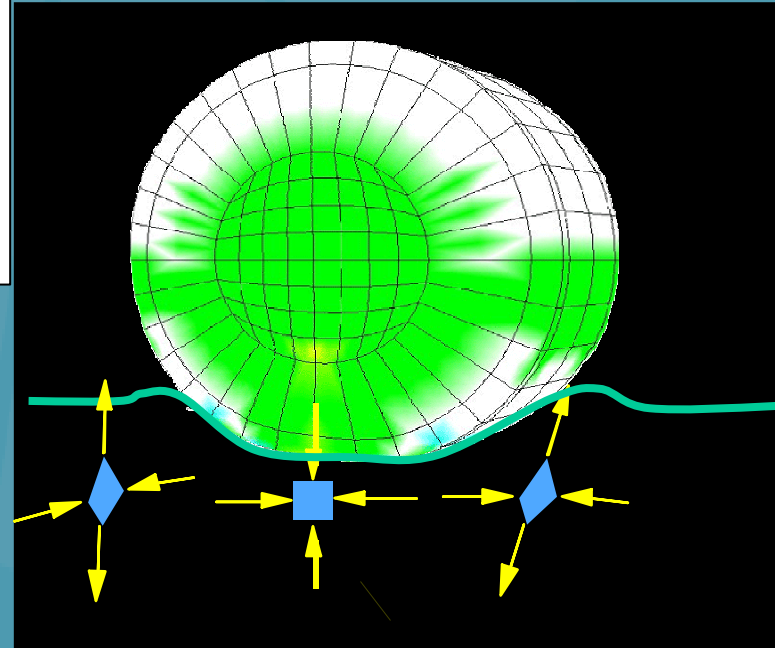
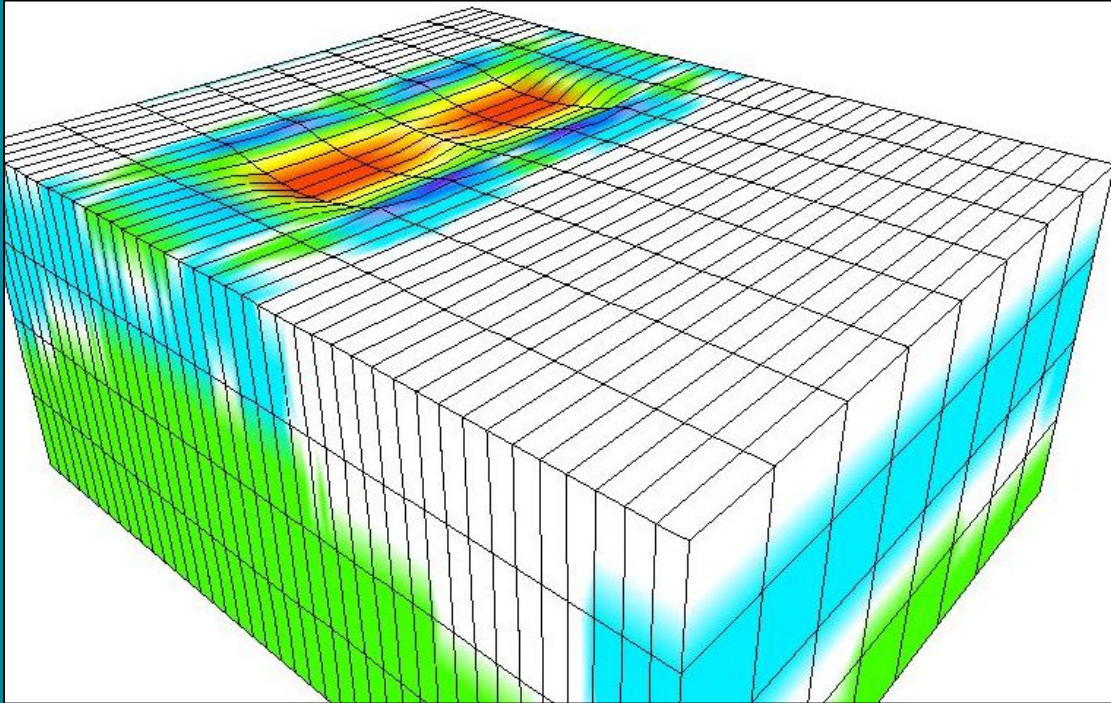
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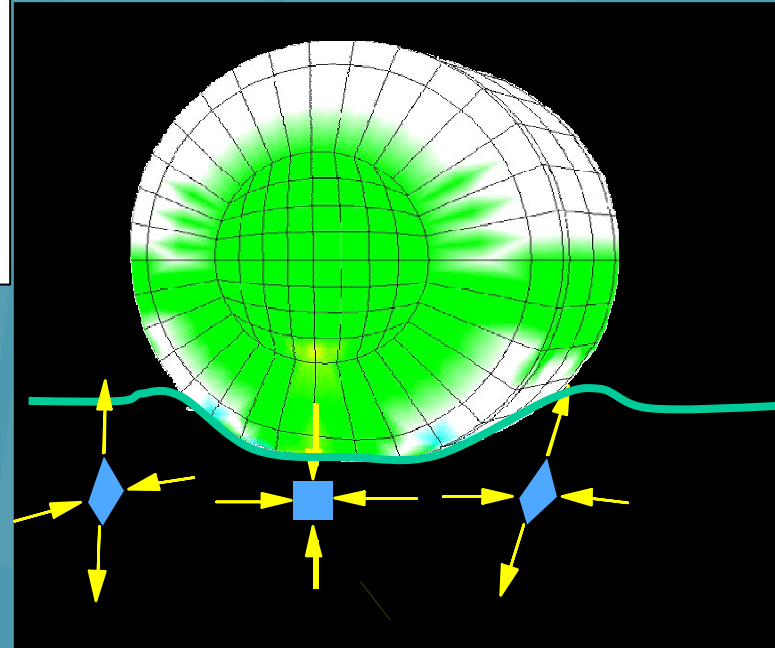
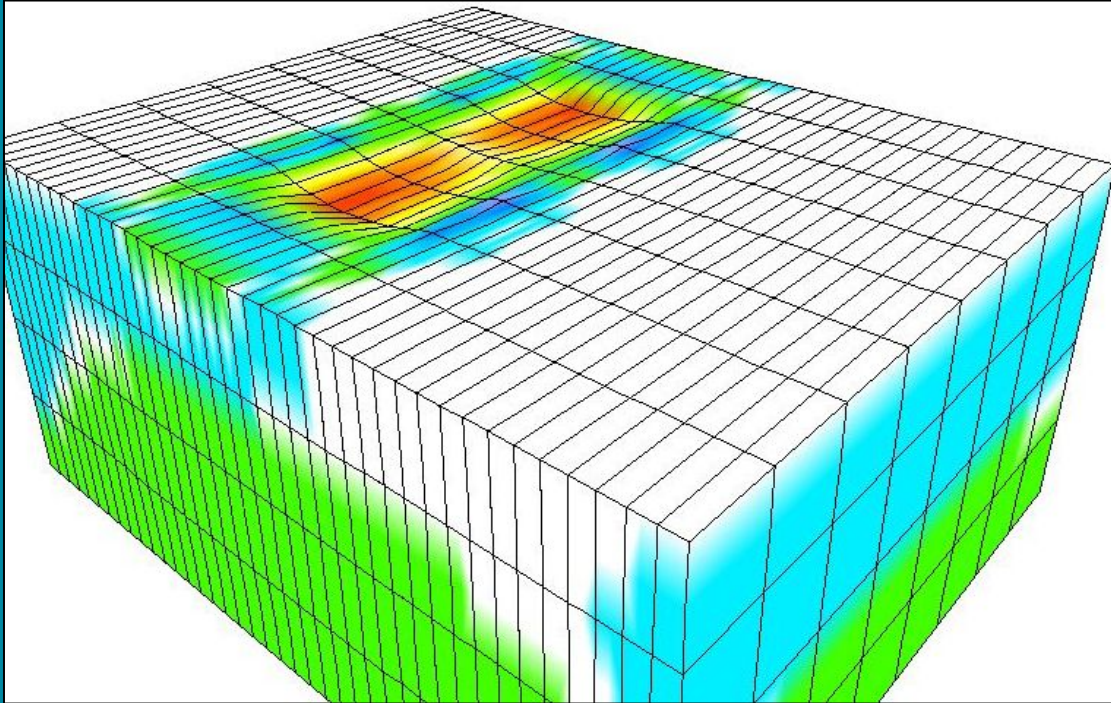
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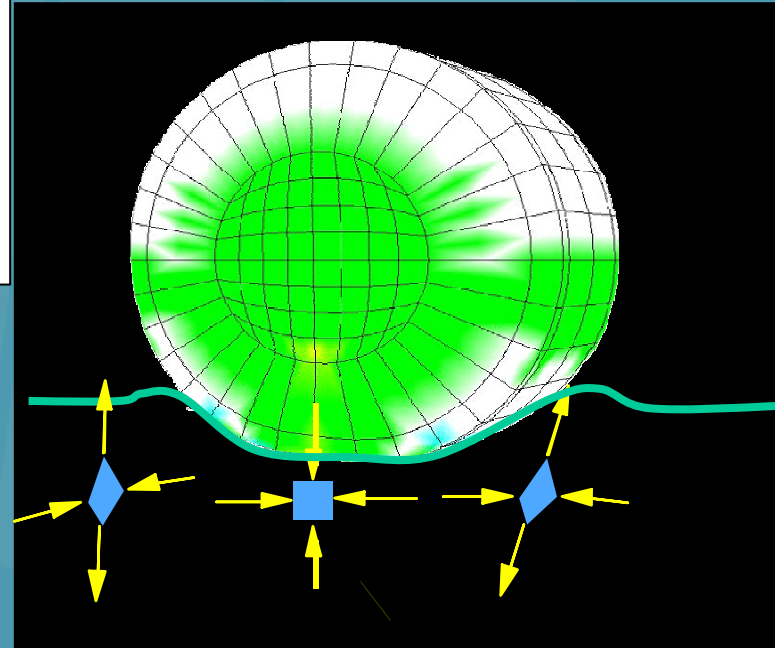
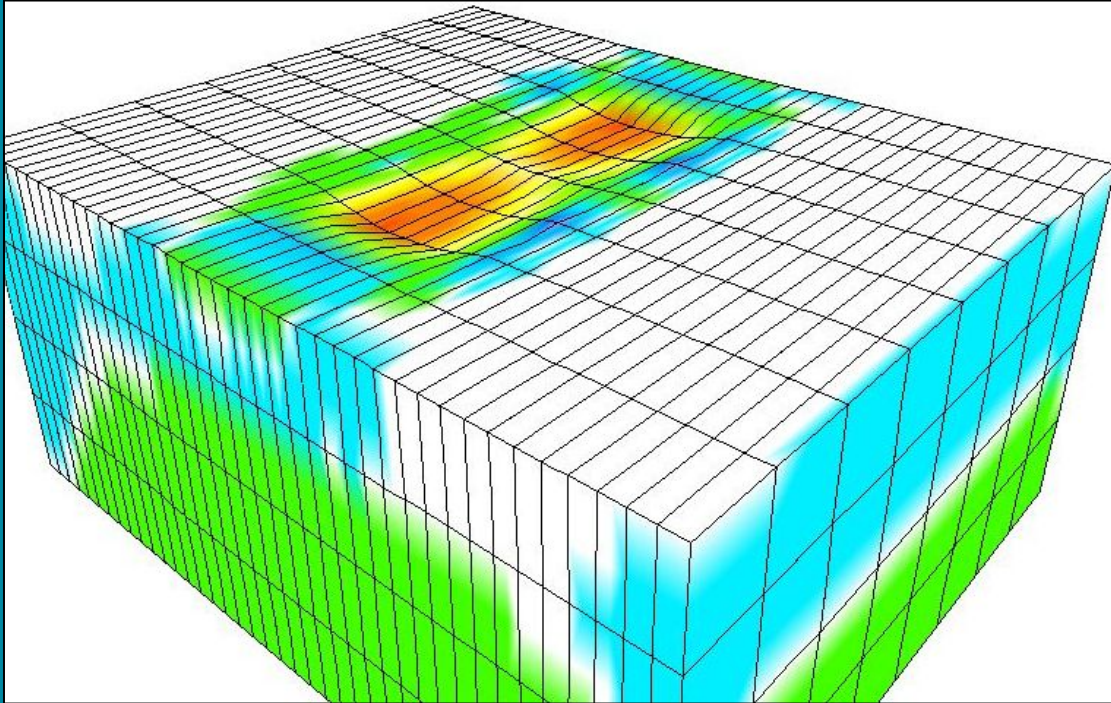
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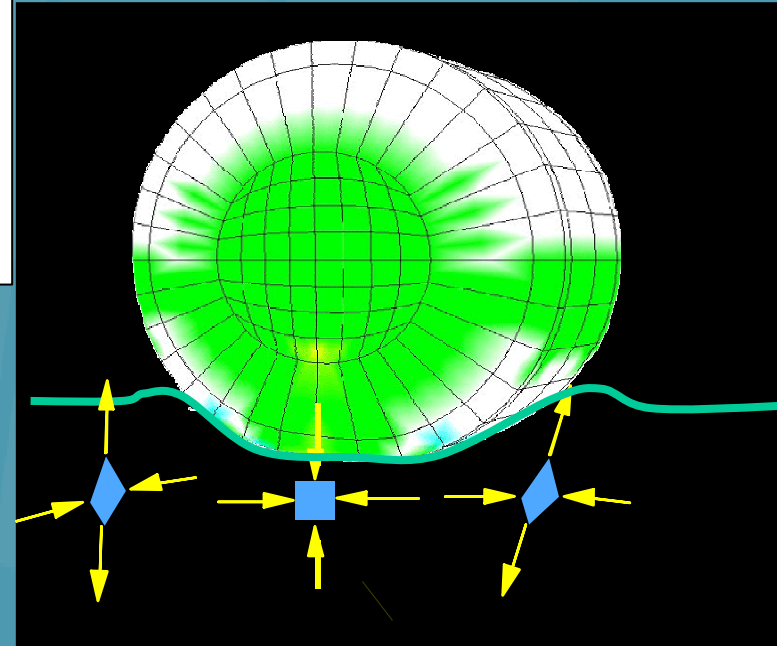
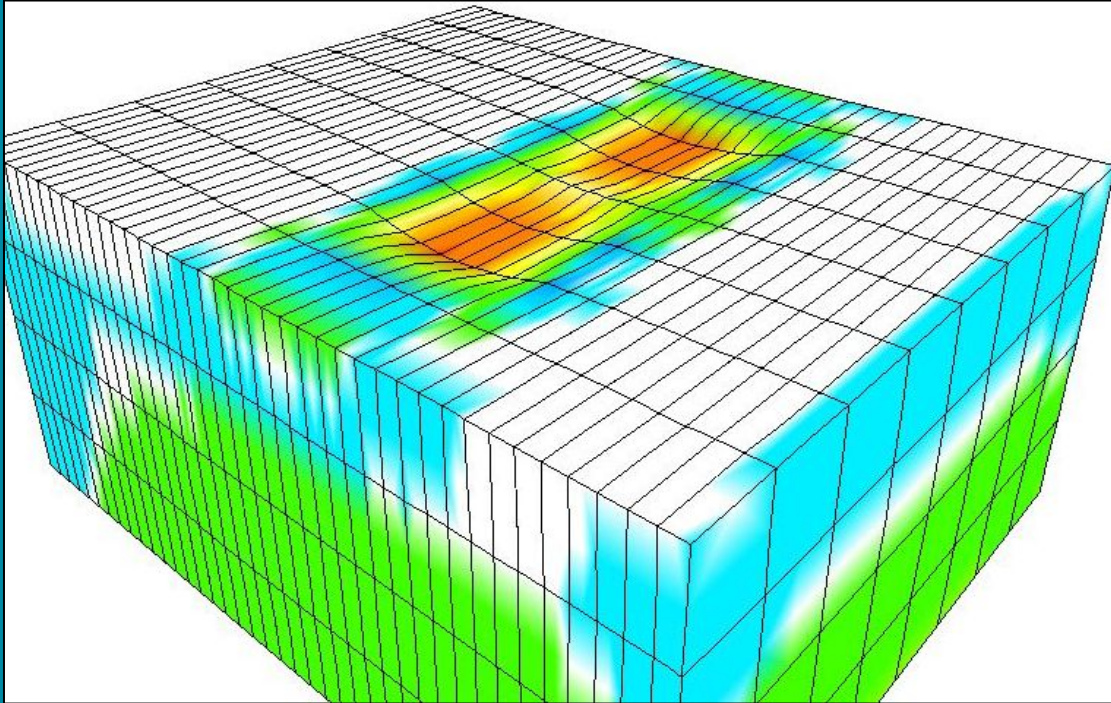
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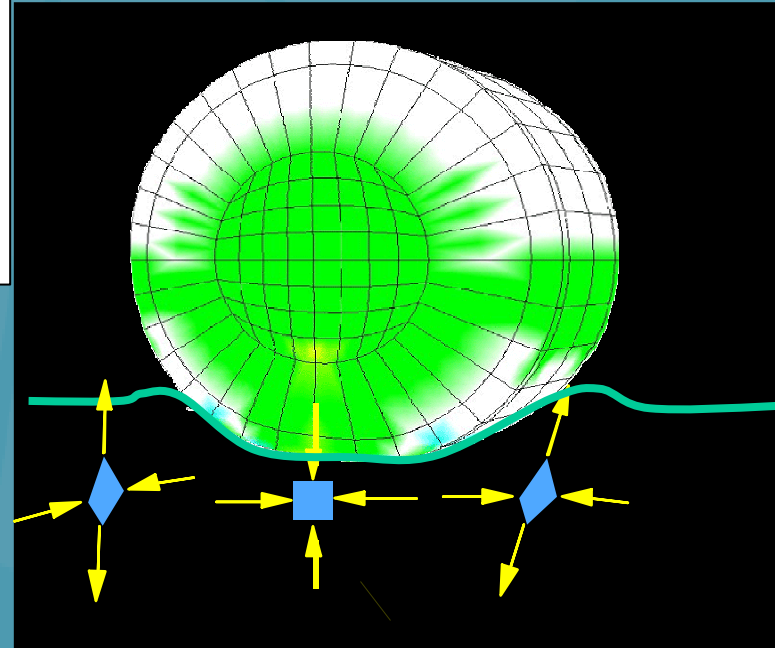
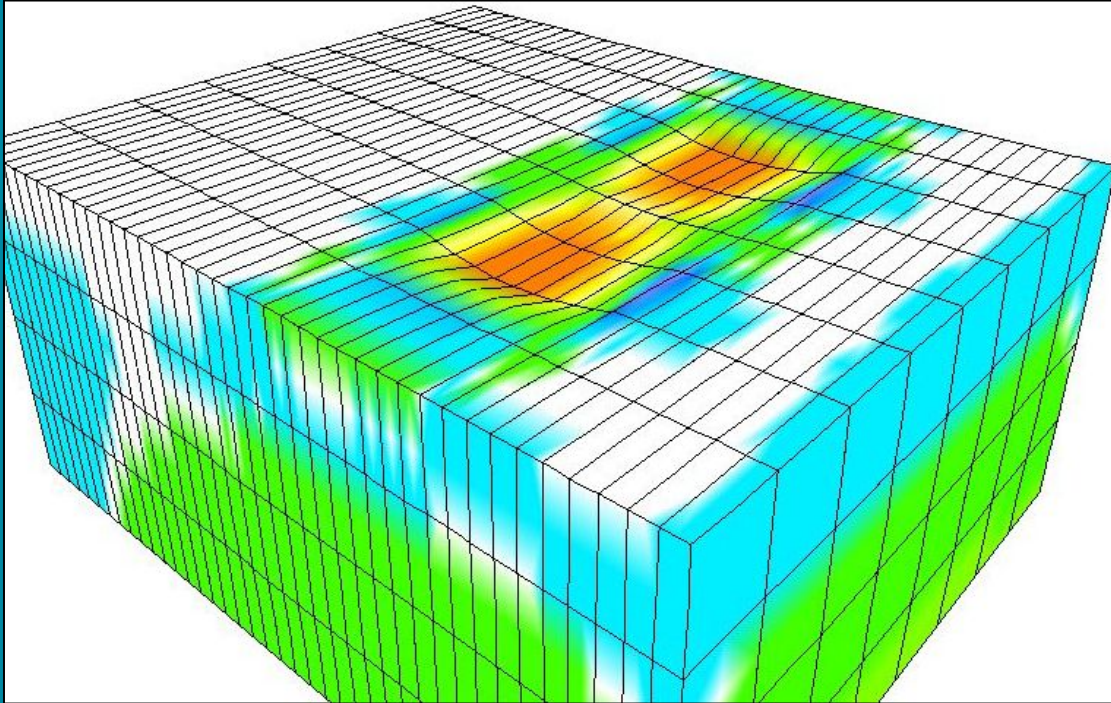
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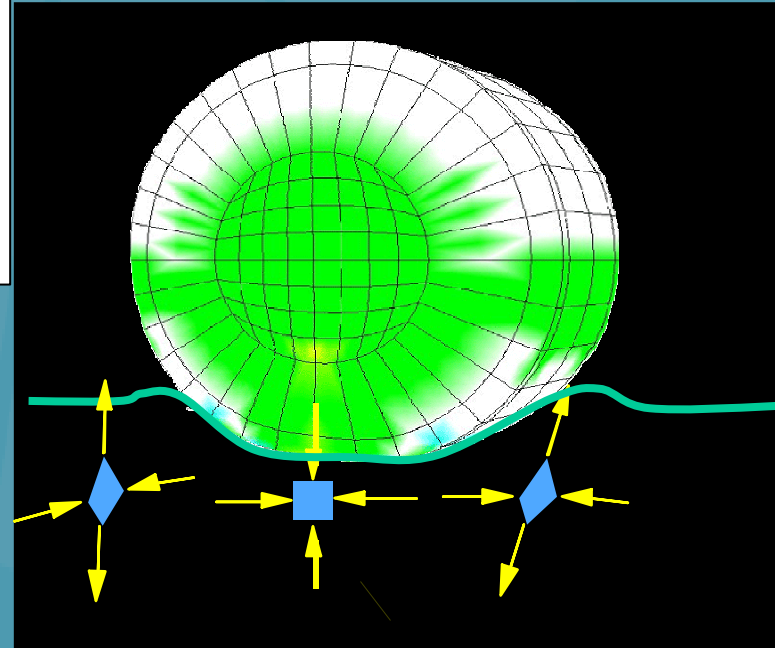
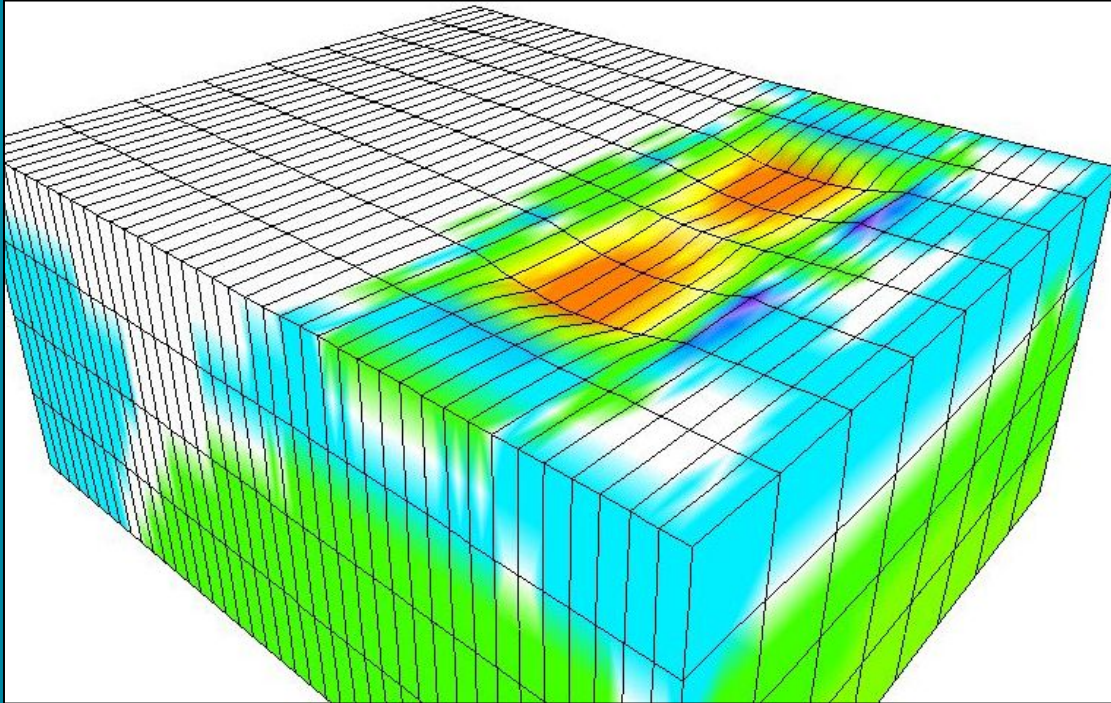
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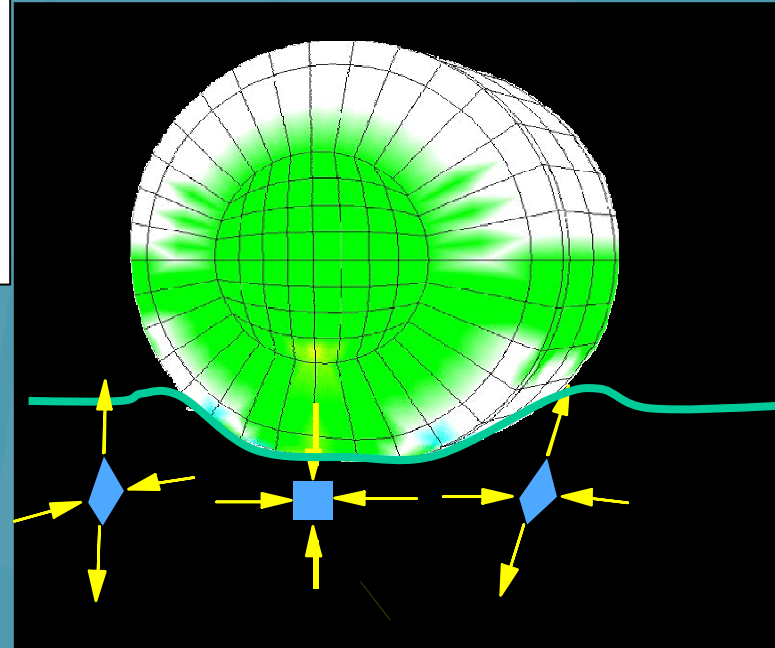
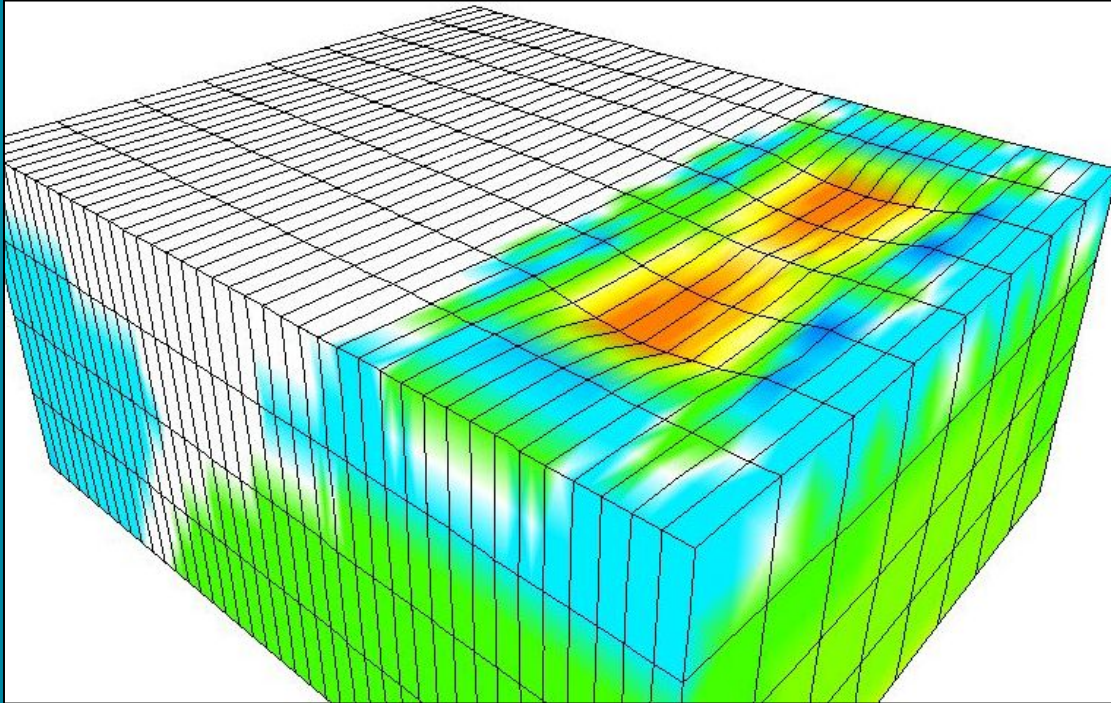
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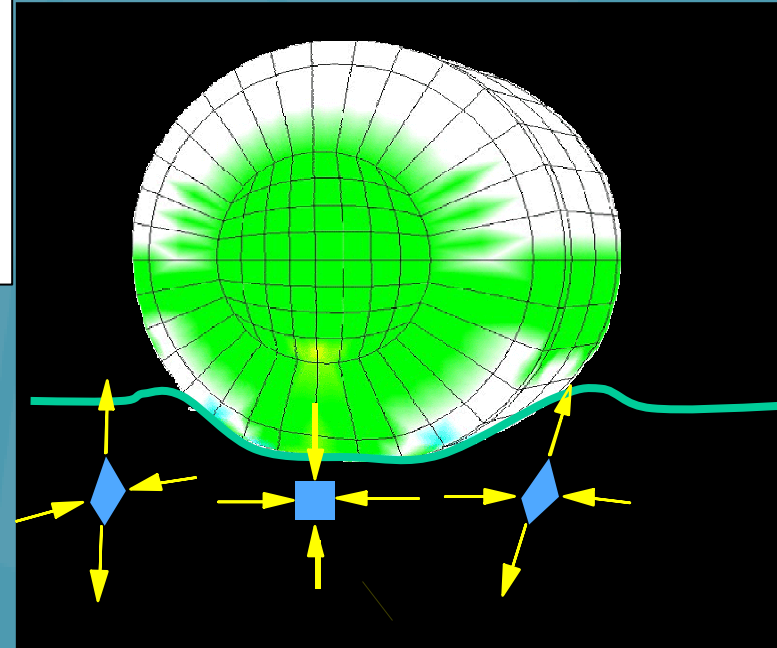
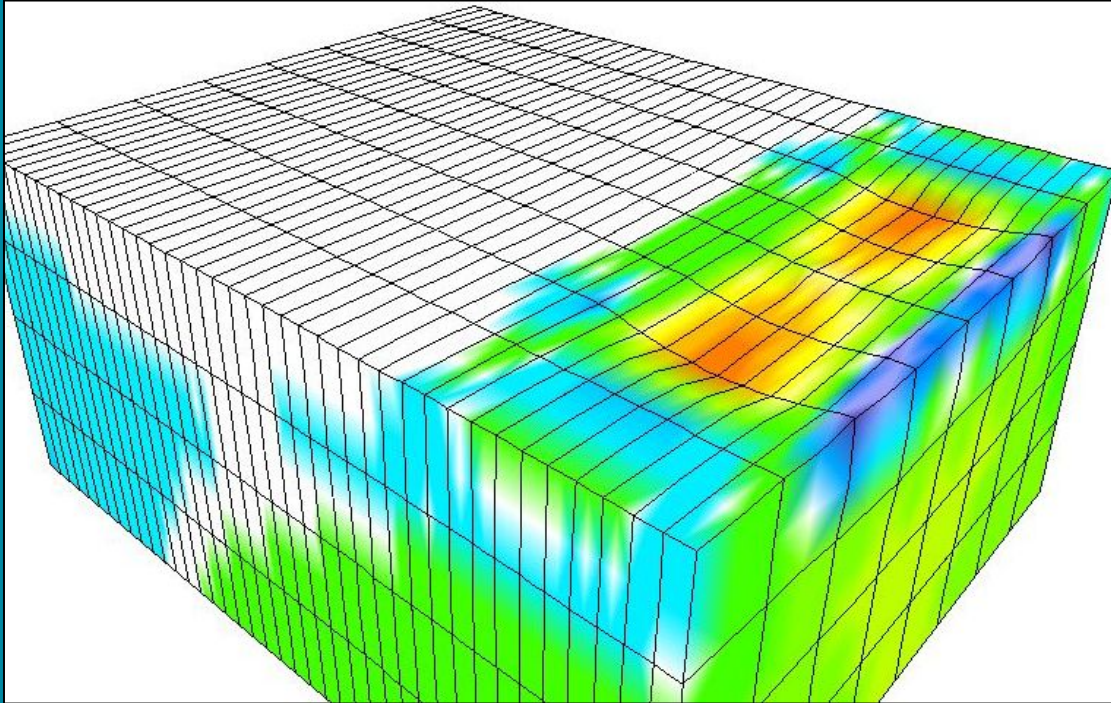
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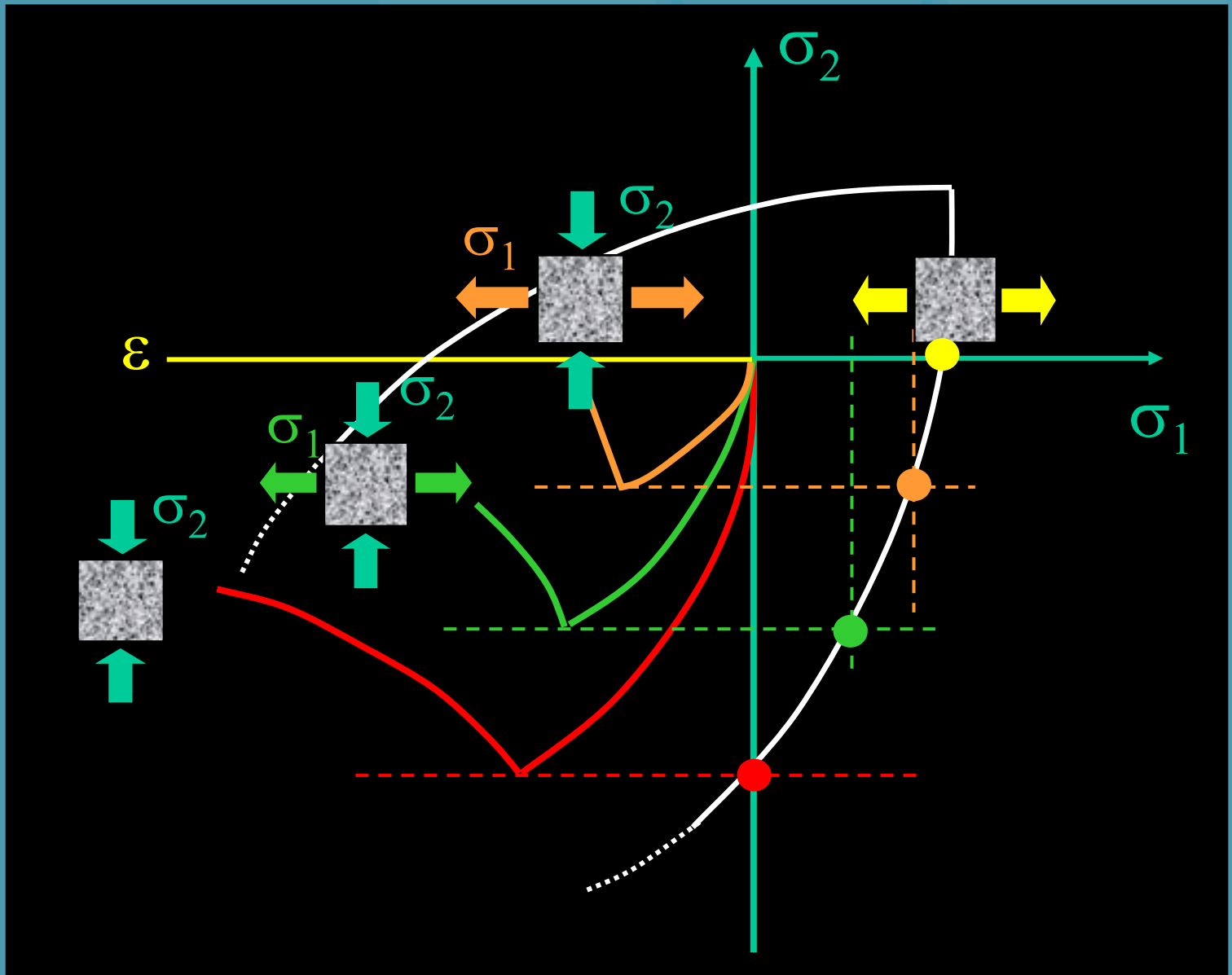
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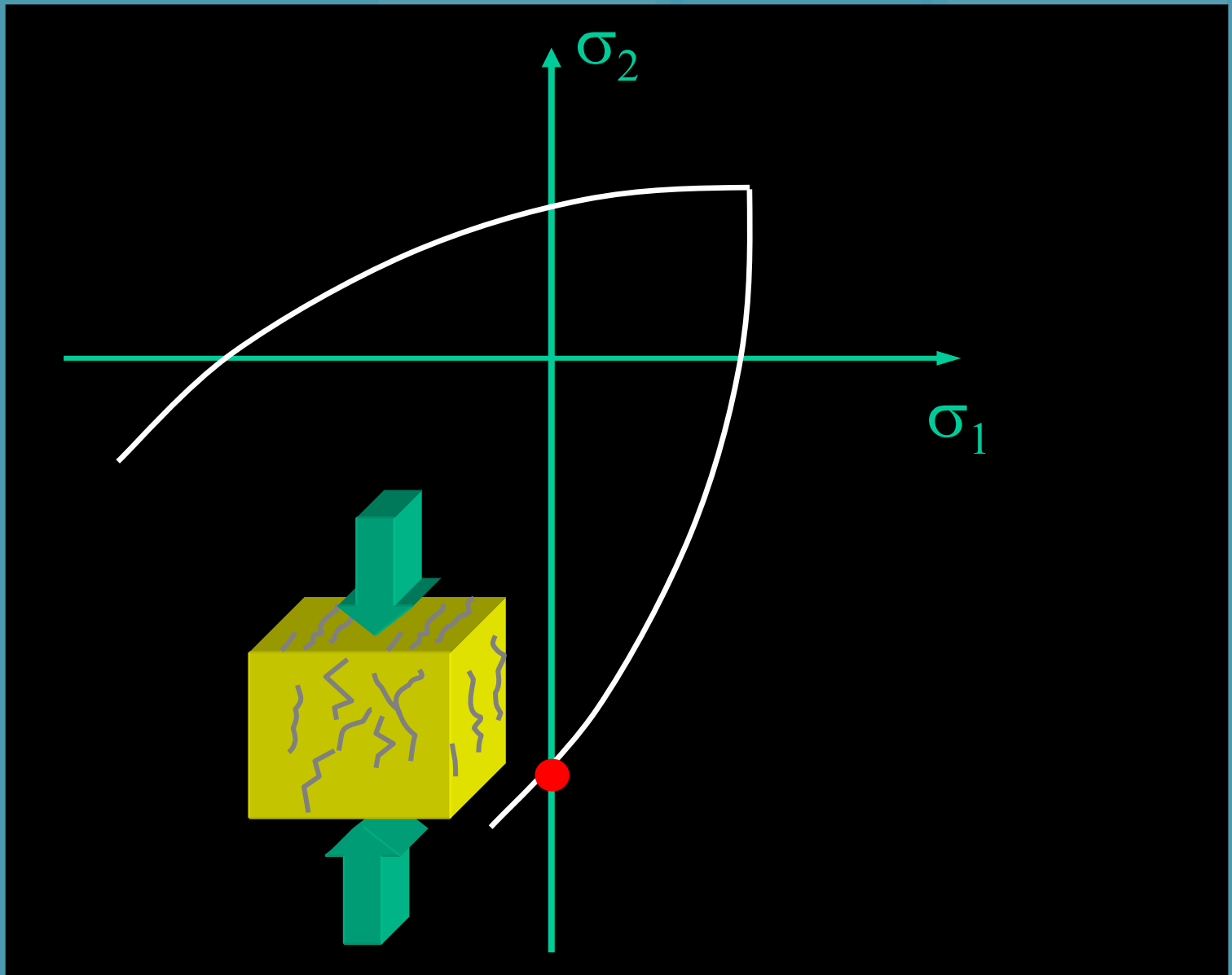
- Wheel induced state of stress



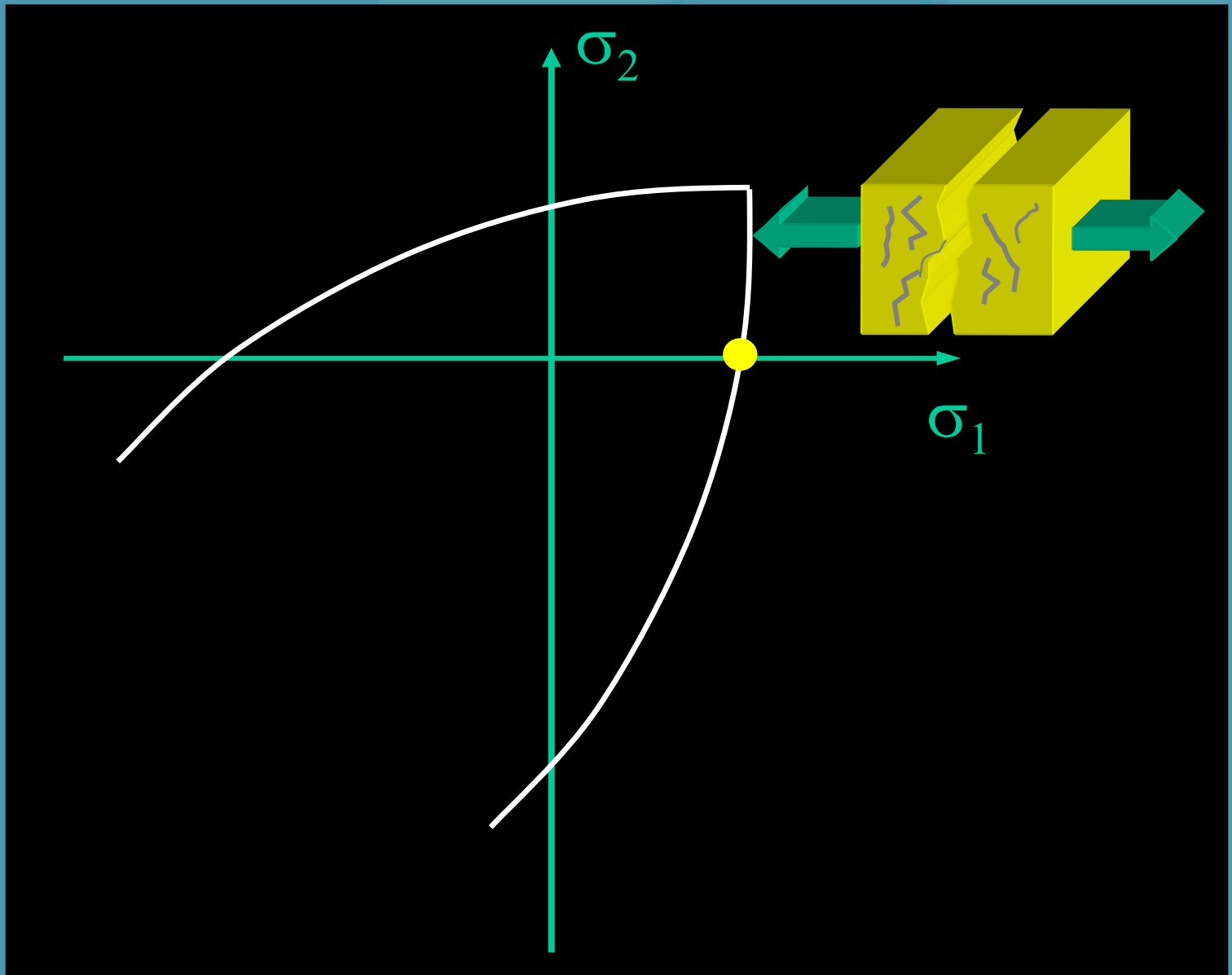
- multiaxial material response



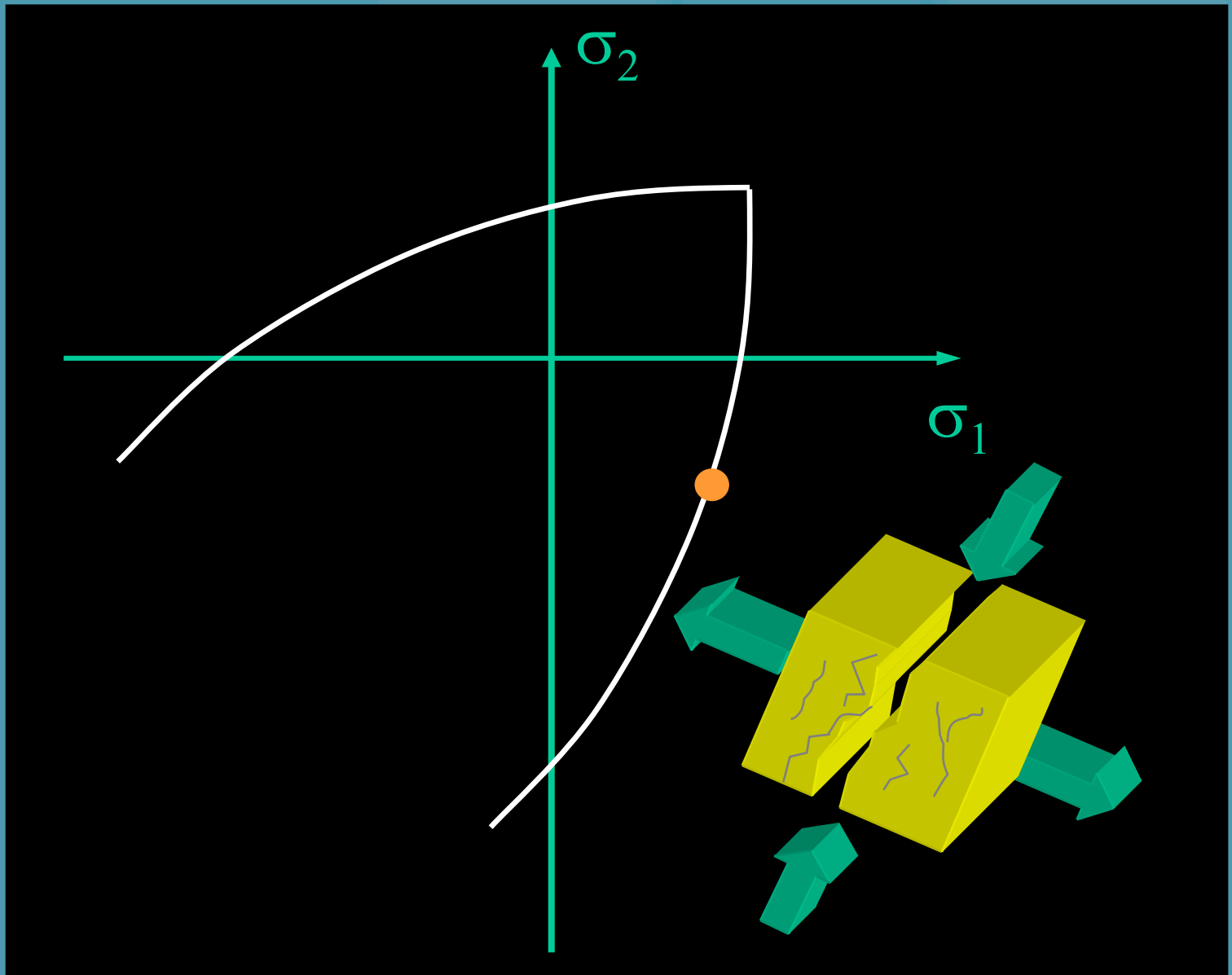
- multiaxial material response



- multiaxial material response

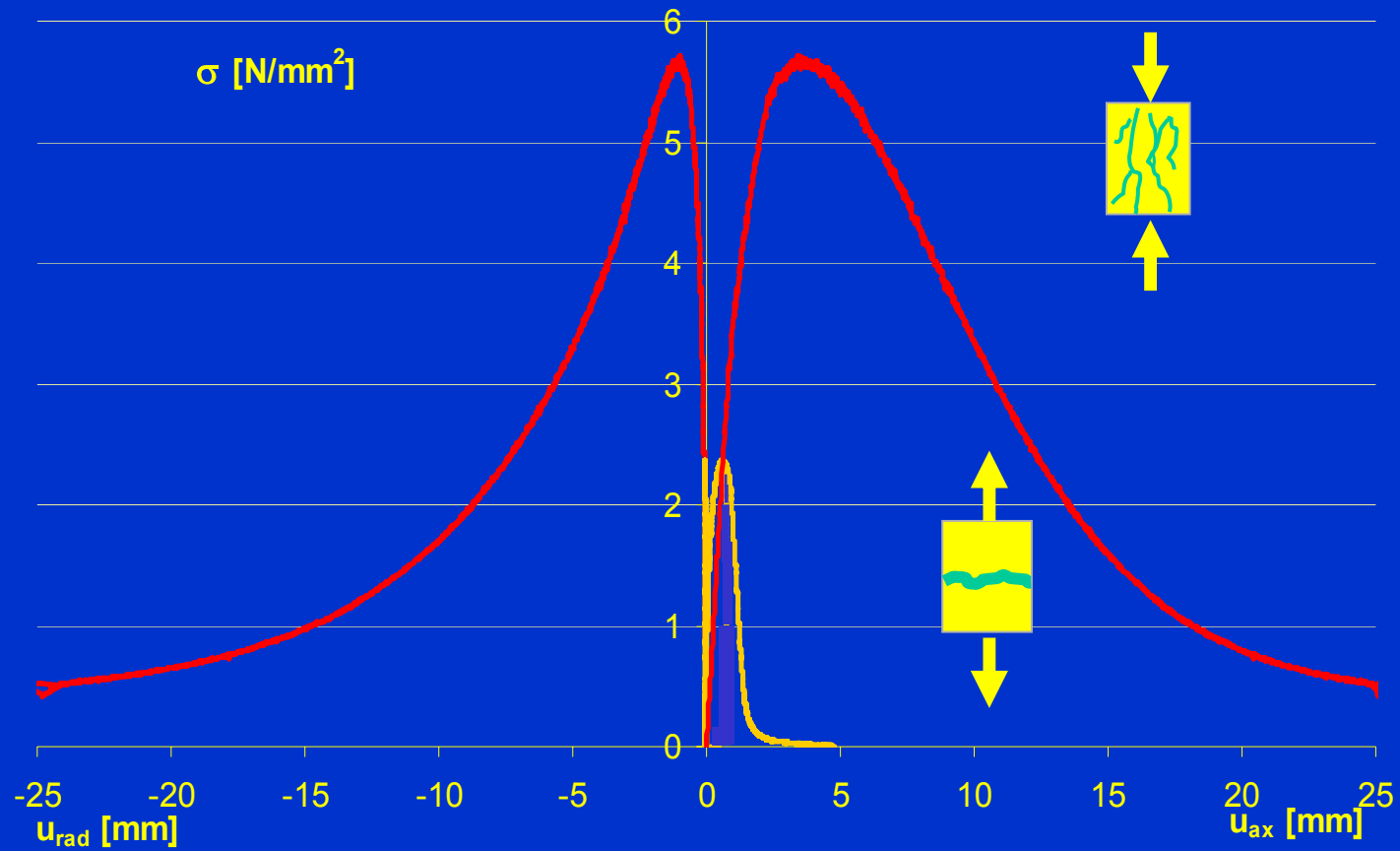


- multiaxial material response

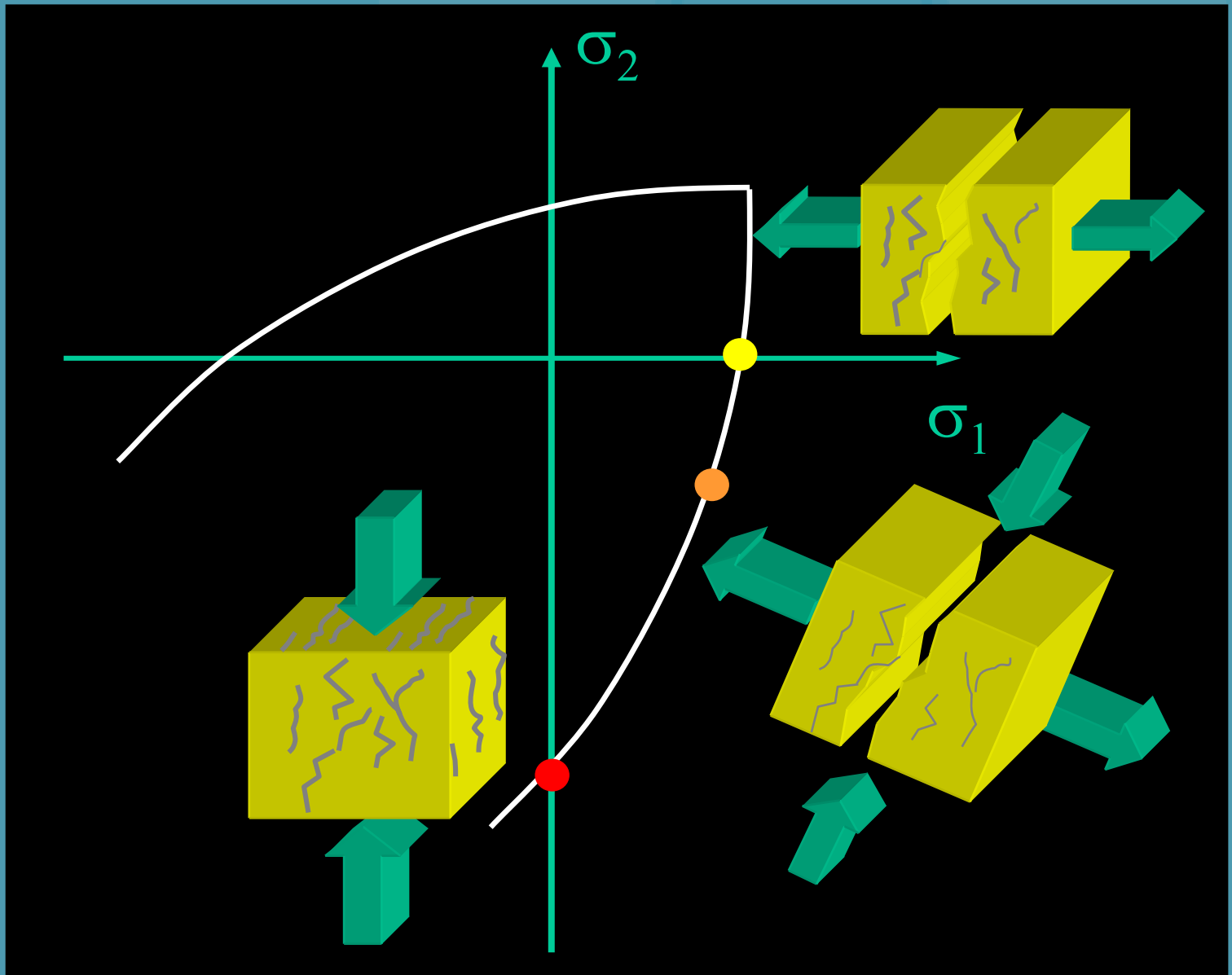


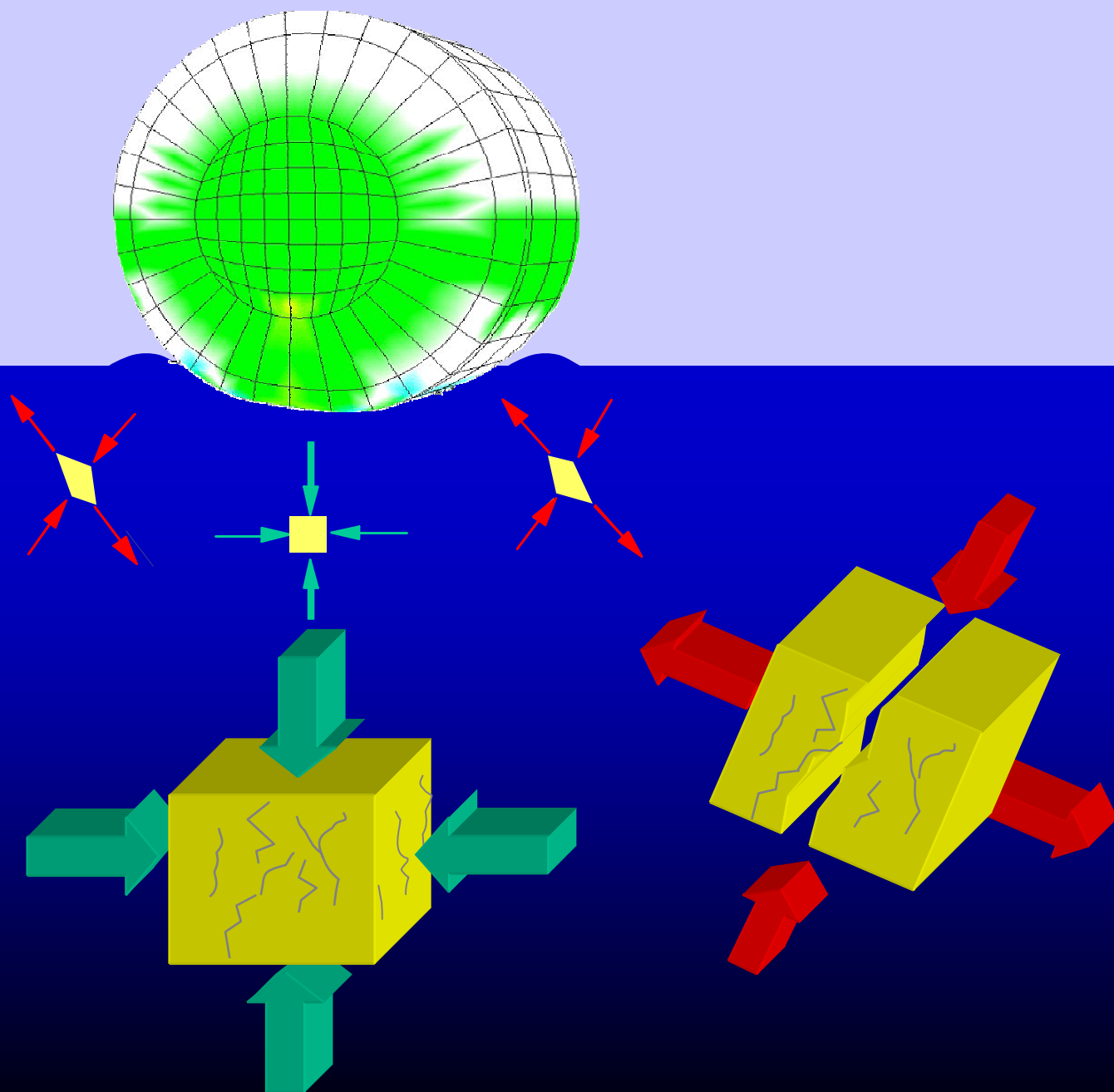
- Compressive vs. tensile response

15°C & 0.1%/sec

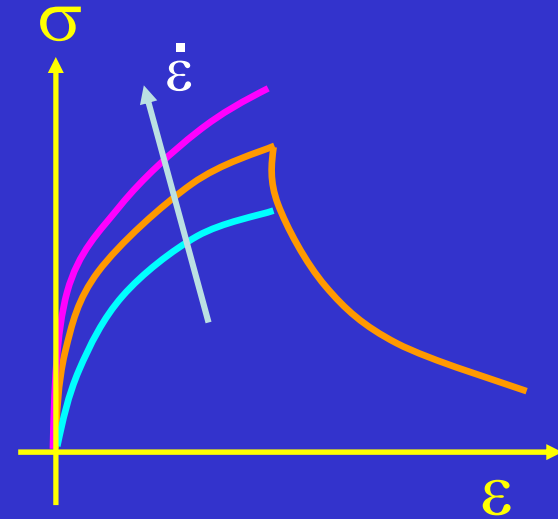
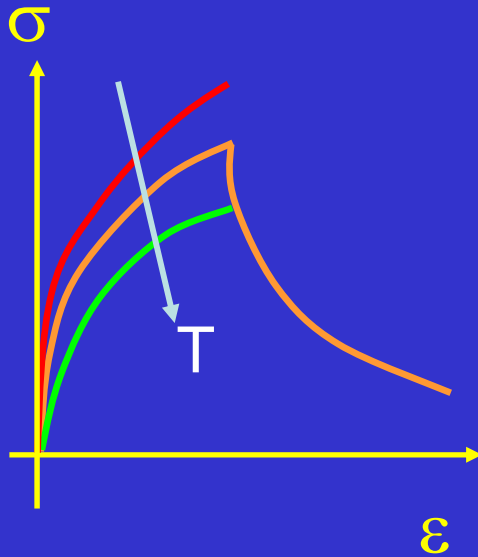


- multiaxial material response

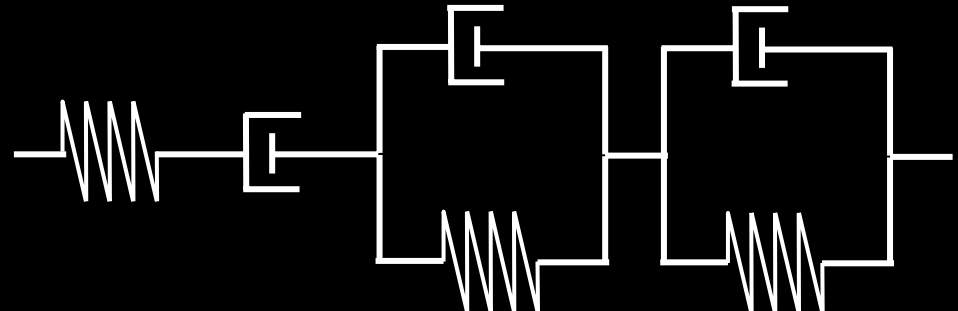
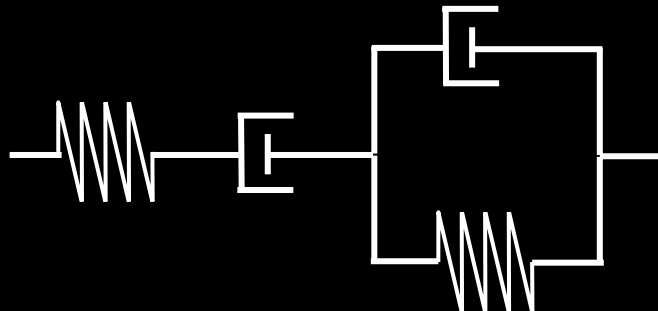




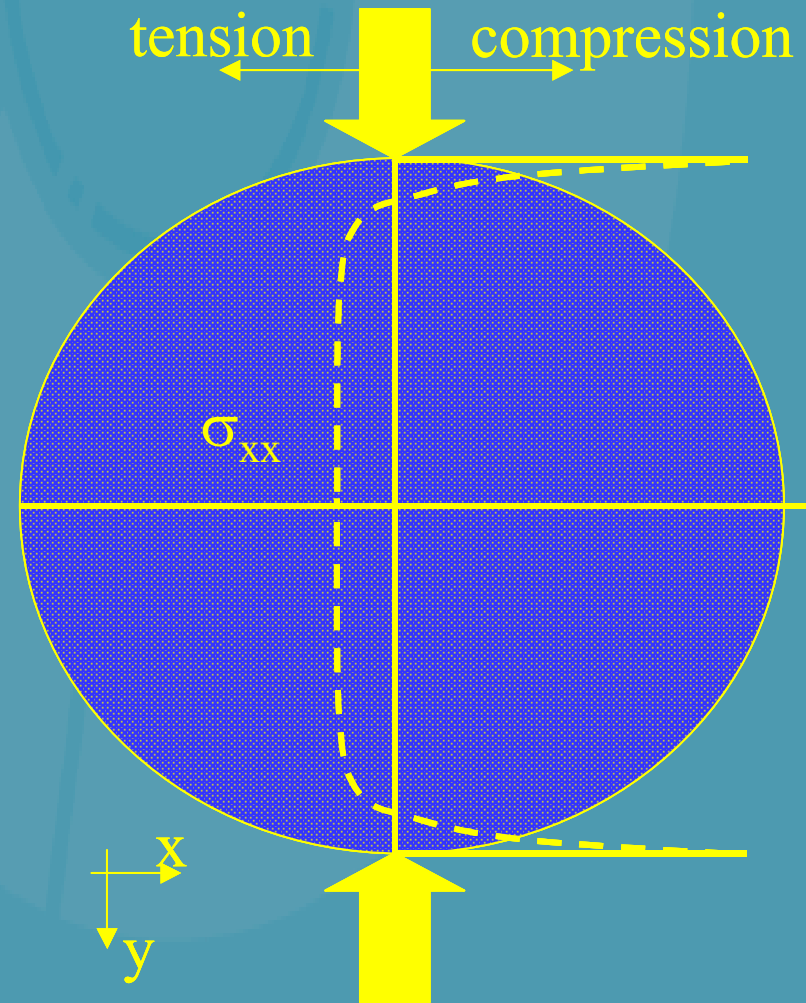
- Material response determination



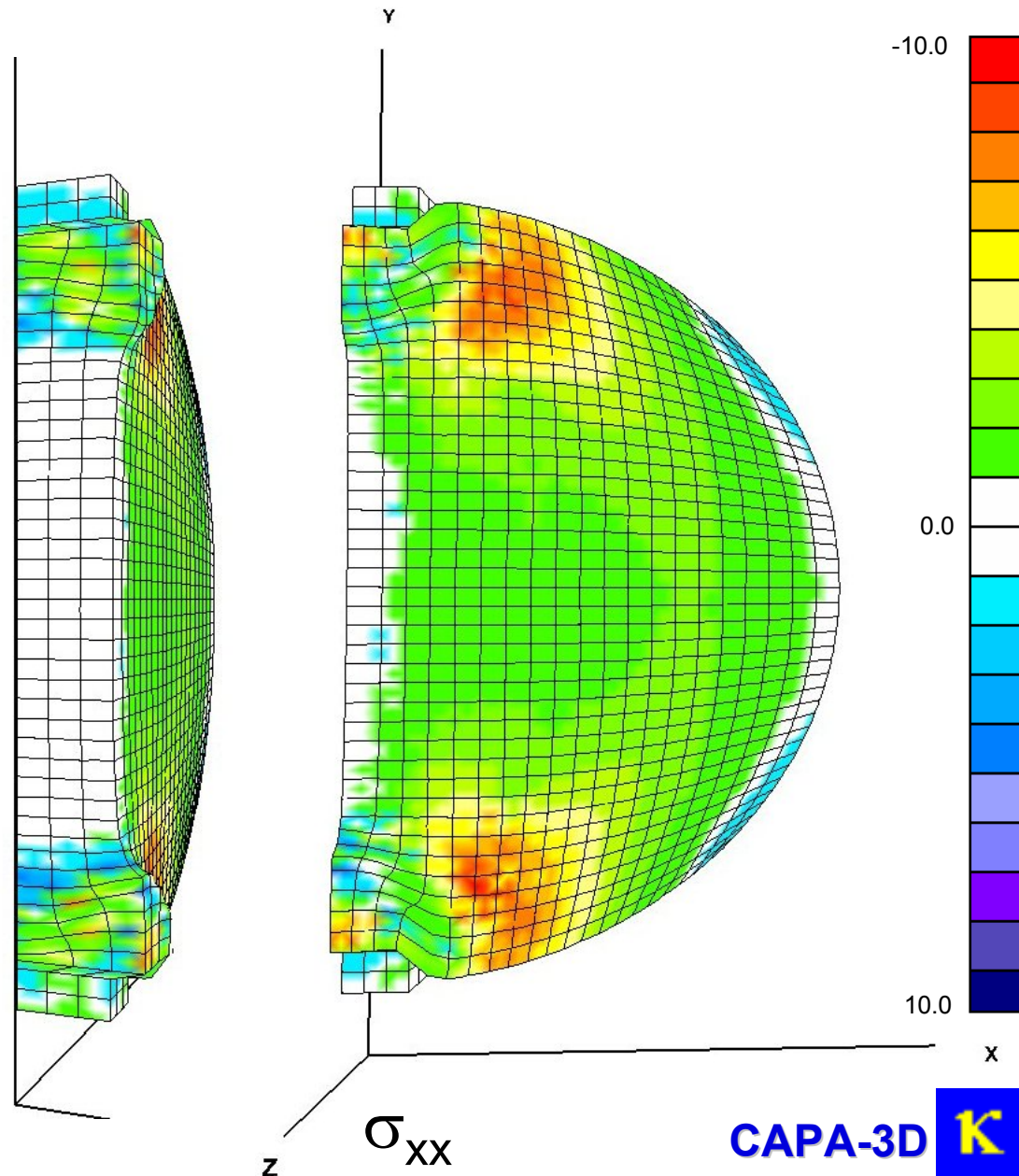
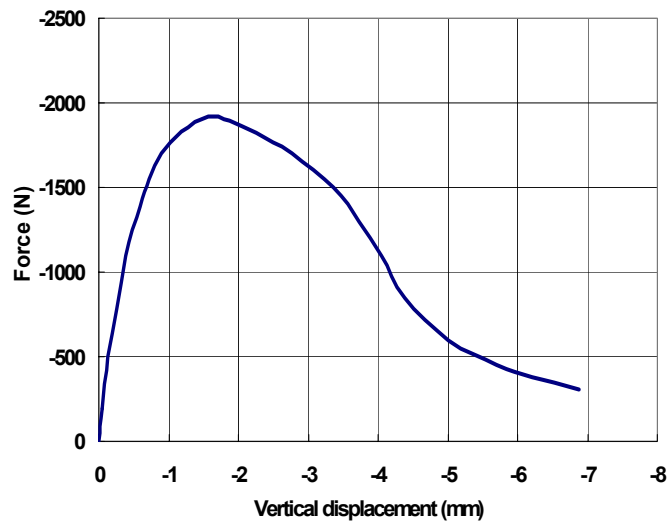
Mechanical analogues

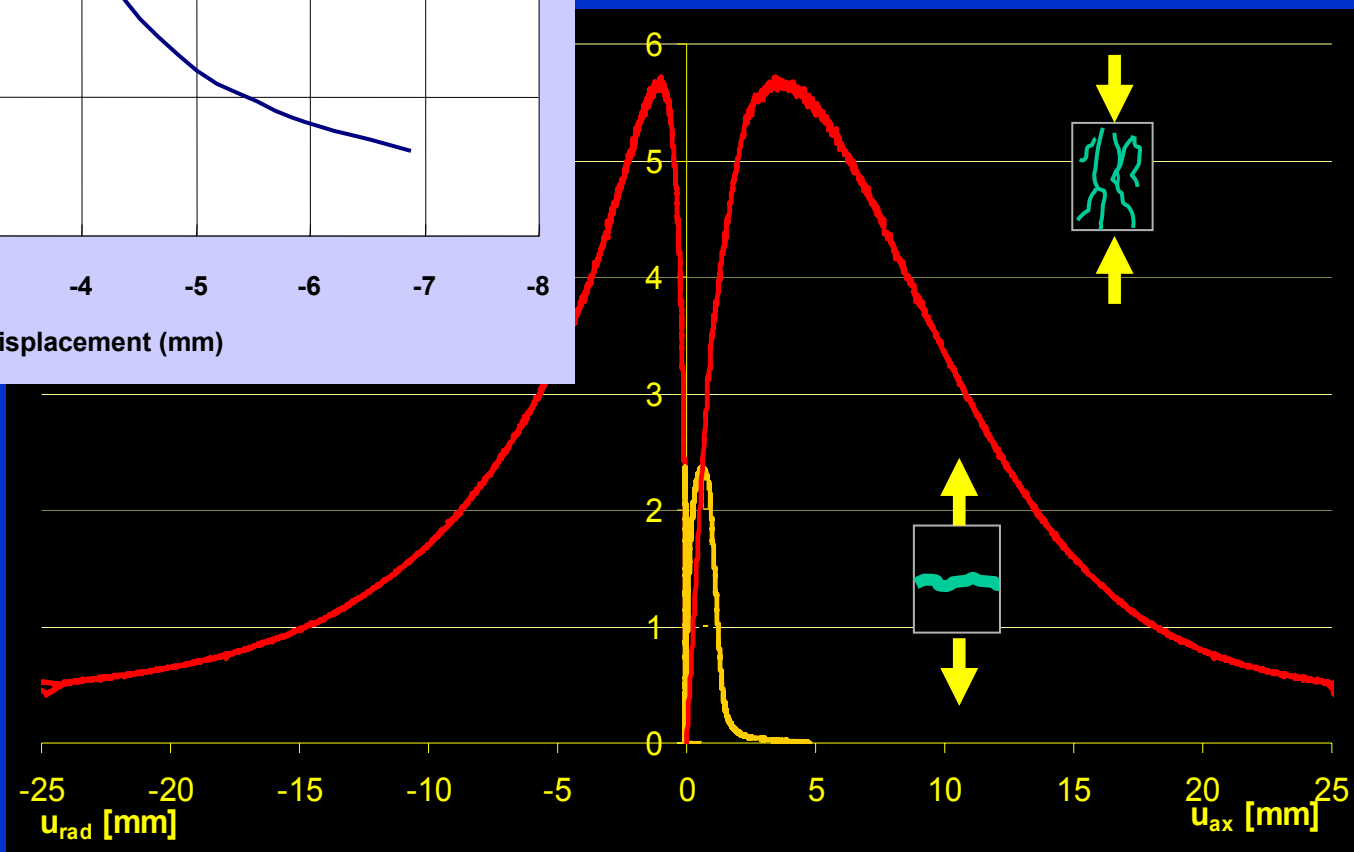
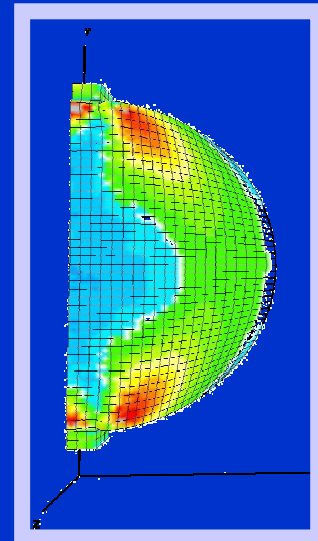
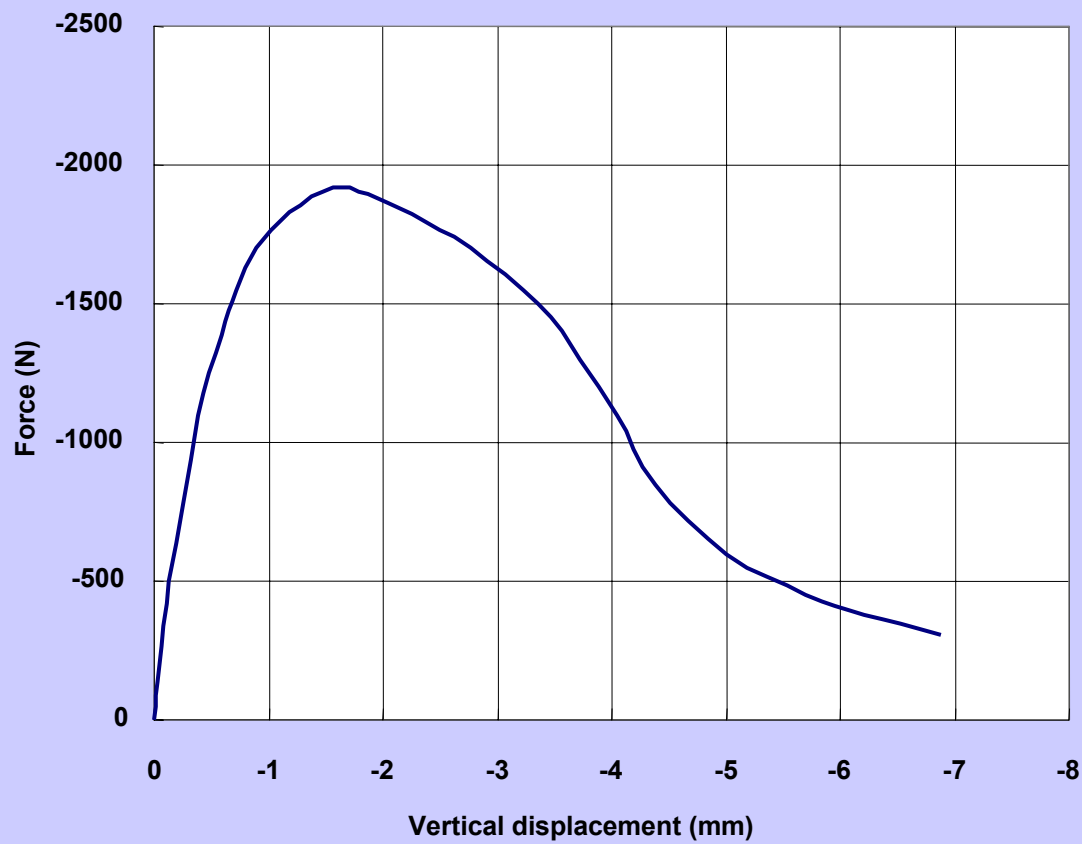


- material response determination

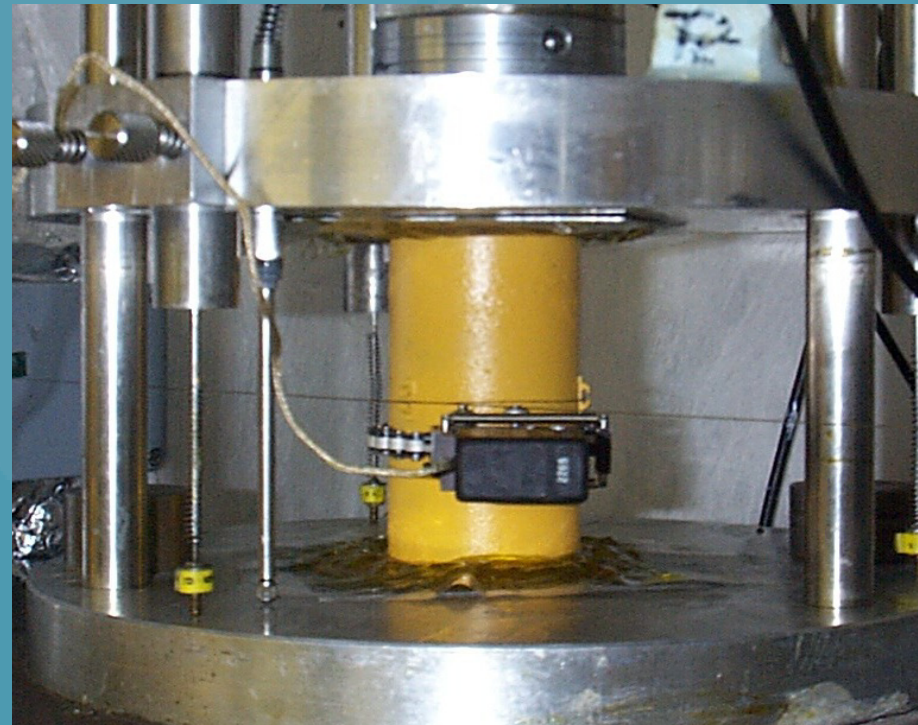


- material response determination

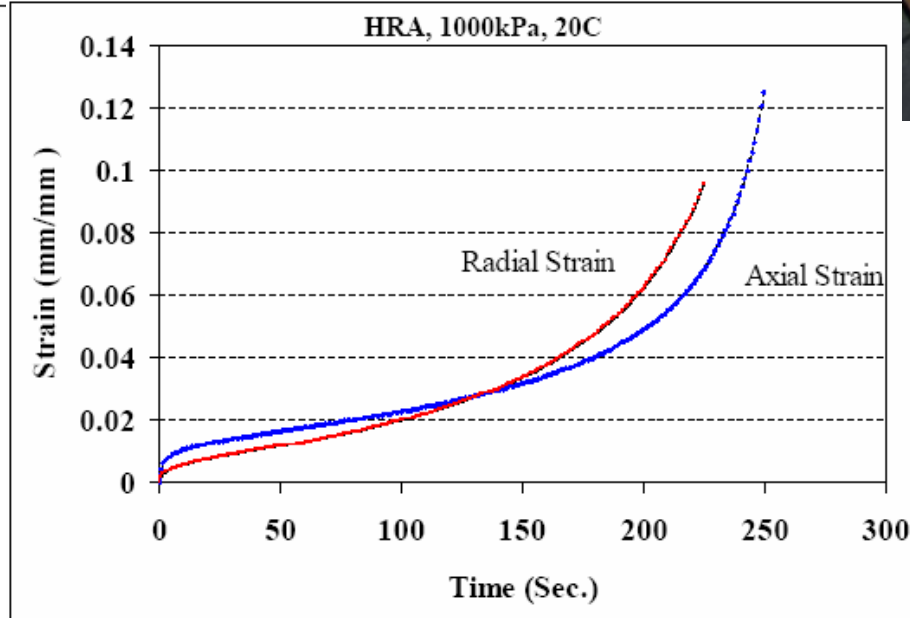
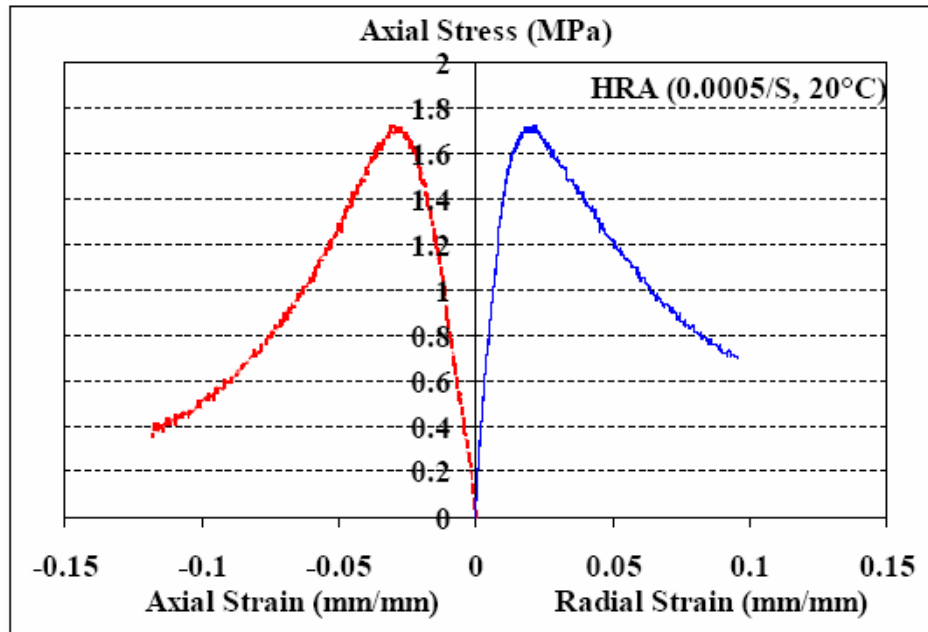




- material response determination

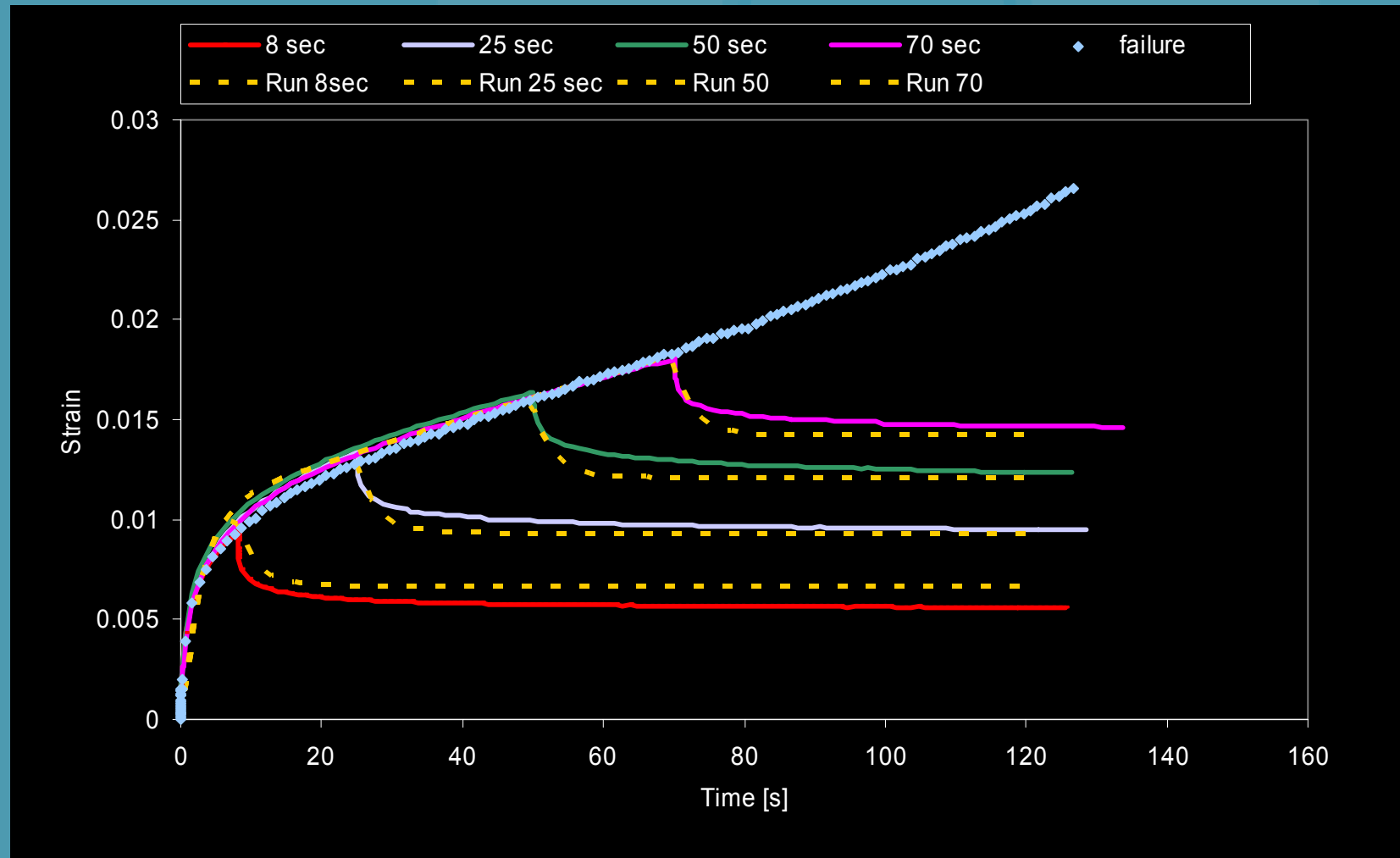


- material response determination

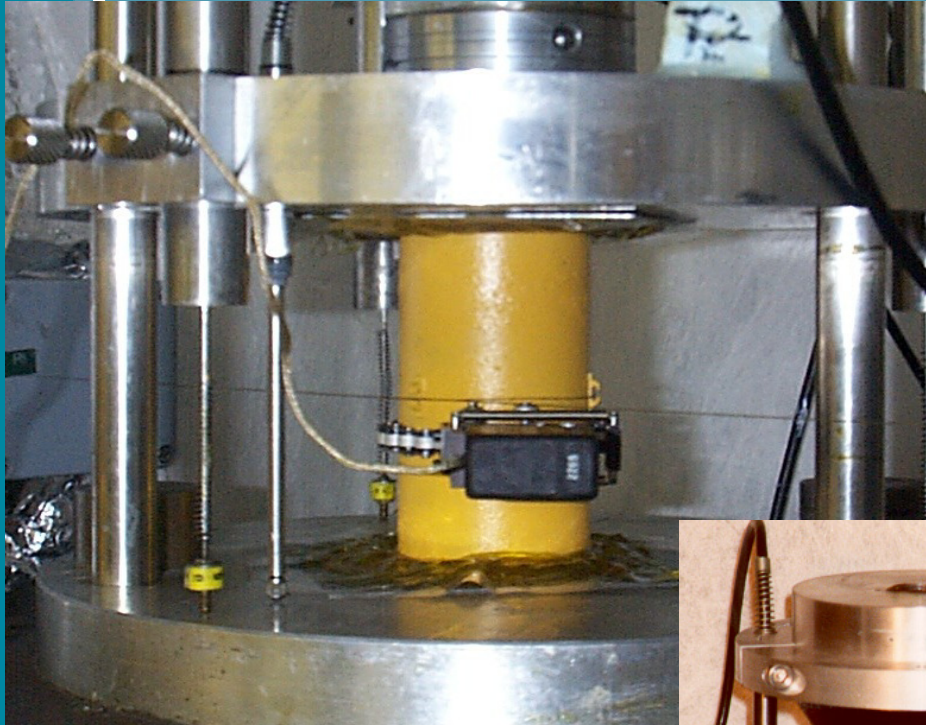


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- material response determination



- material response determination

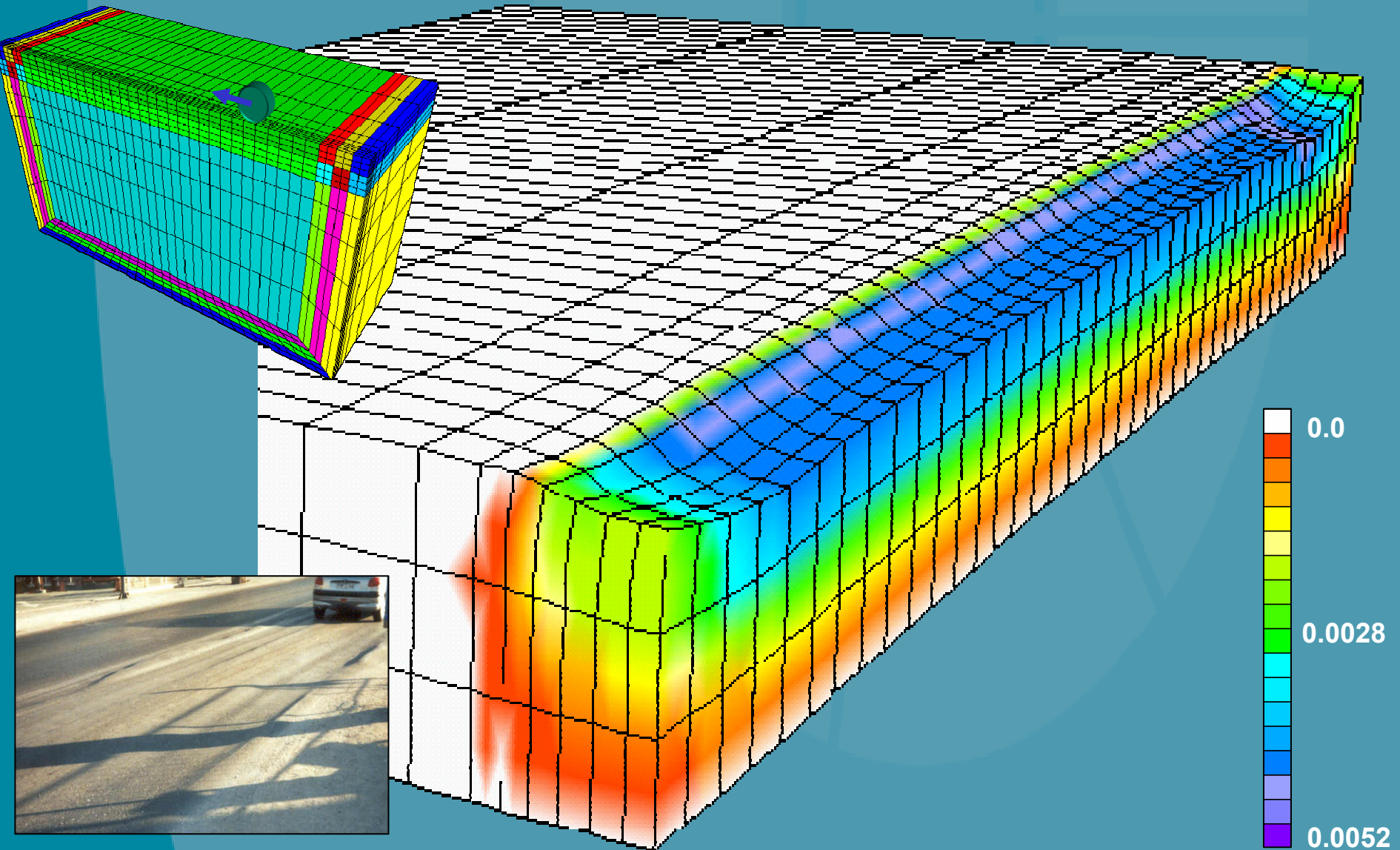


ACRe Mixture

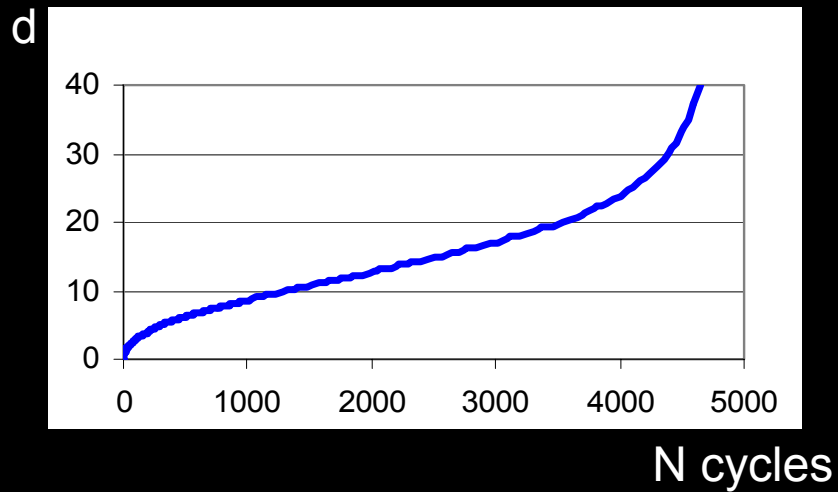
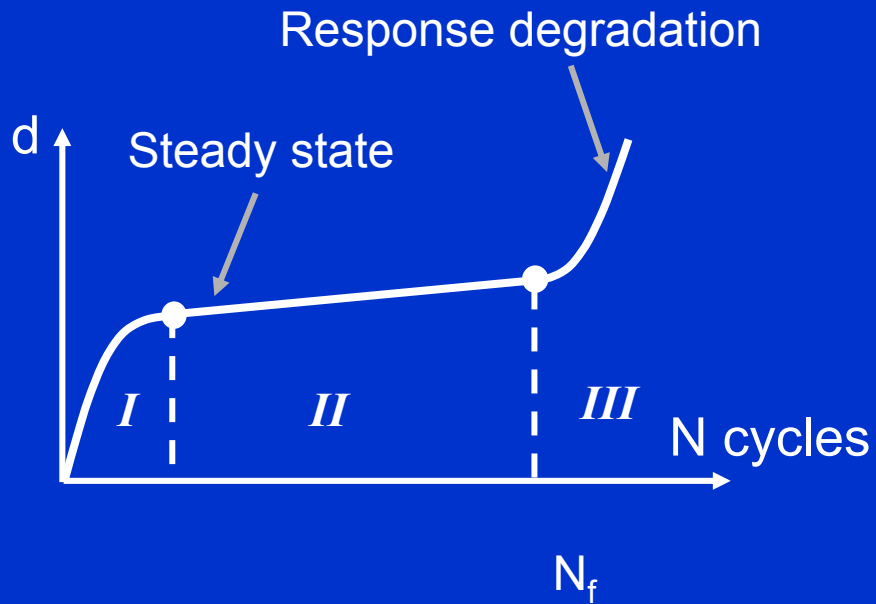


DBM Mixture

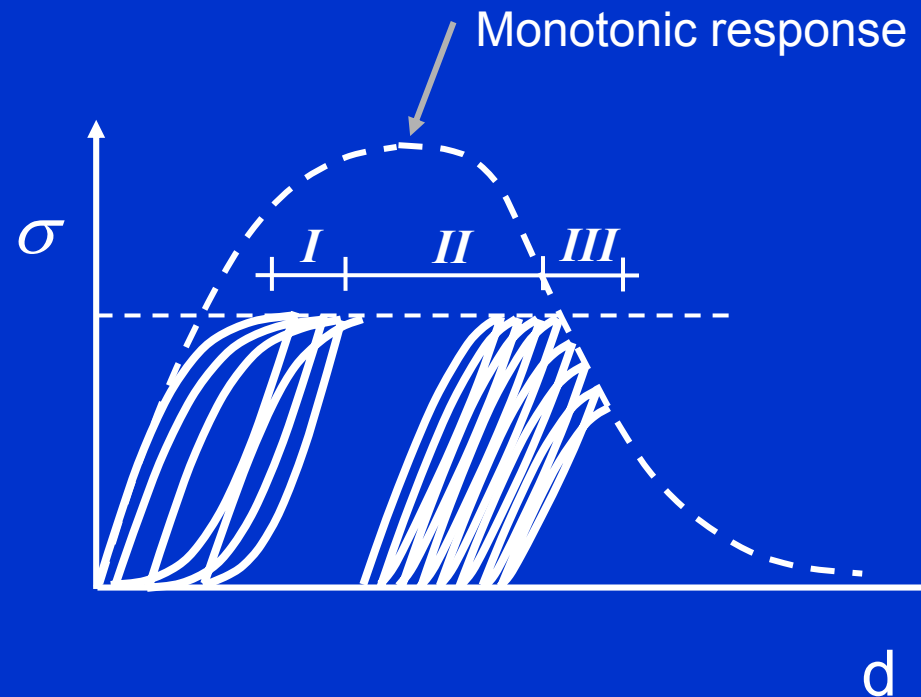
- wheel tracking simulation



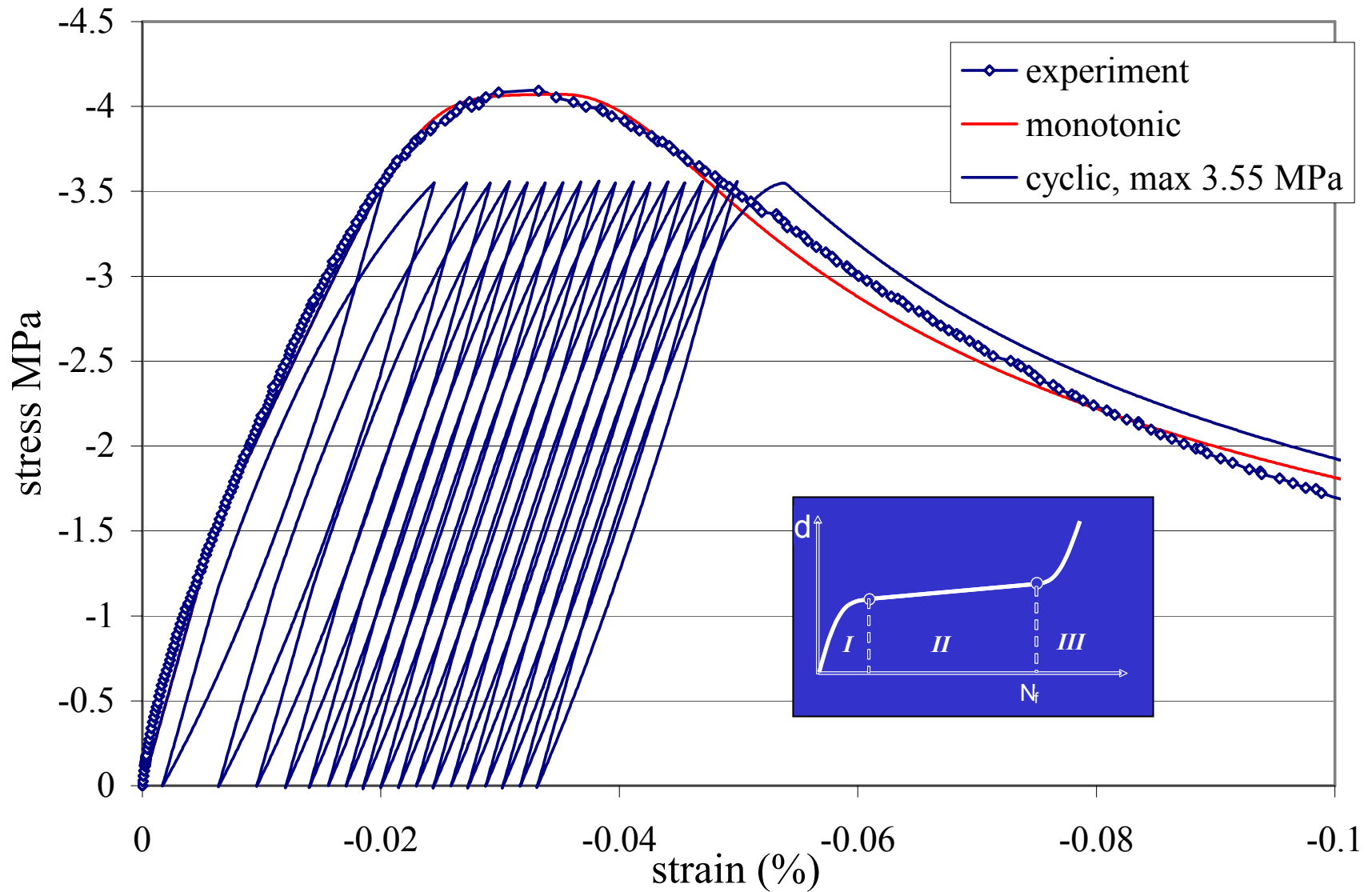
- Cyclic response simulation



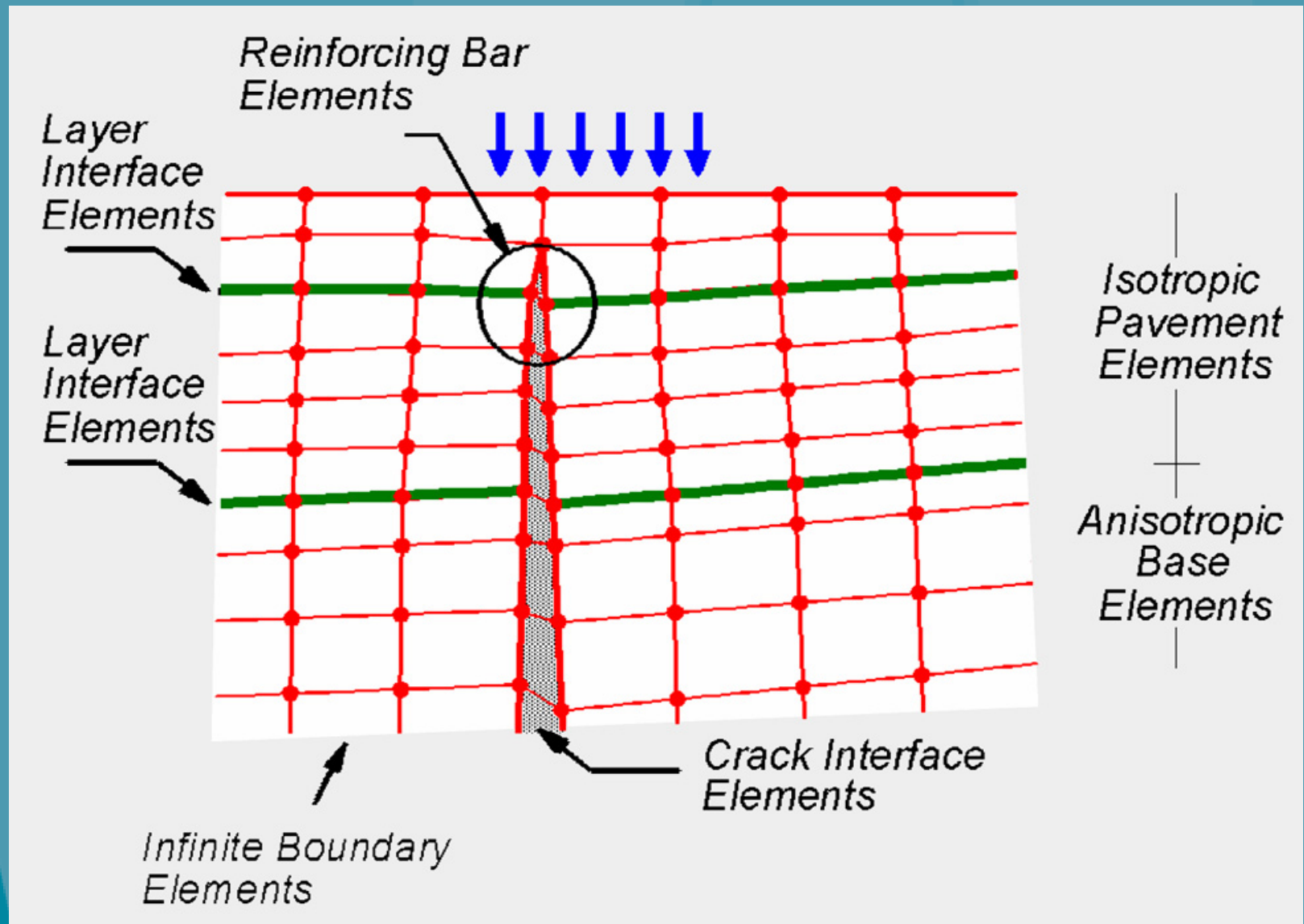
Cyclic Response Degradation Model



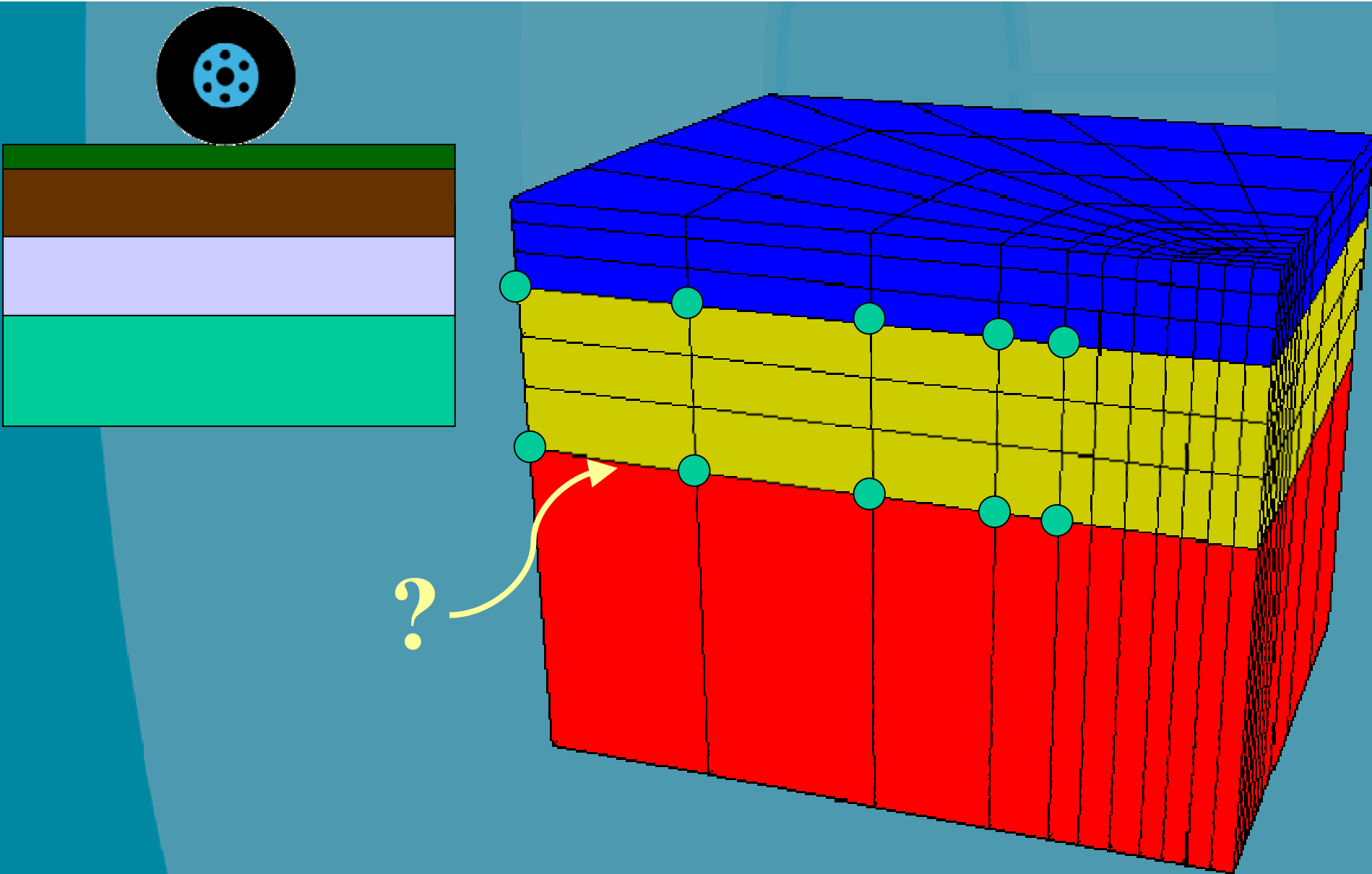
- cyclic response simulation



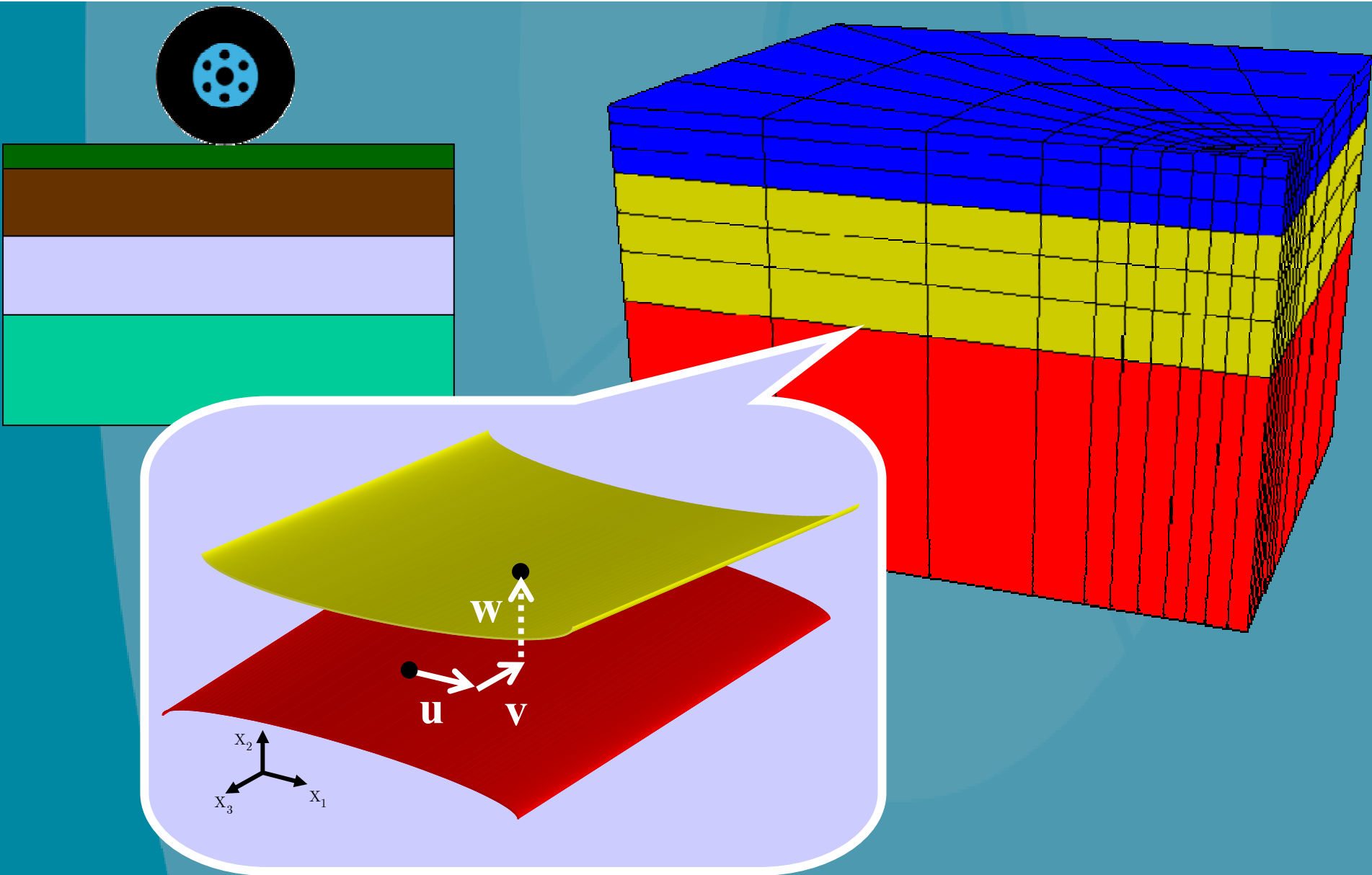
- the simulation problem: interlayer systems



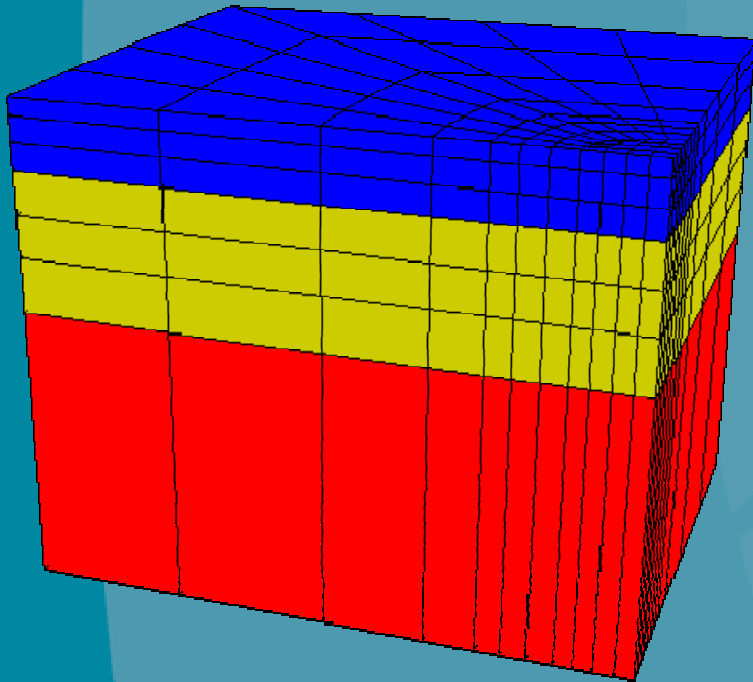
Interlayer systems



Interlayer systems

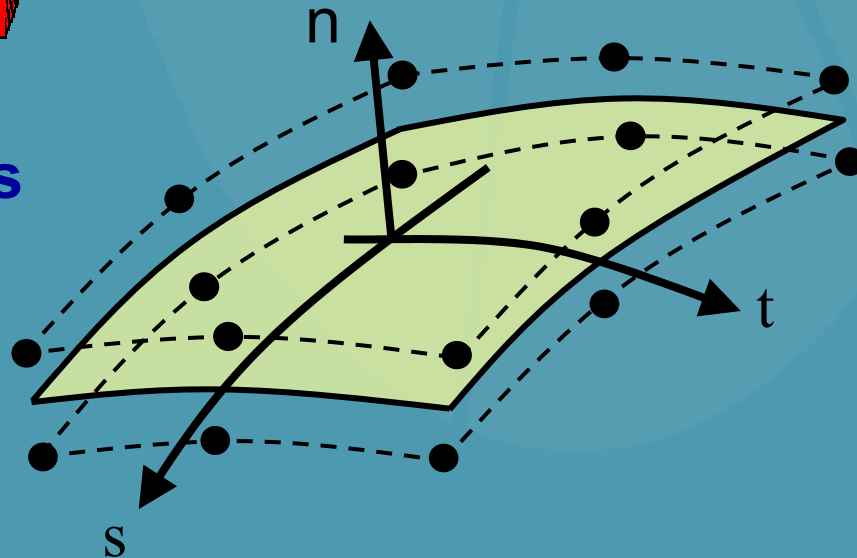
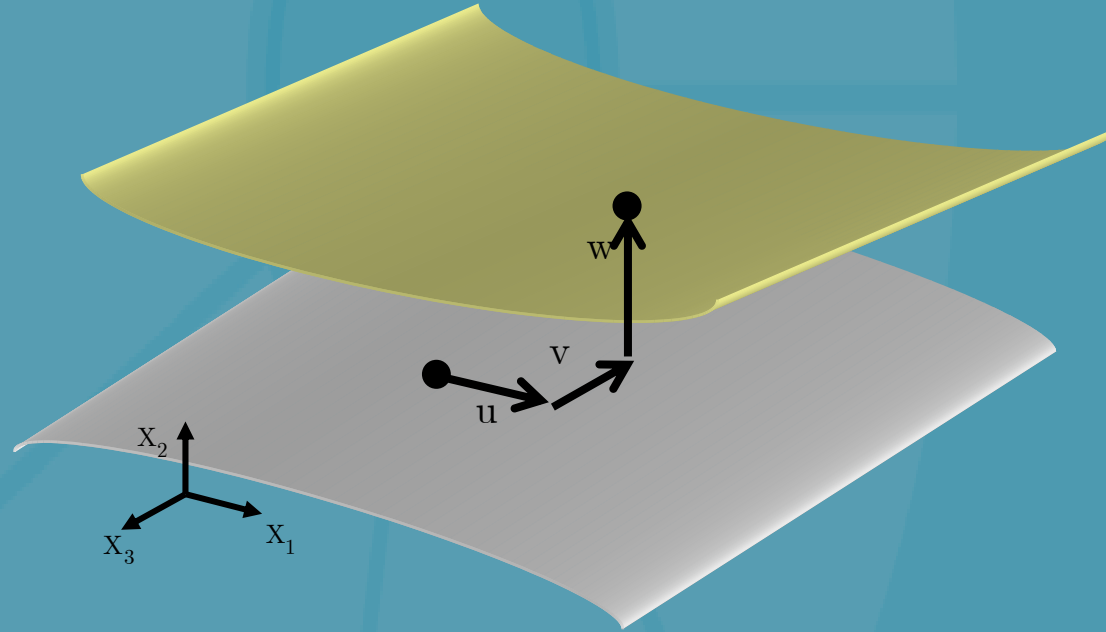


Interlayer systems



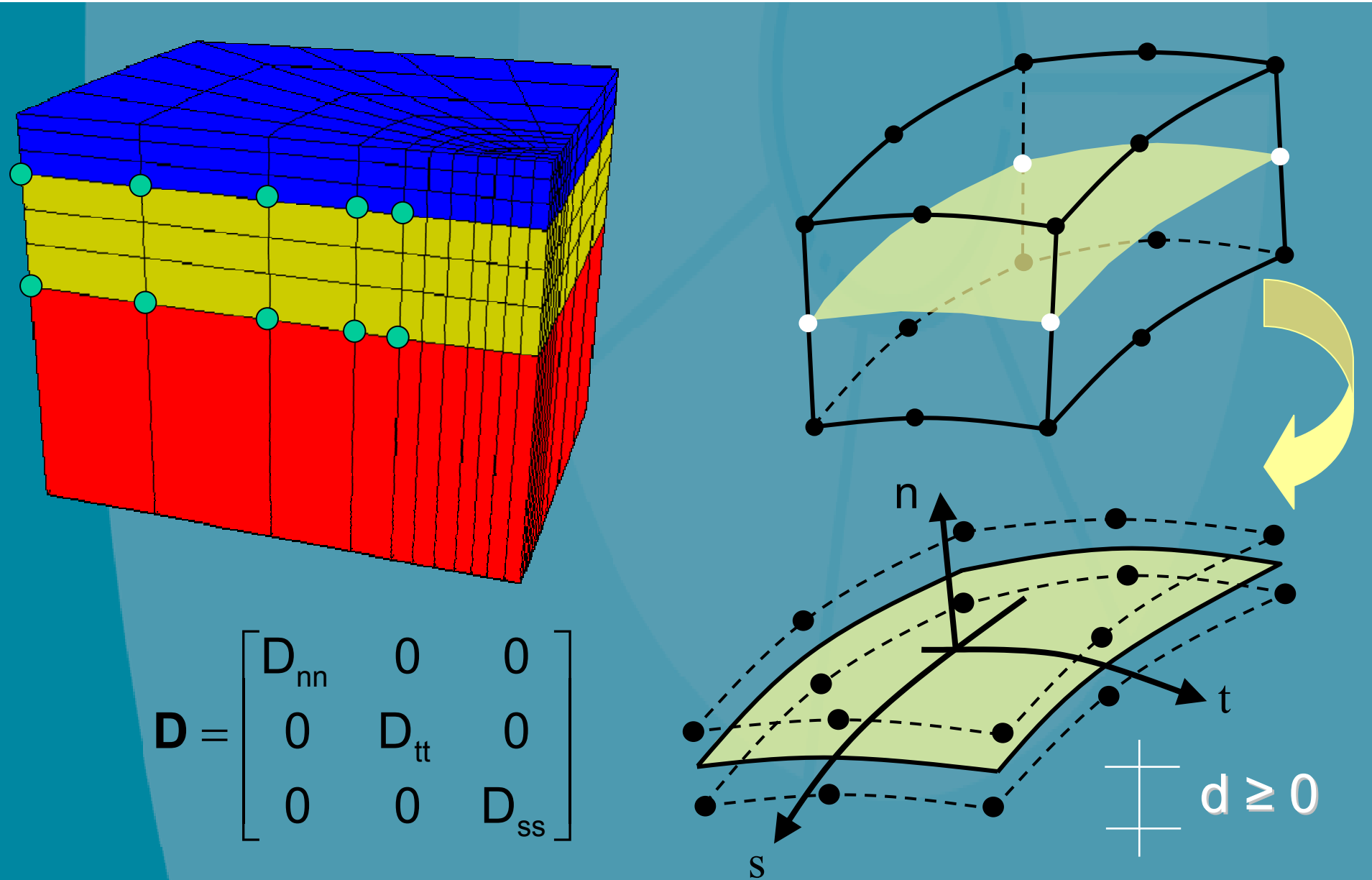
- standard elements
NOT good

$$d \rightarrow 0$$

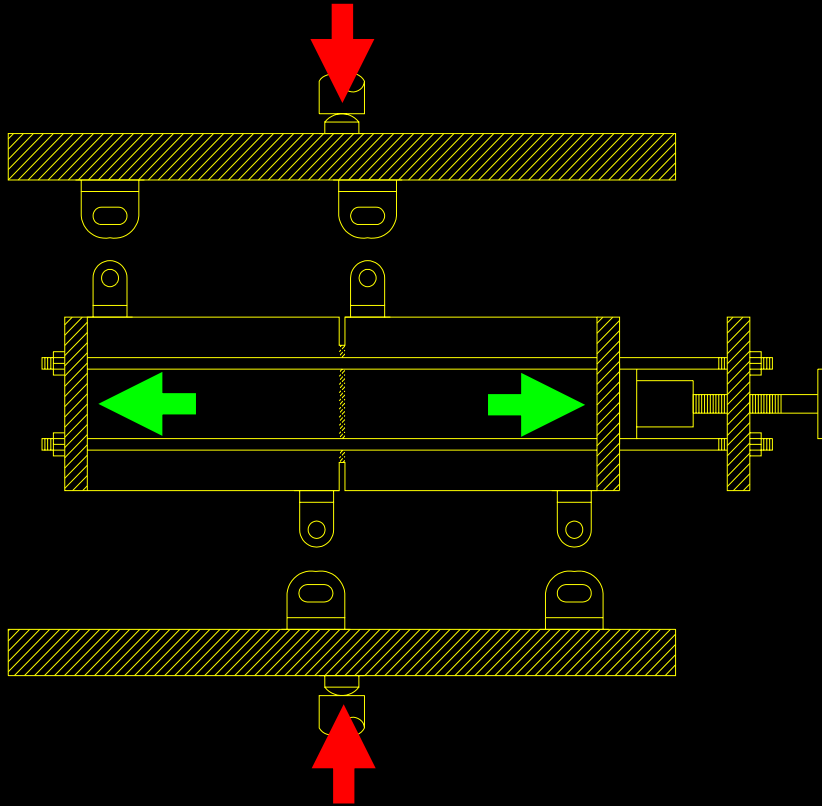


$$d \geq 0$$

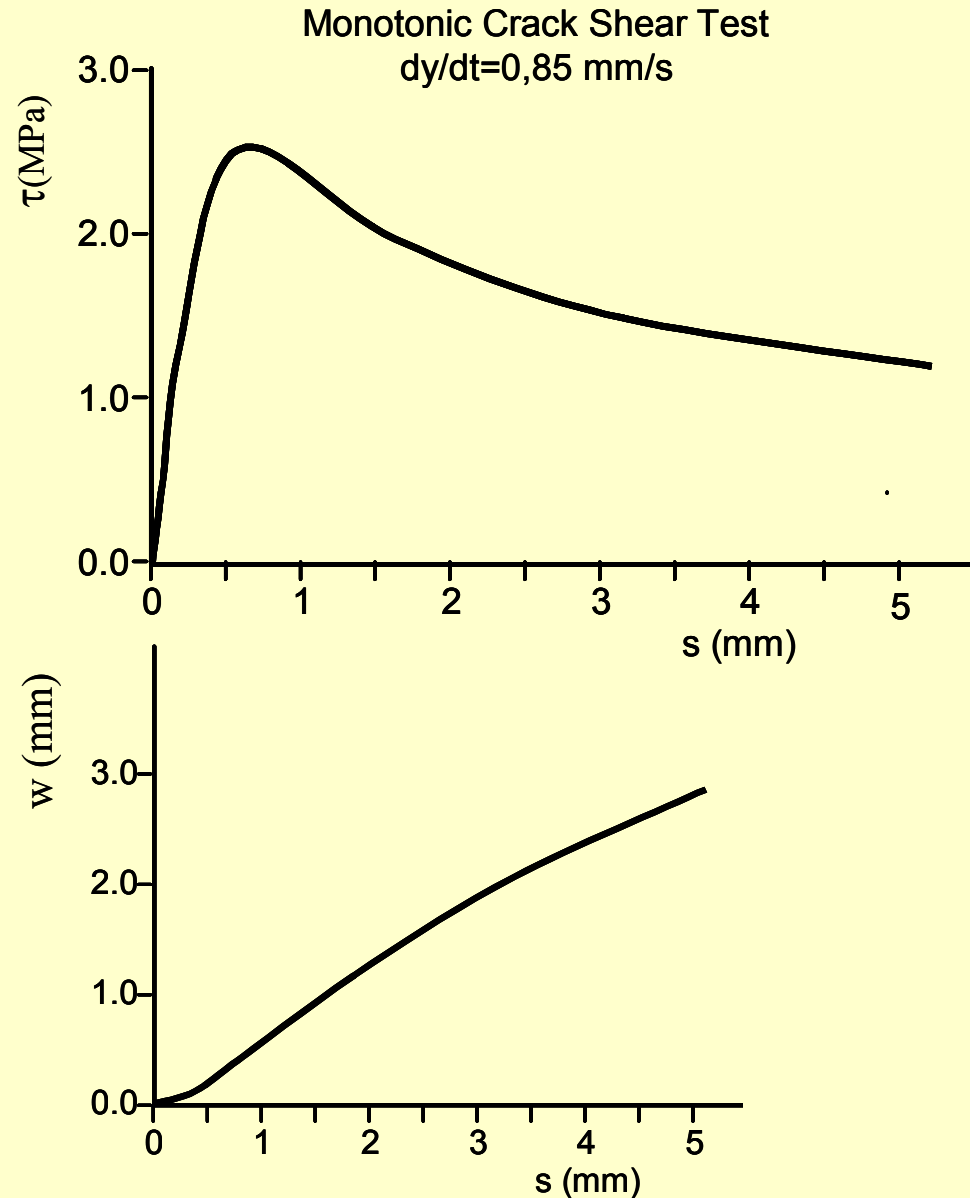
Interlayer systems: interface elements



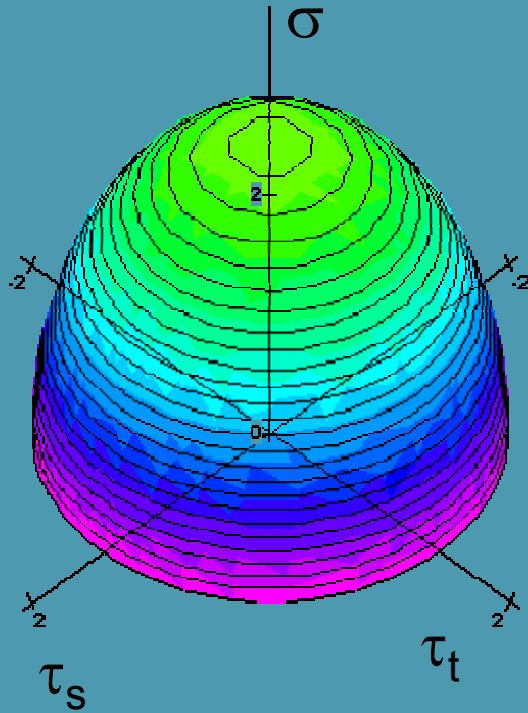
Interlayer systems: tangential stiffness



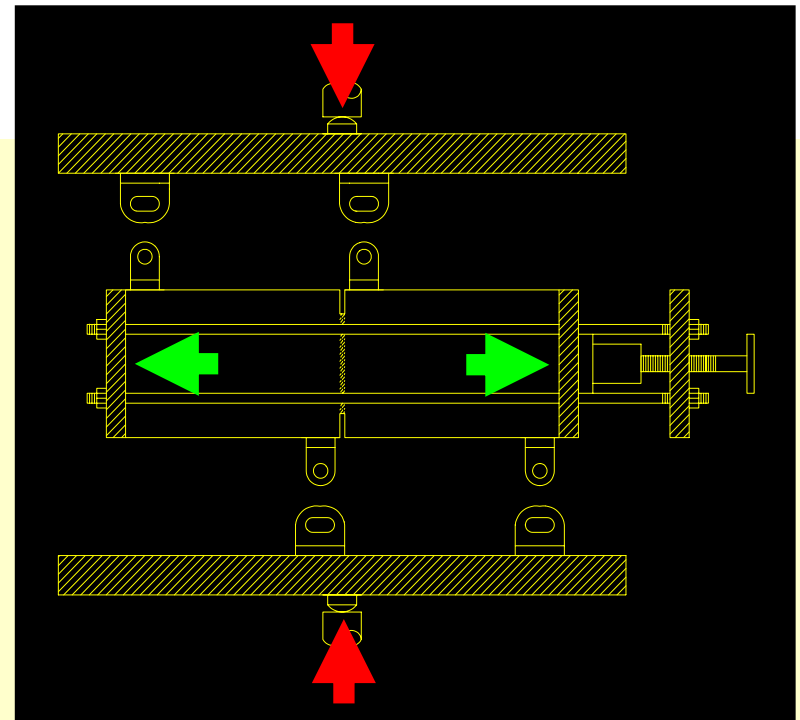
$$\mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$



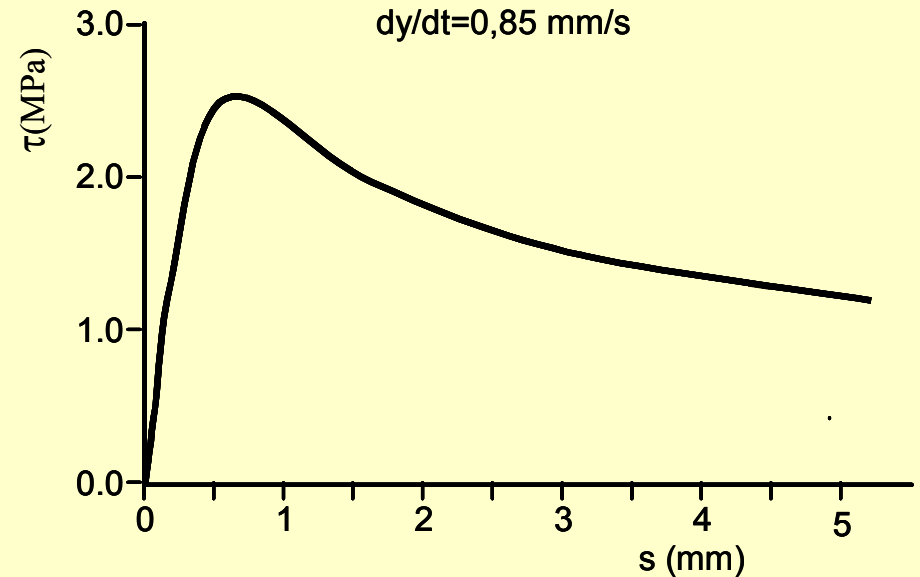
Interlayer systems



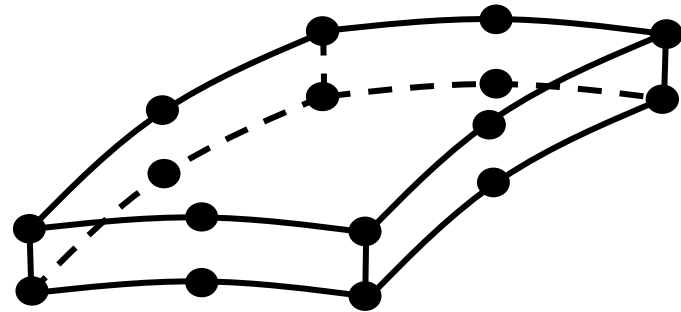
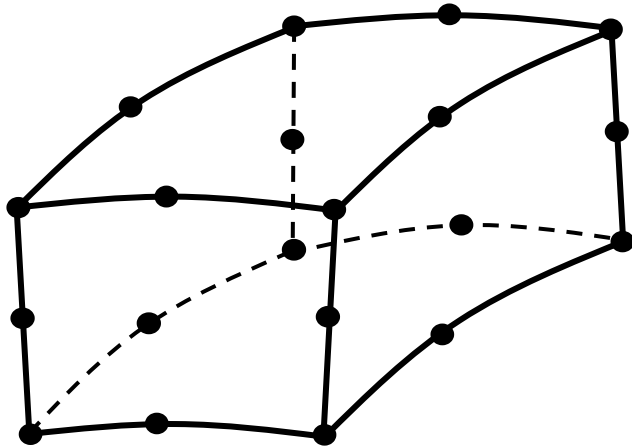
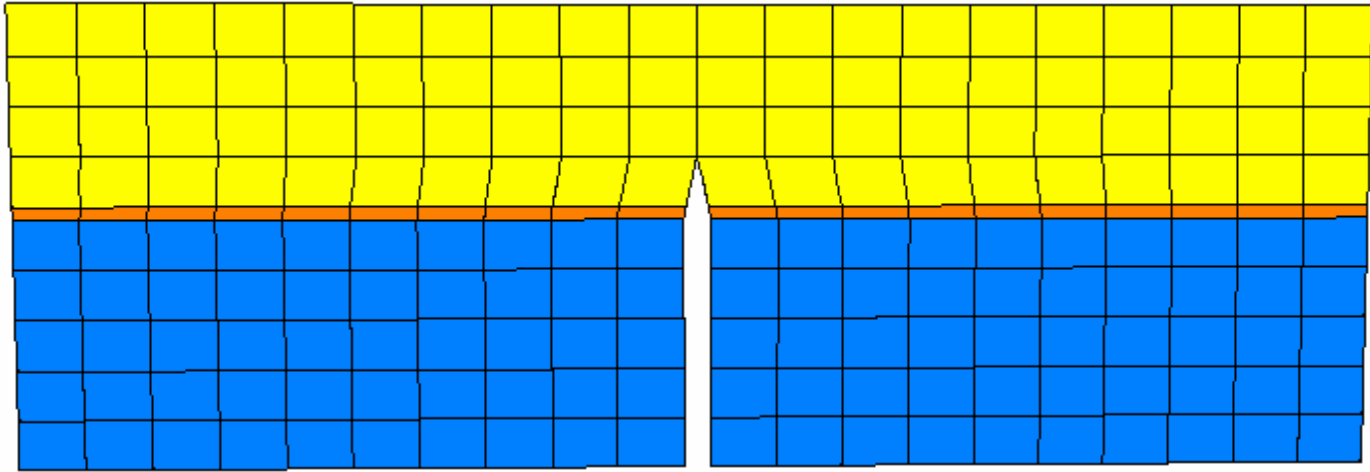
$$\mathbf{D} = \begin{bmatrix} D_{nn} & D_{nt} & D_{ns} \\ D_{tn} & D_{tt} & D_{ts} \\ D_{sn} & D_{st} & D_{ss} \end{bmatrix}$$



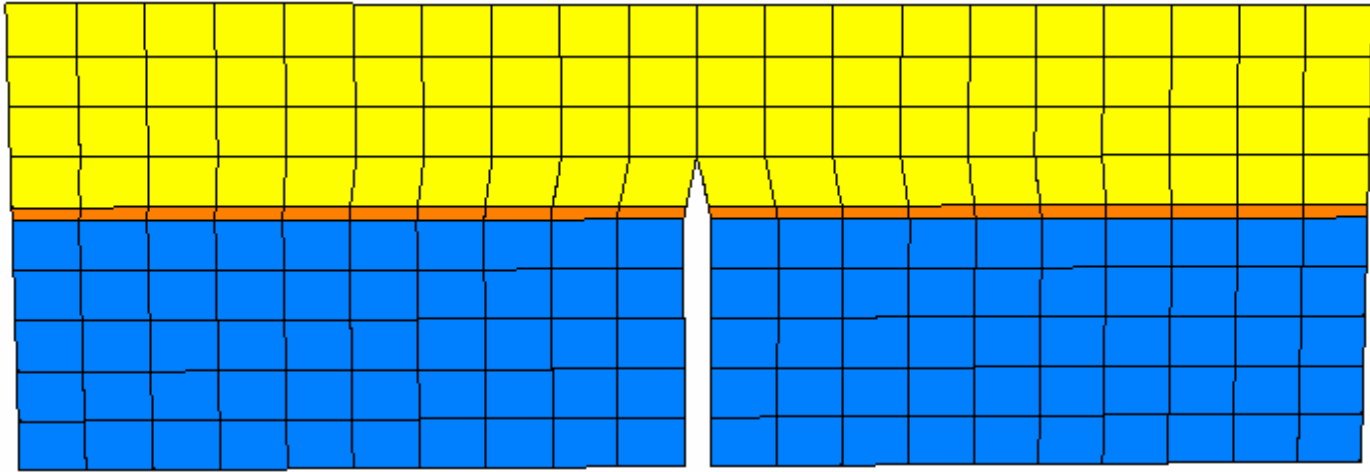
Monotonic Crack Shear Test
dy/dt=0,85 mm/s



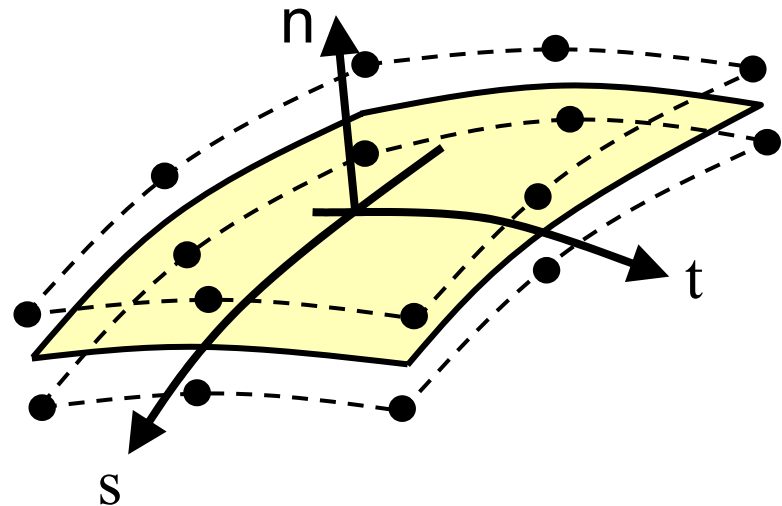
- Interface systems
 - soft inplane stiffness example



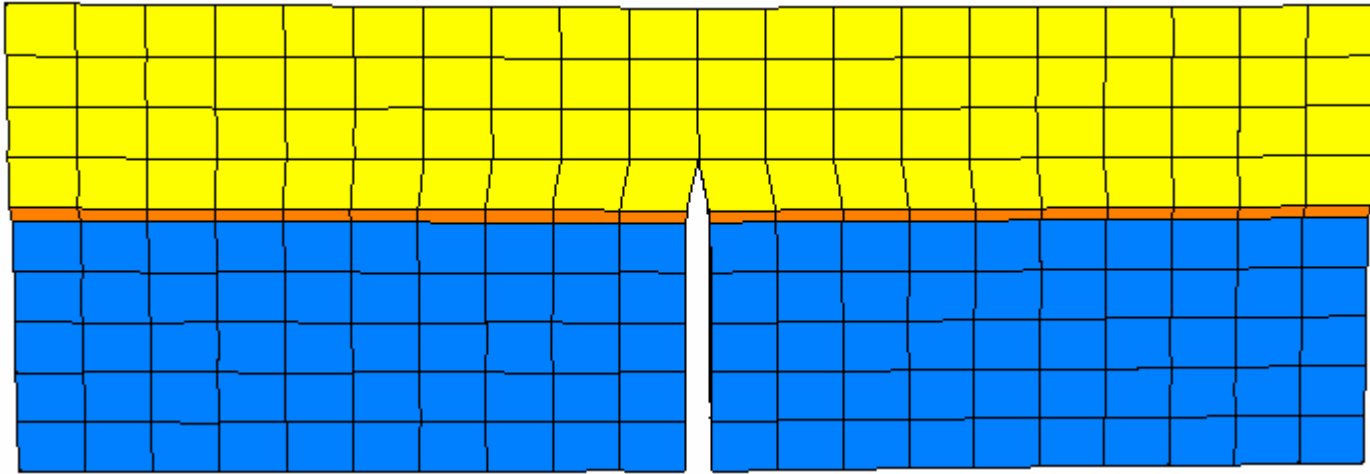
- Interface systems
 - soft inplane stiffness



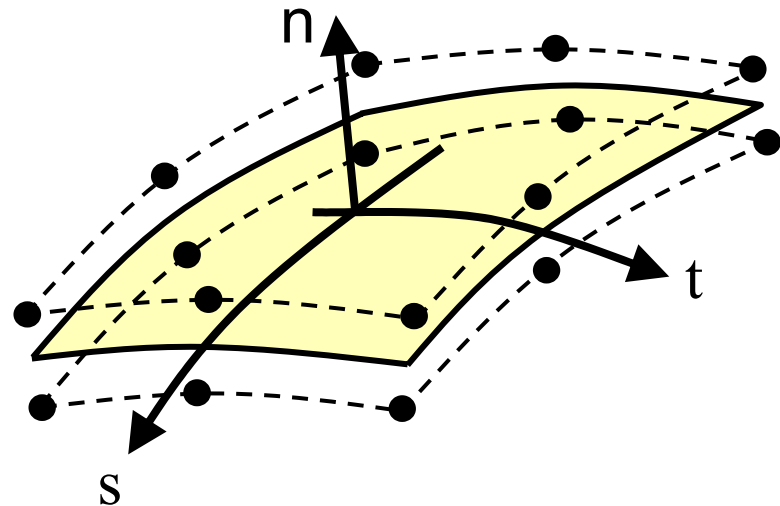
$$\mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$



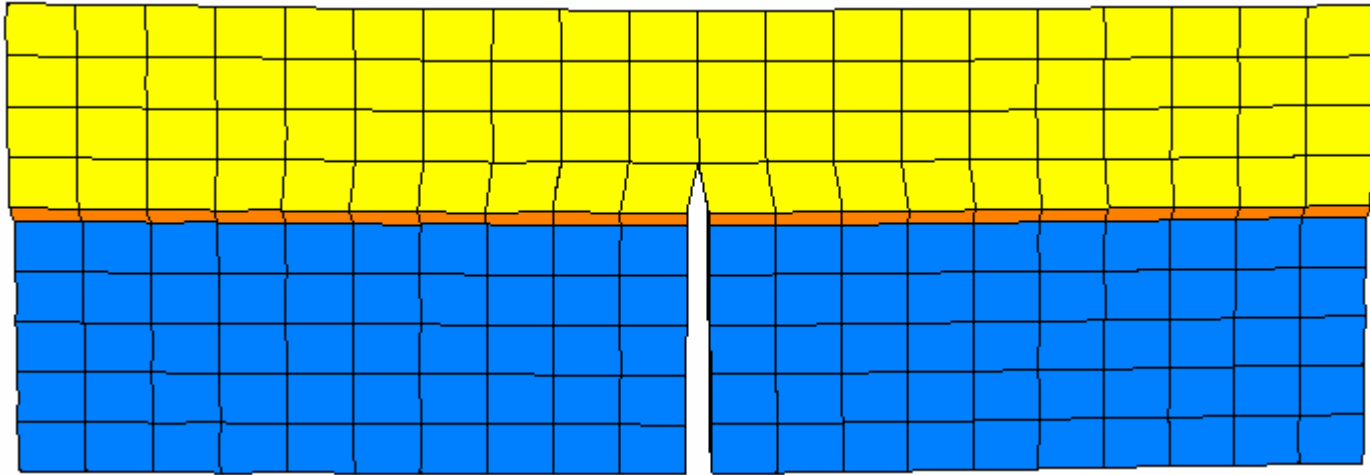
- Interface systems
 - soft inplane stiffness



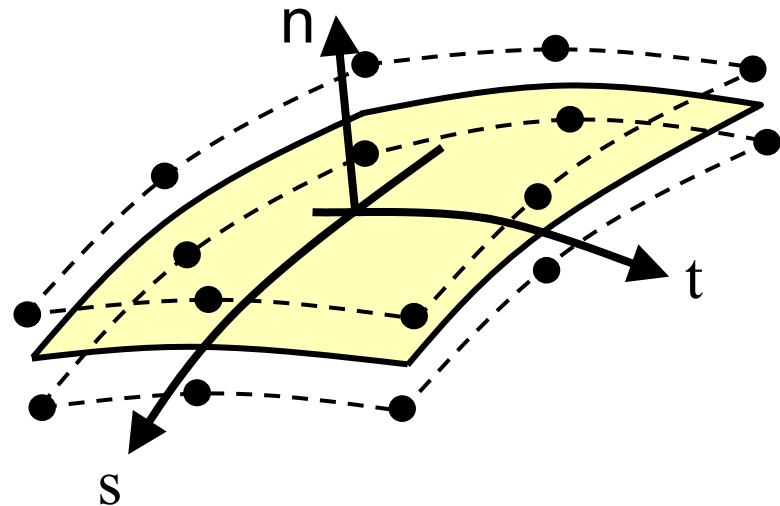
$$\mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$



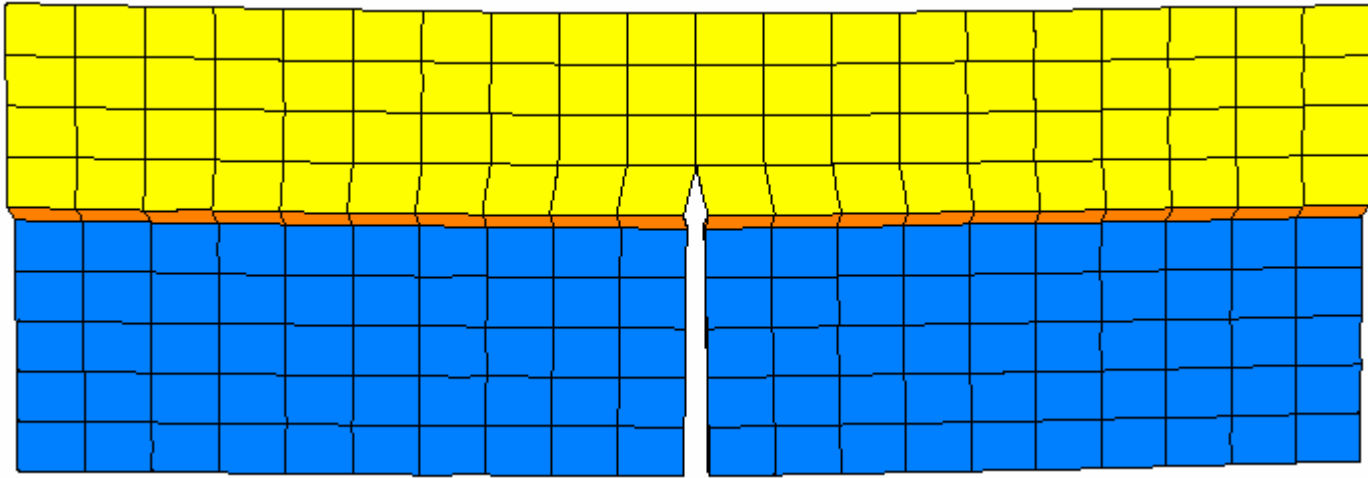
- Interface systems
 - soft inplane stiffness



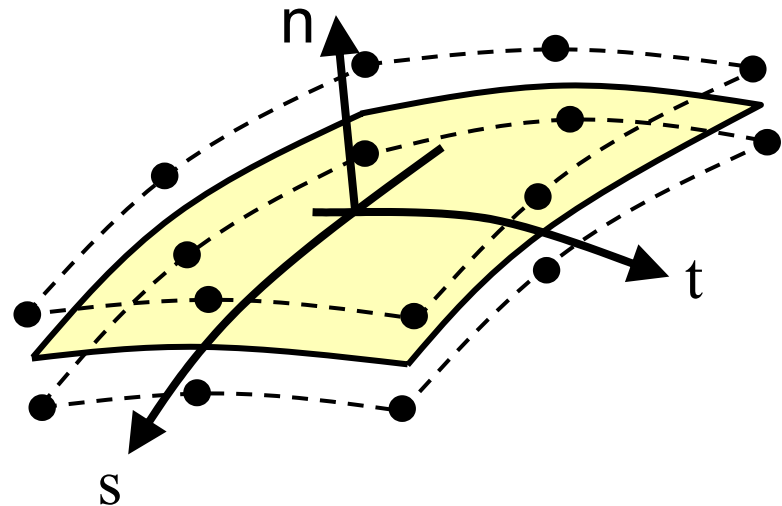
$$\mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$



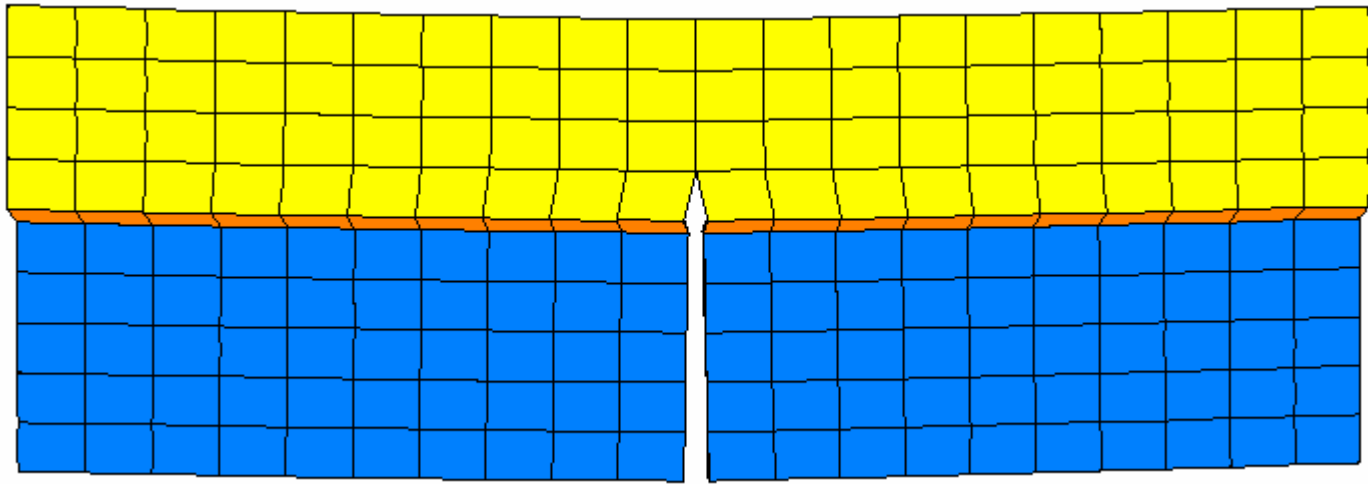
- Interface systems
 - soft inplane stiffness



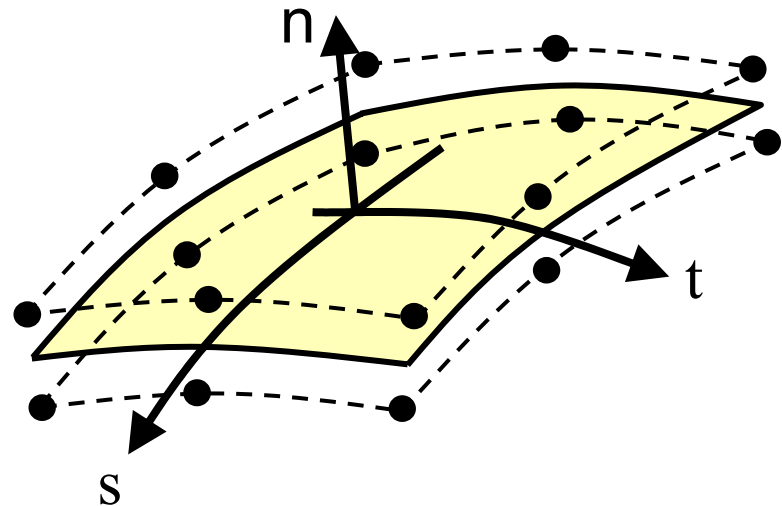
$$\mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$



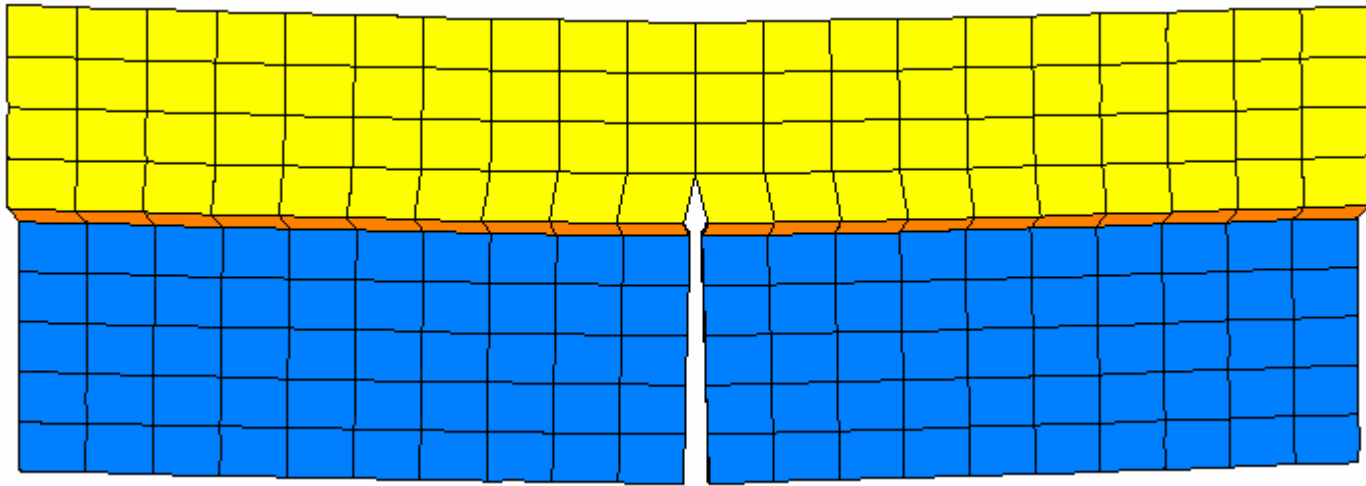
- Interface systems
 - soft inplane stiffness



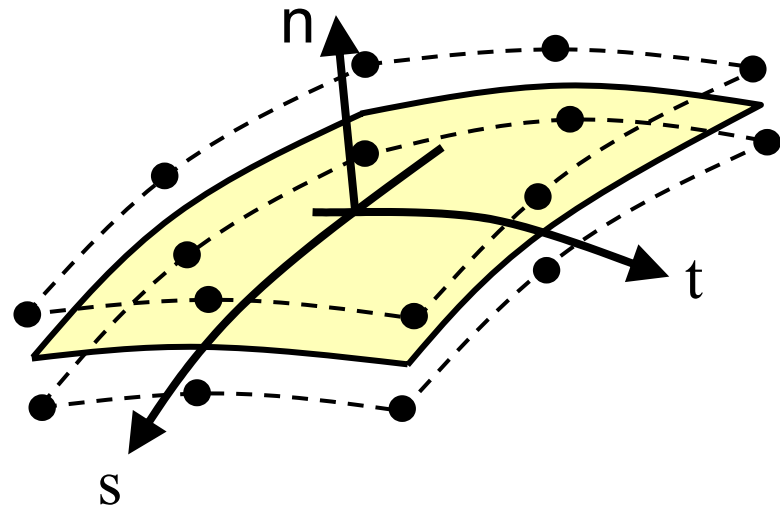
$$\mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$



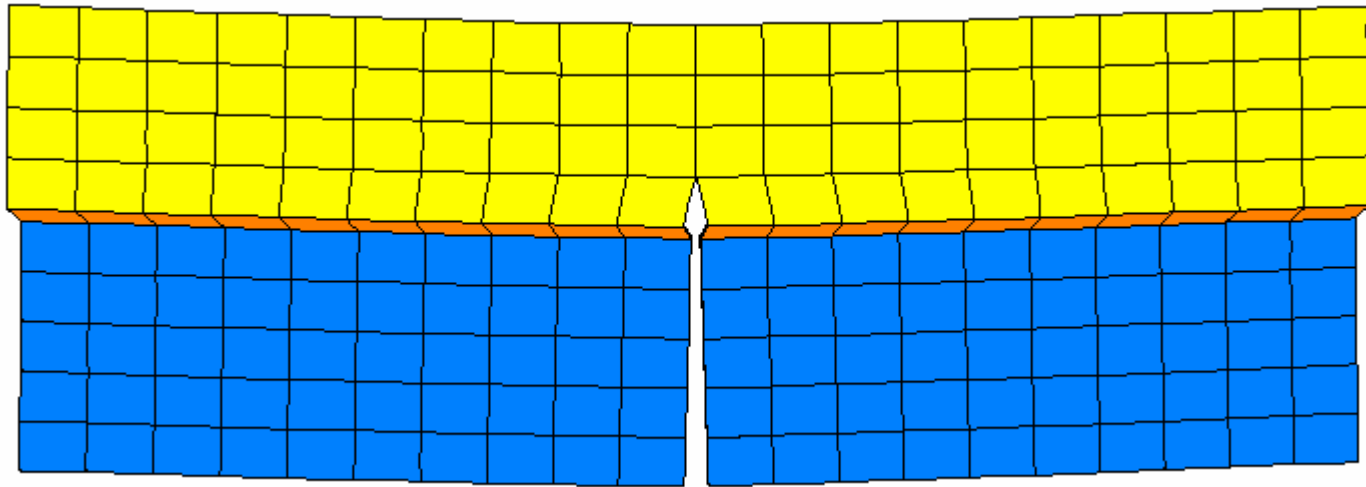
- Interface systems
 - soft inplane stiffness



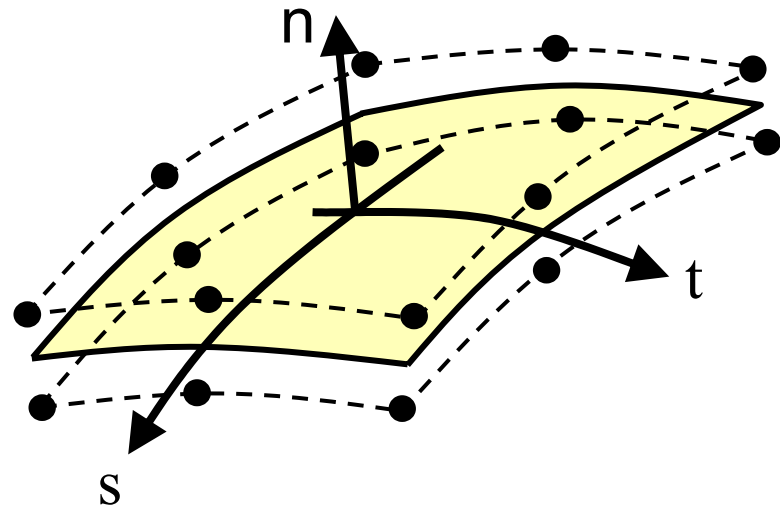
$$\mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$



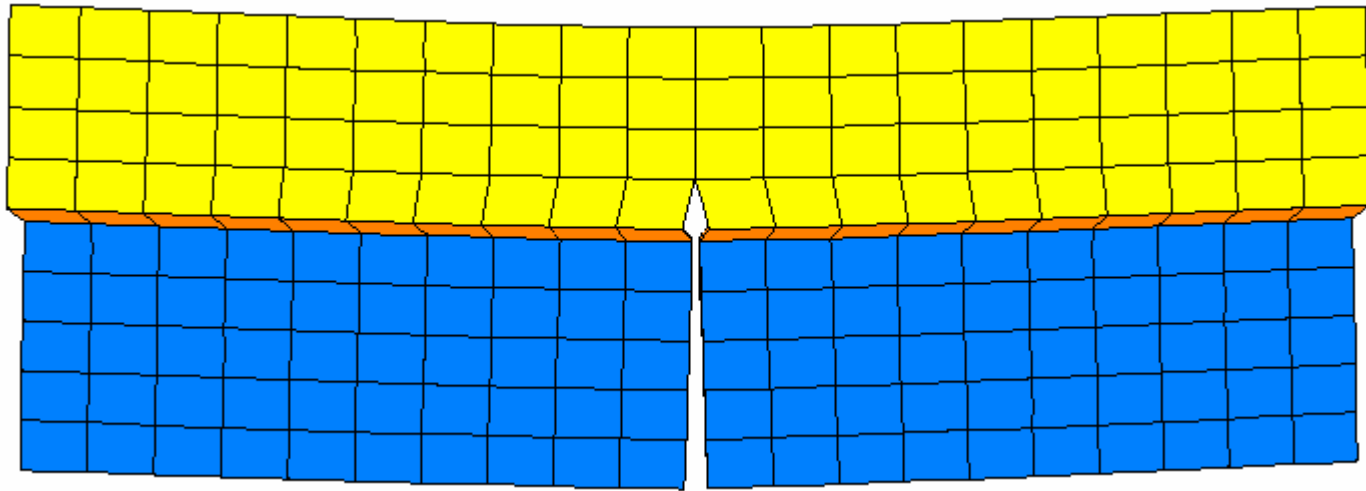
- Interface systems
 - soft inplane stiffness



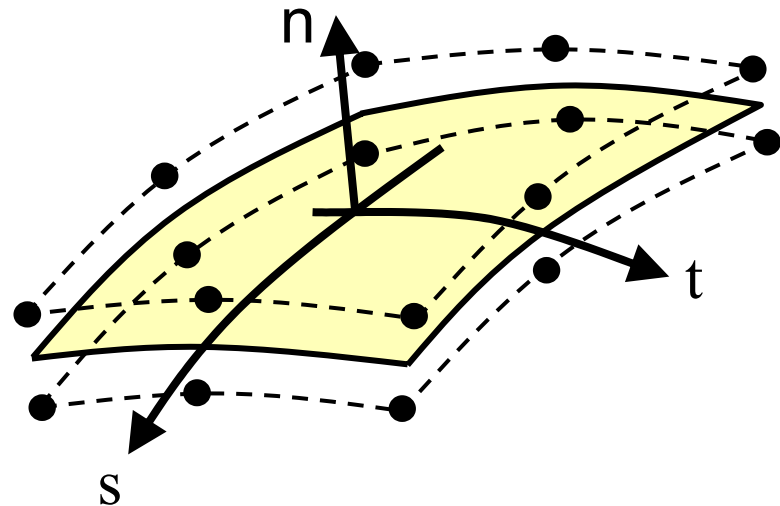
$$\mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$



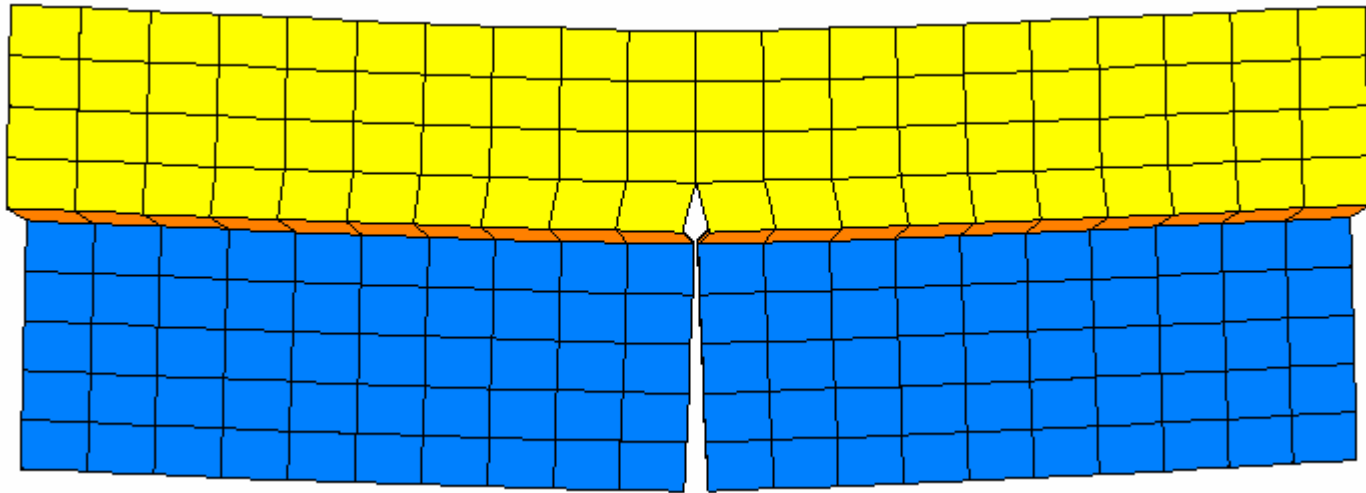
- Interface systems
 - soft inplane stiffness



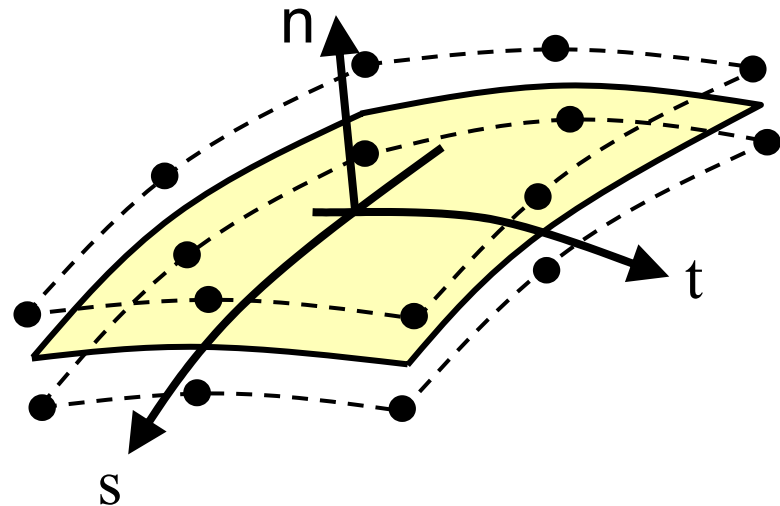
$$\mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$



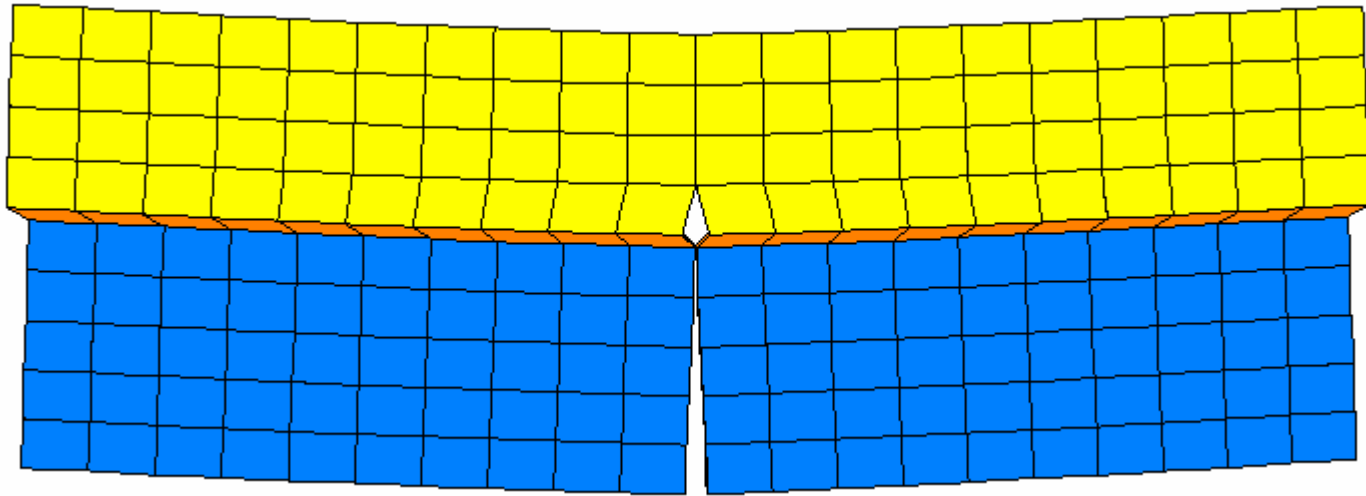
- Interface systems
 - soft inplane stiffness



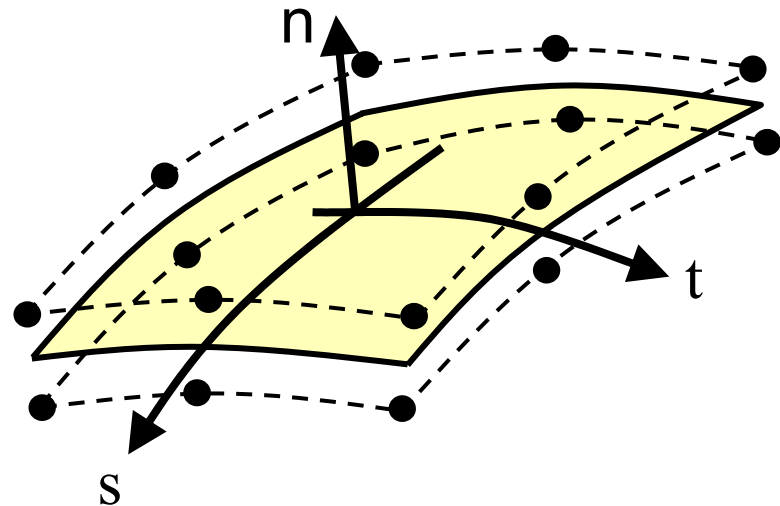
$$\mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$



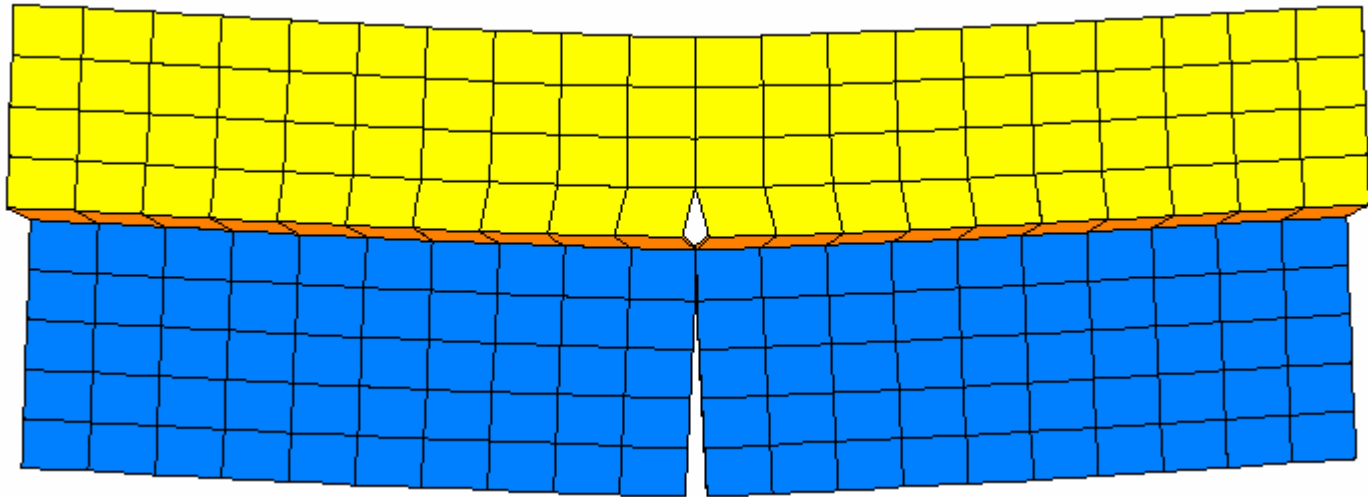
- Interface systems
 - soft inplane stiffness



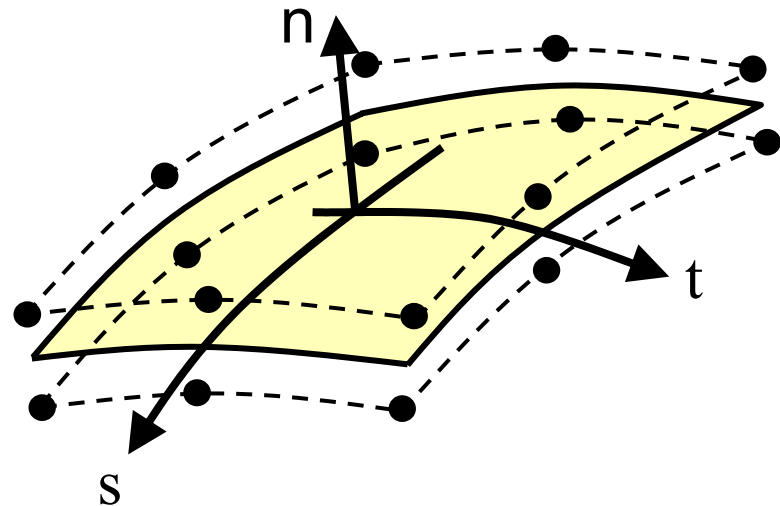
$$\mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$



- Interface systems
 - soft inplane stiffness

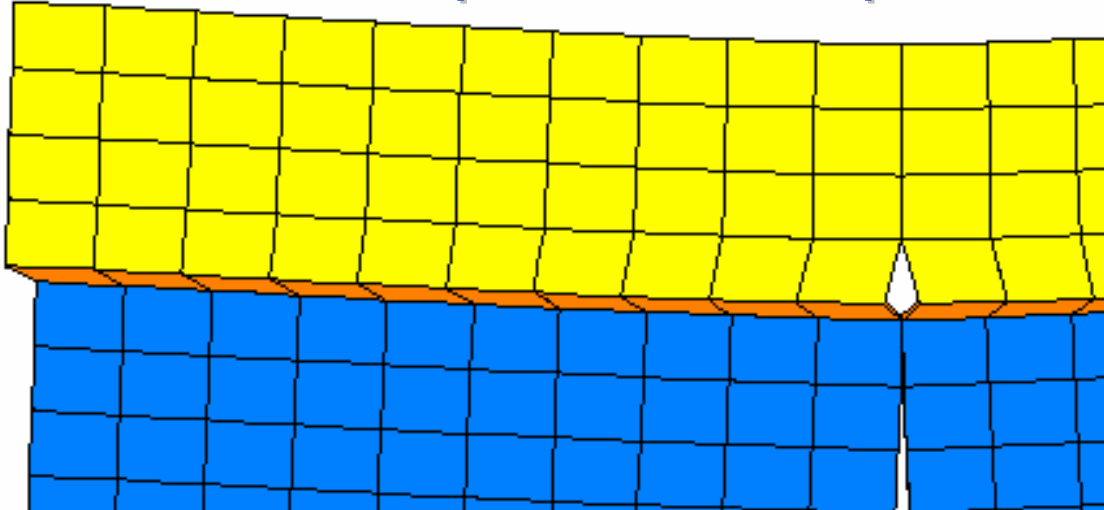


$$\mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$

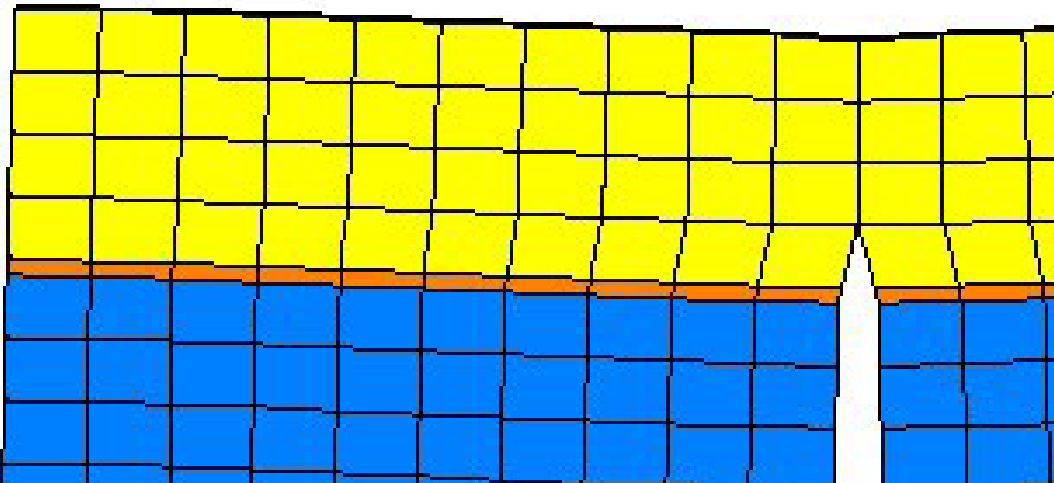


- Interface systems

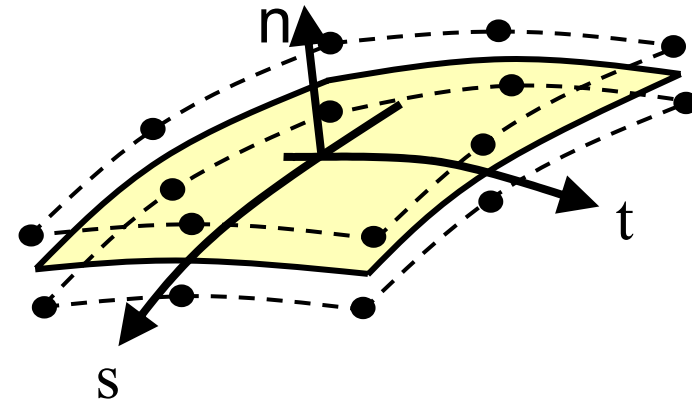
- comparison of inplane stiffness influence



- soft inplane stiffness

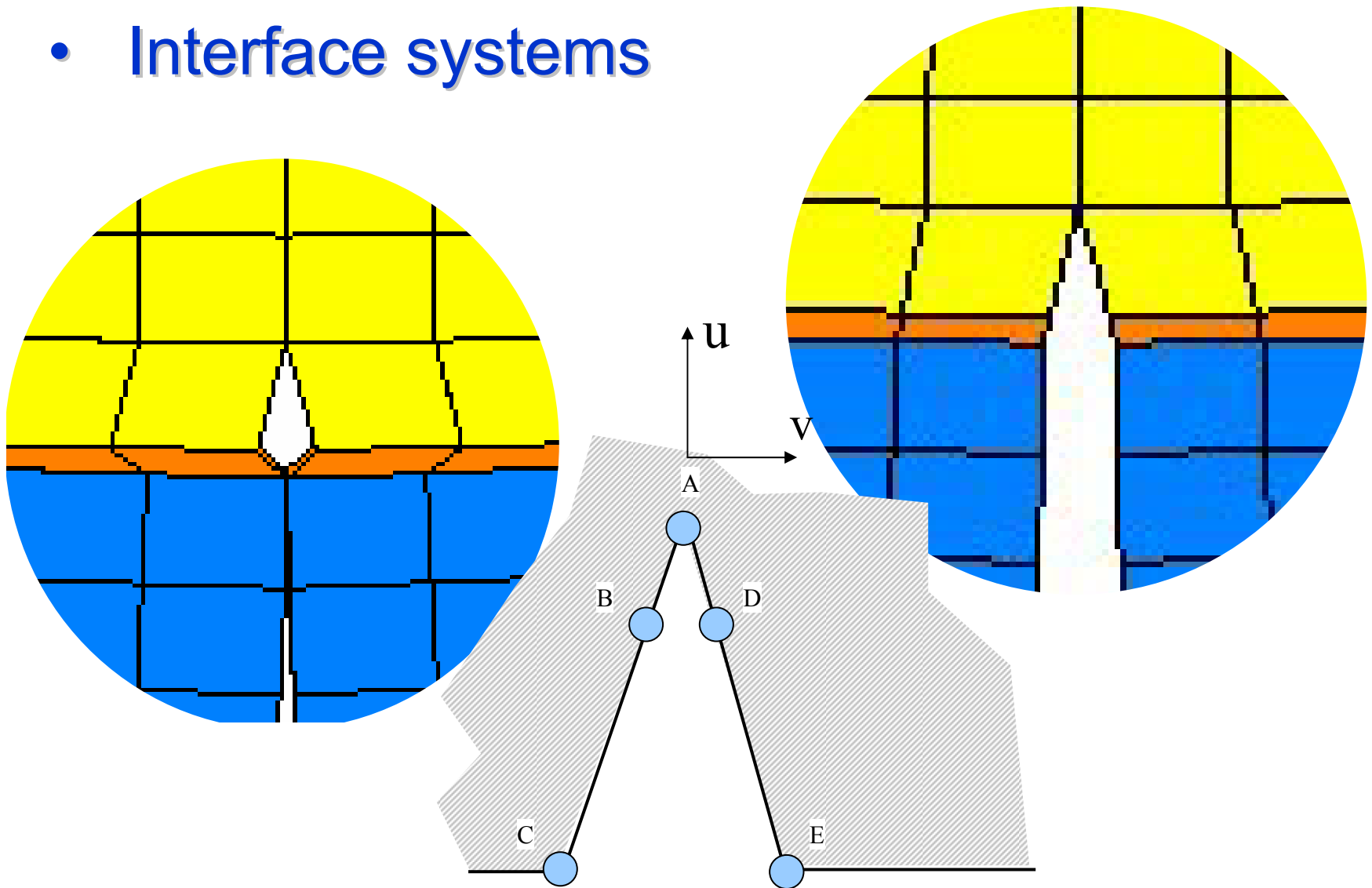


- stiff inplane stiffness



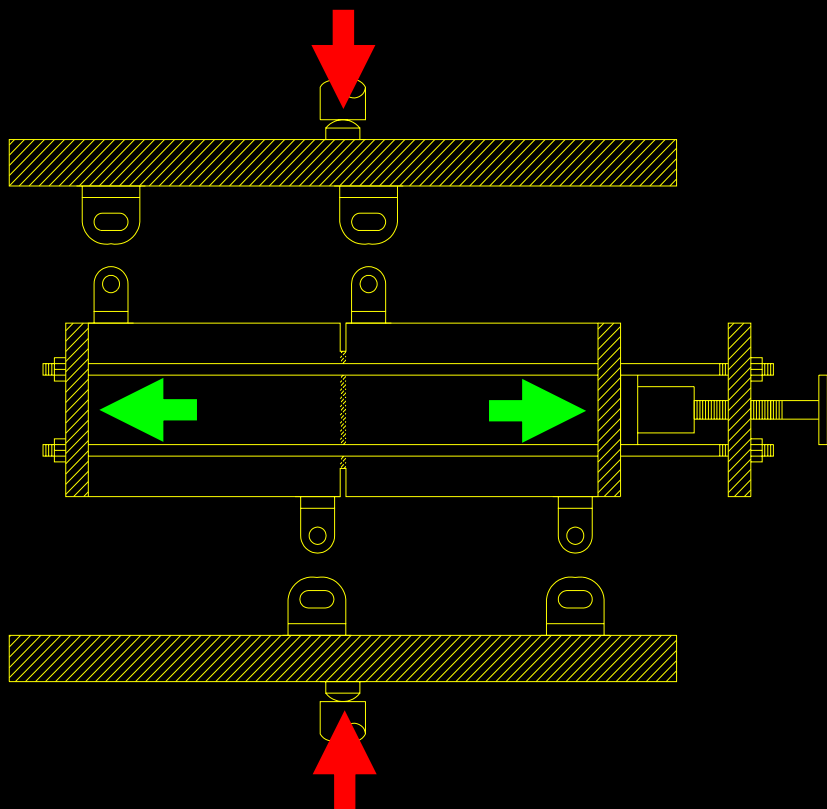
$$\mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$

- Interface systems

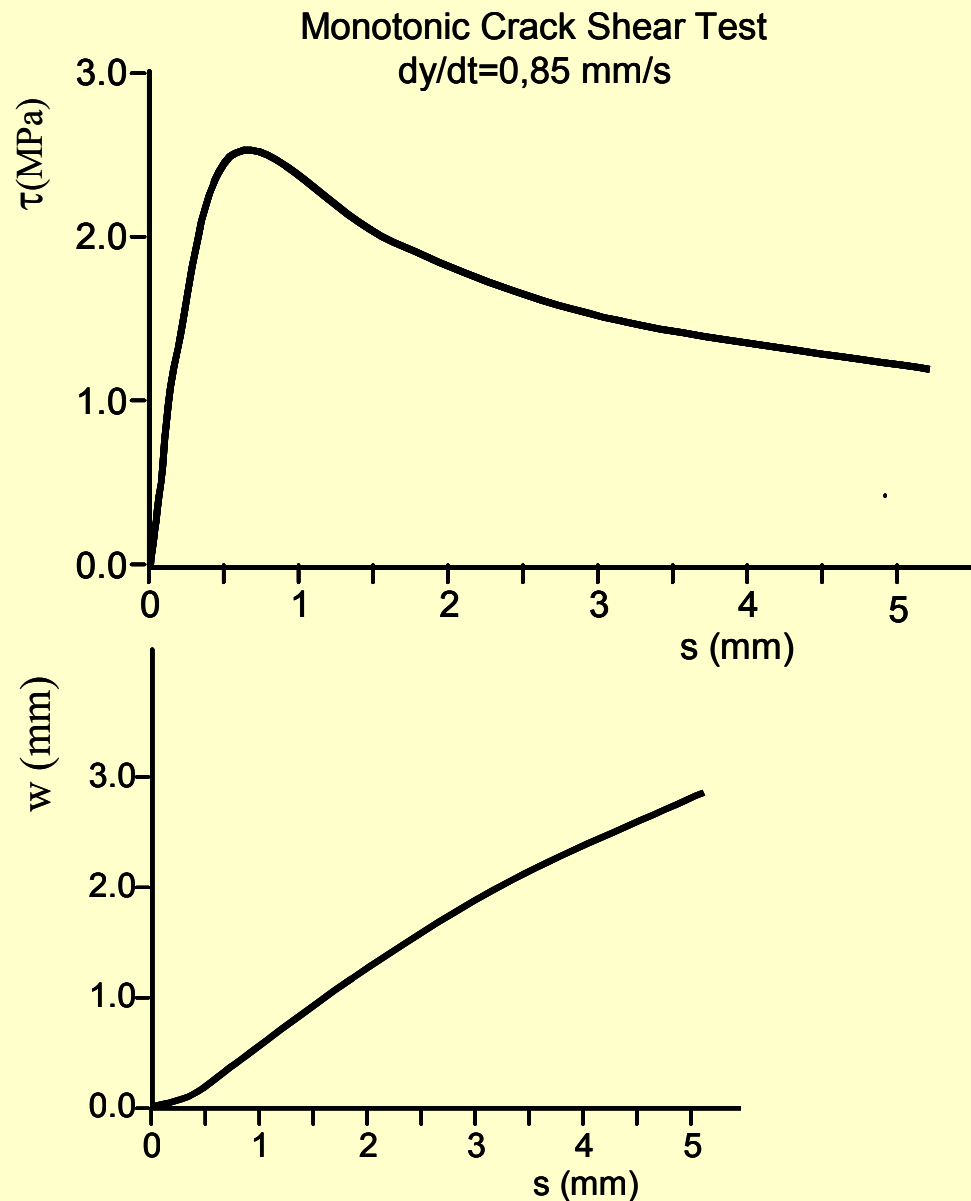


$$K_I = \frac{G}{k+1} \sqrt{\frac{2\pi}{L}} \left(4(v_B - v_D) + (v_E - v_C) \right)$$

Interlayer systems: normal component

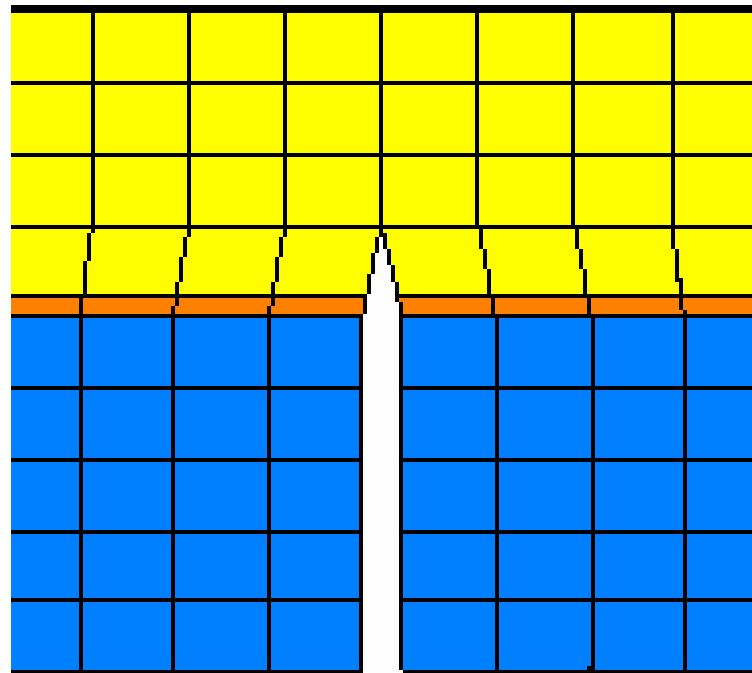
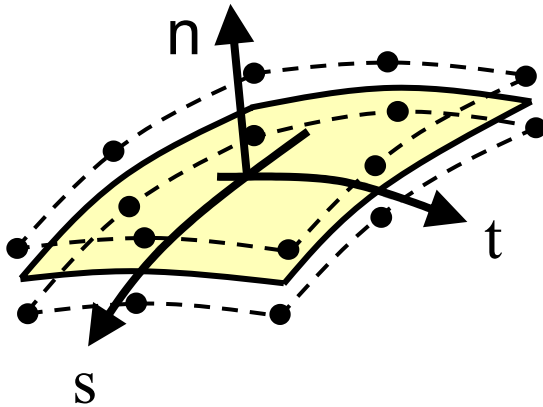


$$\mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$



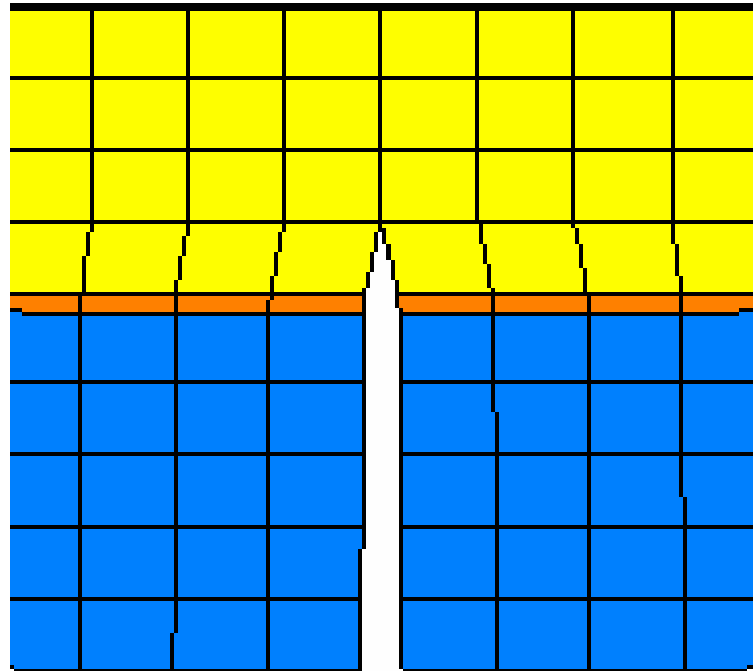
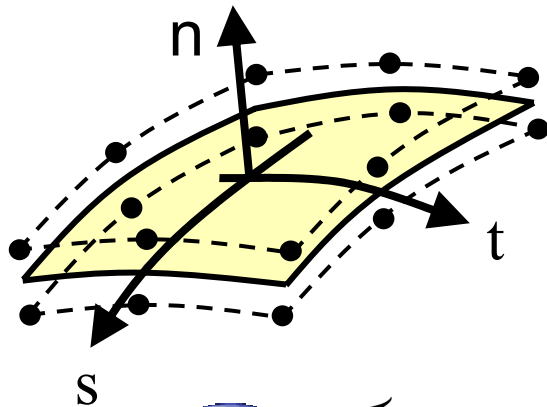
- Interface systems
 - influence of soft normal stiffness

$$\mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$



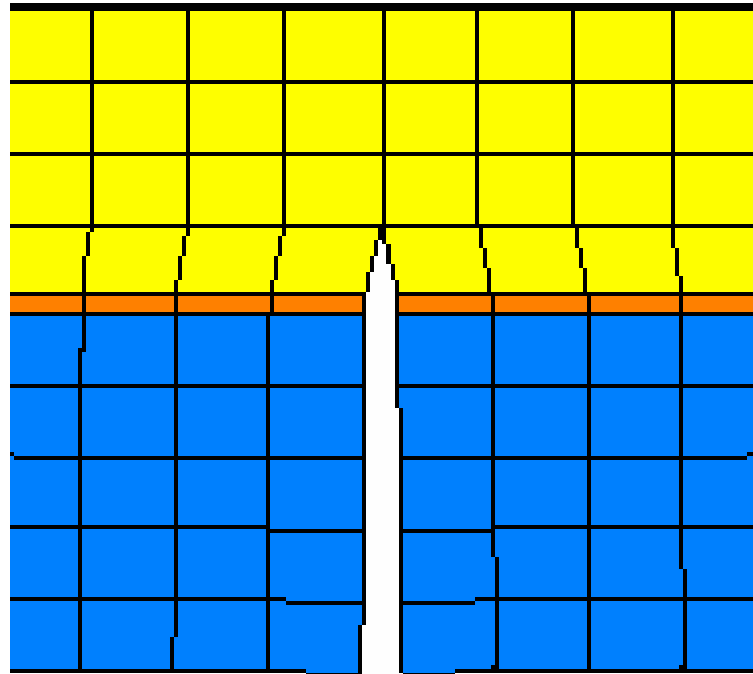
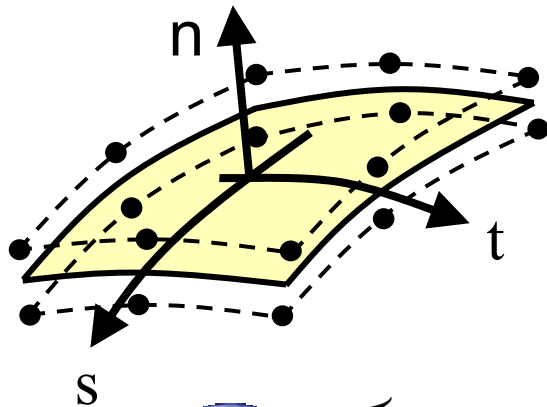
- Interface systems
 - soft normal stiffness

$$\mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$



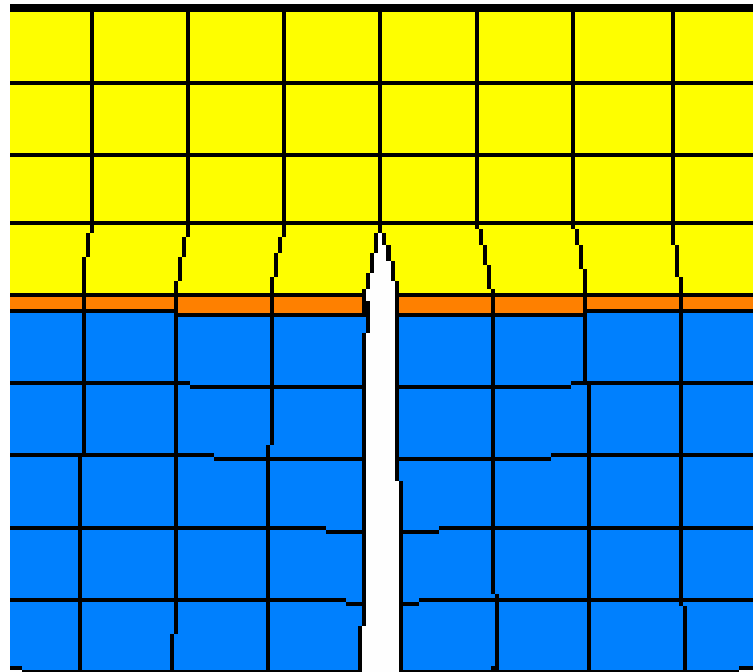
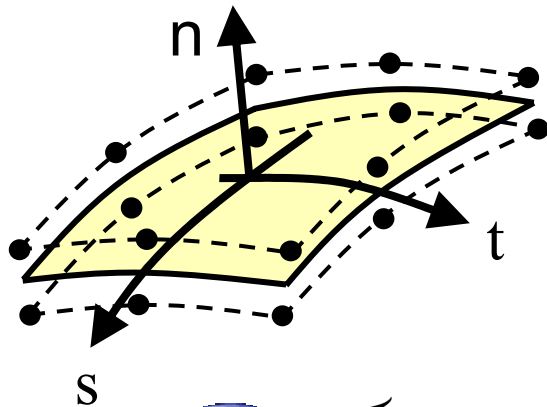
- Interface systems
 - soft normal stiffness

$$\mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$



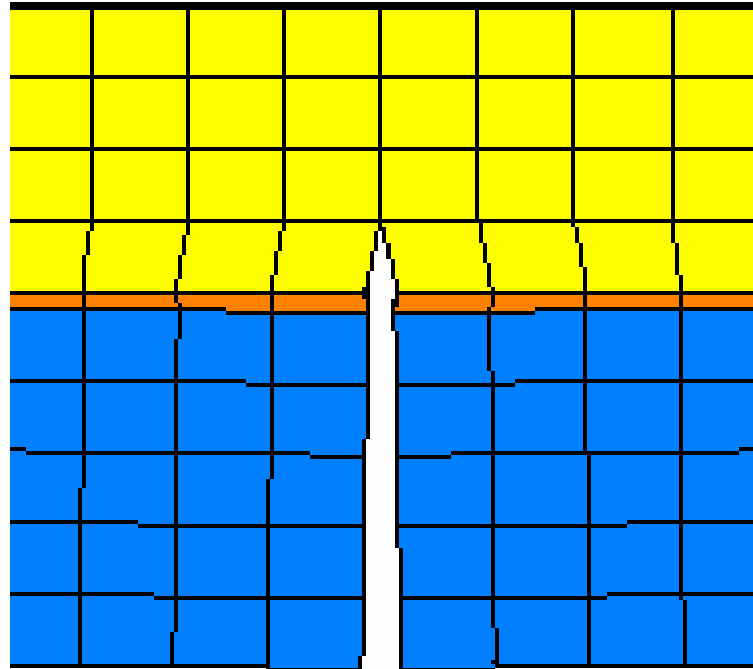
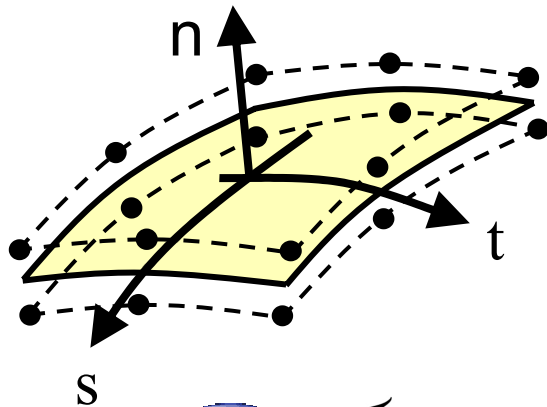
- Interface systems
 - soft normal stiffness

$$\mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$



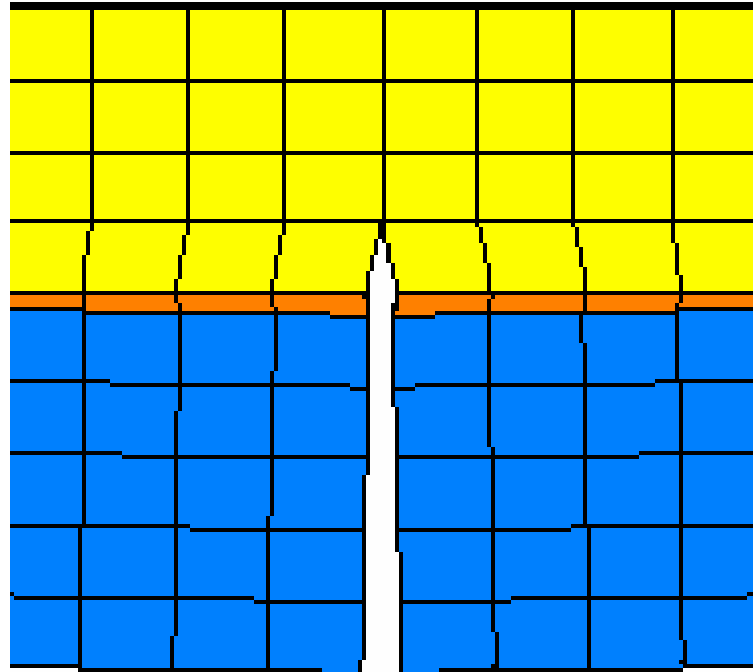
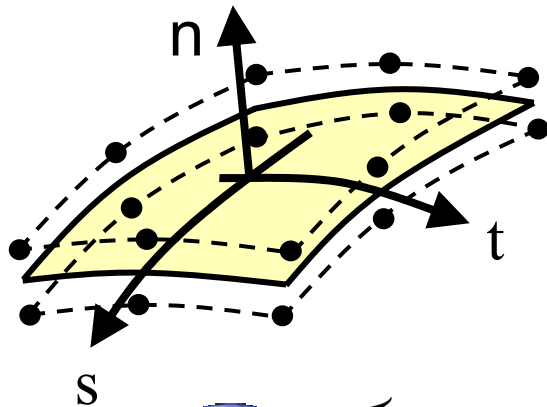
- Interface systems
 - soft normal stiffness

$$\mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$



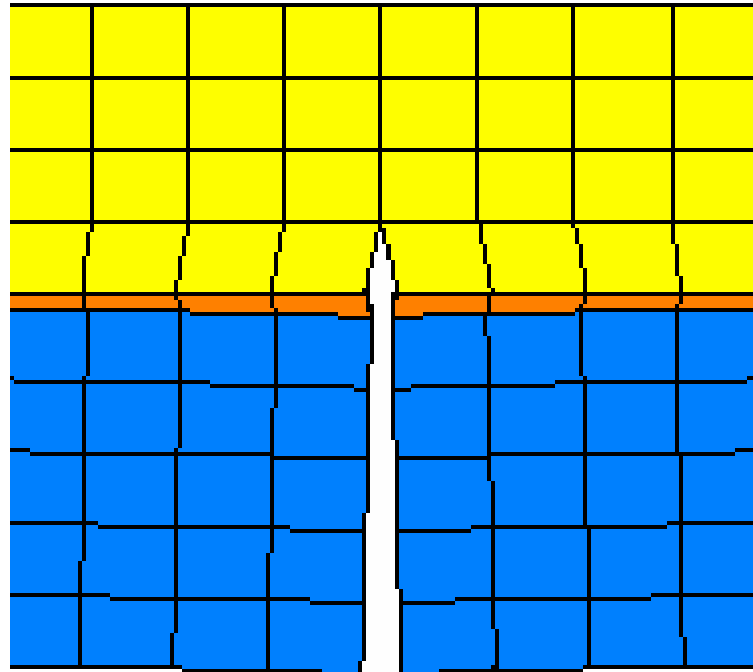
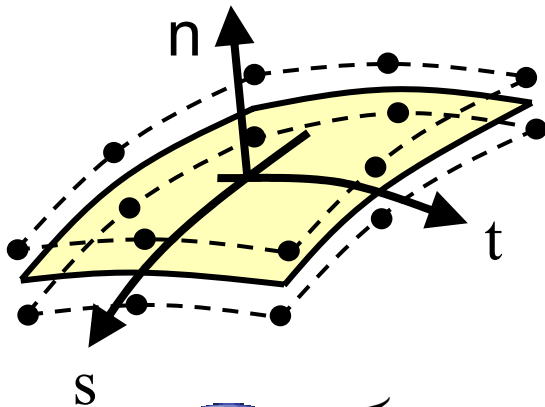
- Interface systems
 - soft normal stiffness

$$\mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$



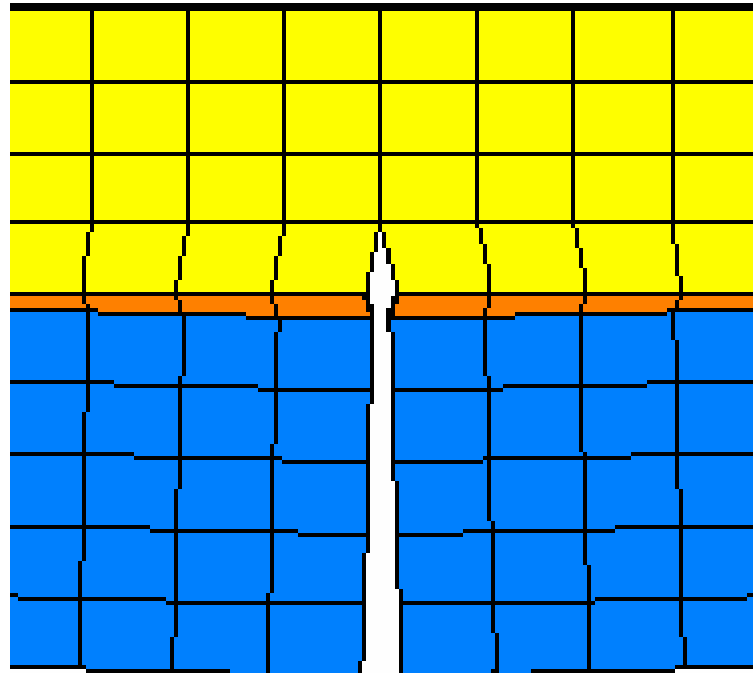
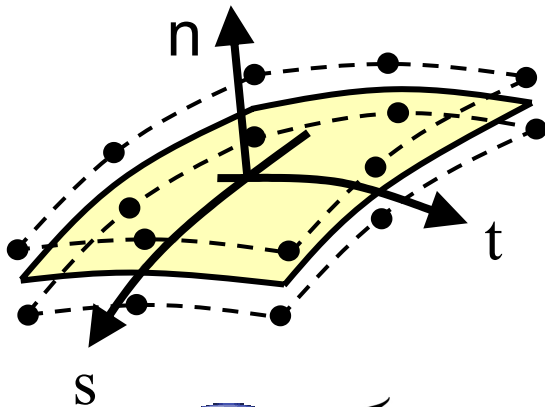
- Interface systems
 - soft normal stiffness

$$\mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$



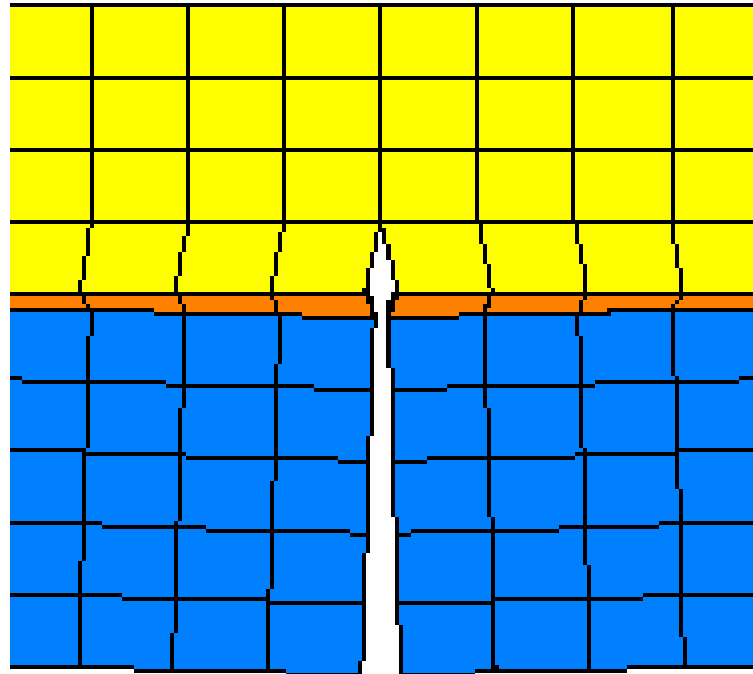
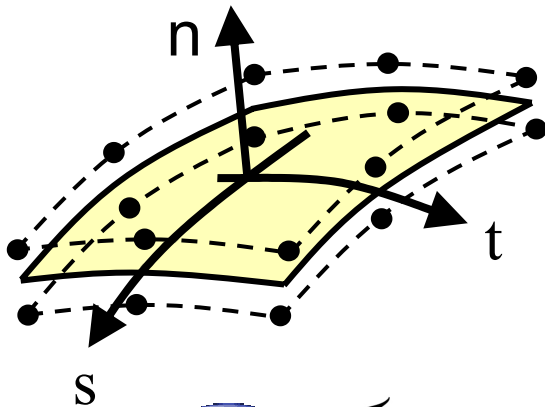
- Interface systems
 - soft normal stiffness

$$\mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$



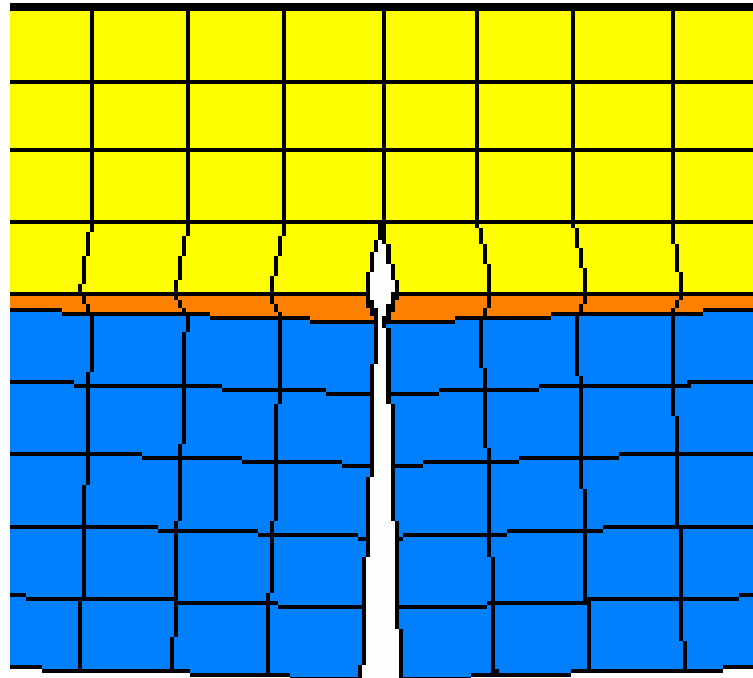
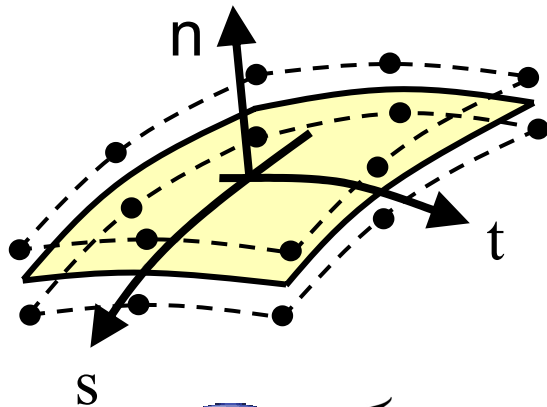
- Interface systems
 - soft normal stiffness

$$\mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$



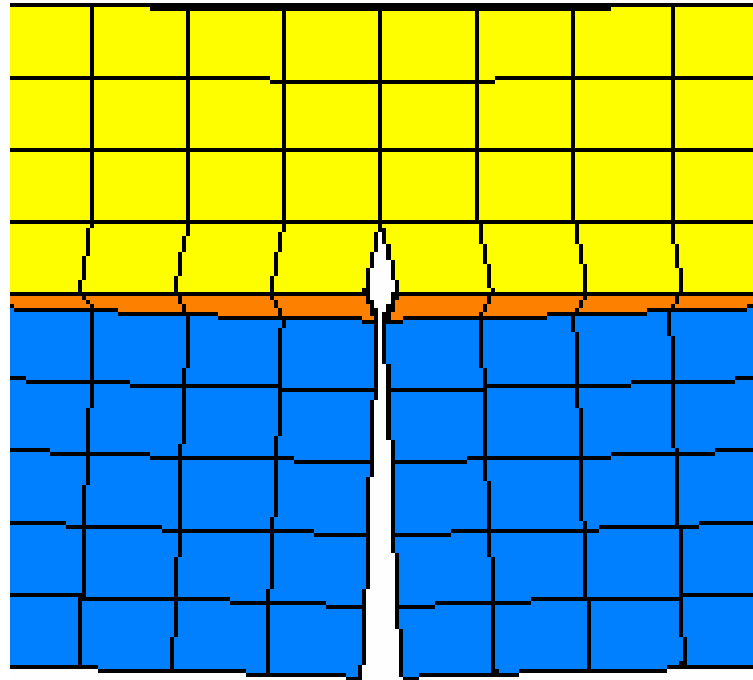
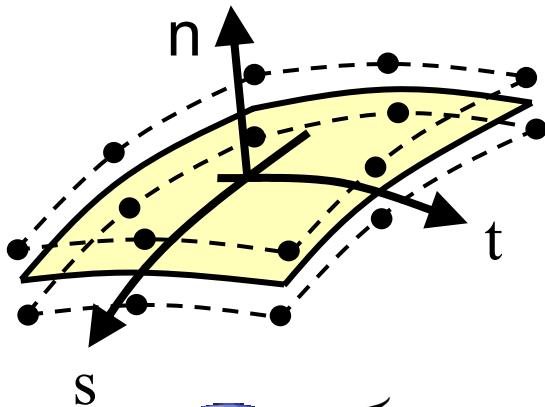
- Interface systems
 - soft normal stiffness

$$\mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$



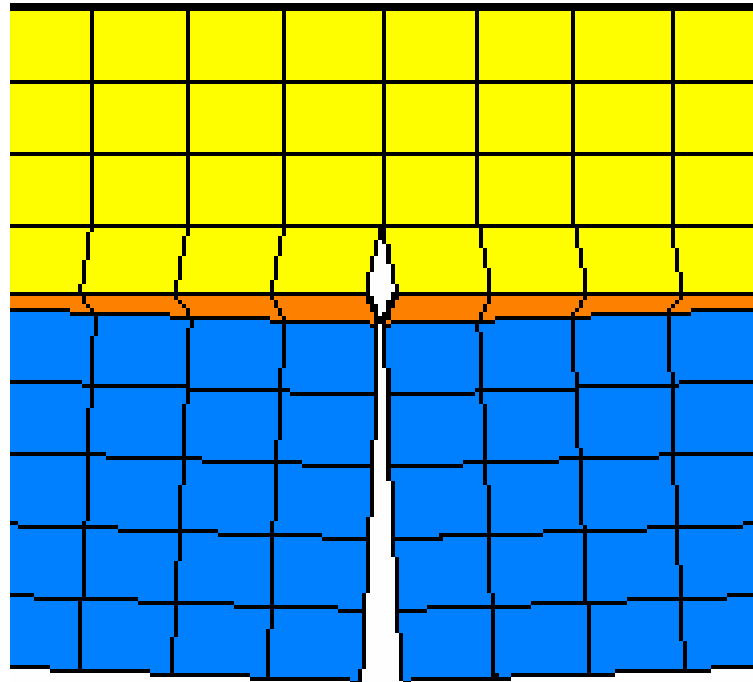
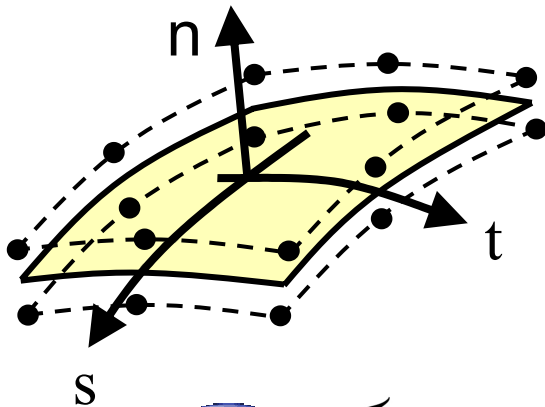
- Interface systems
 - soft normal stiffness

$$\mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$



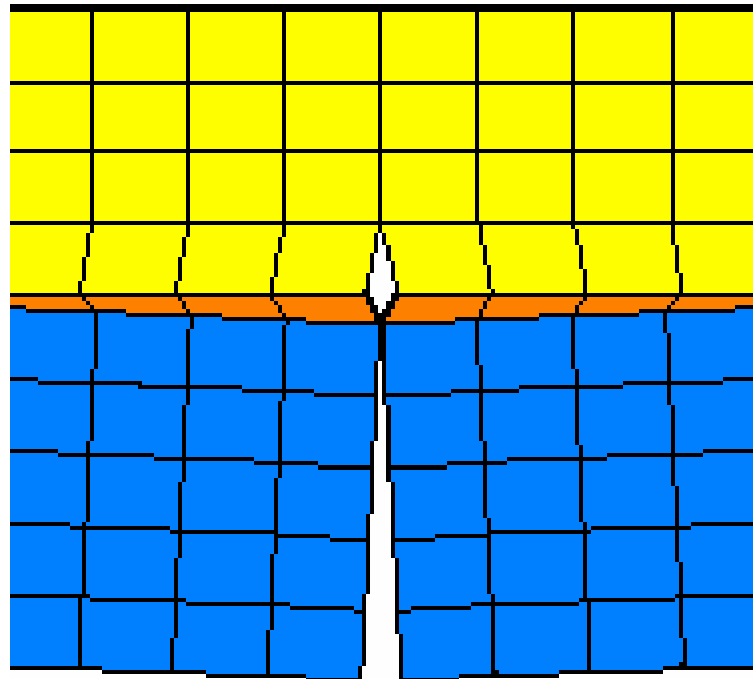
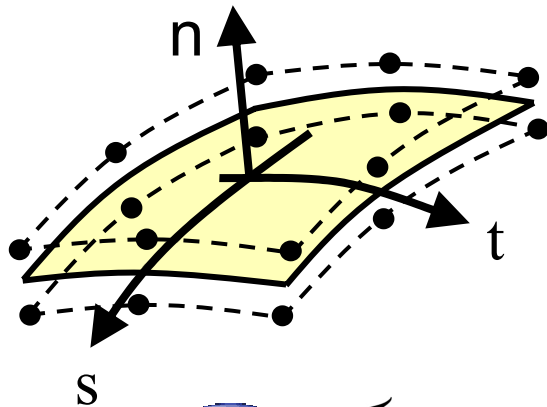
- Interface systems
 - soft normal stiffness

$$\mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$



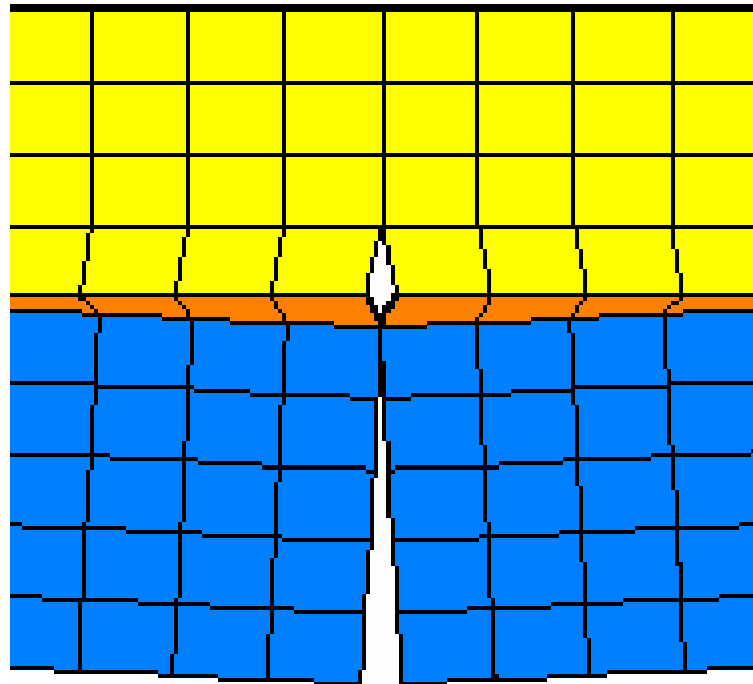
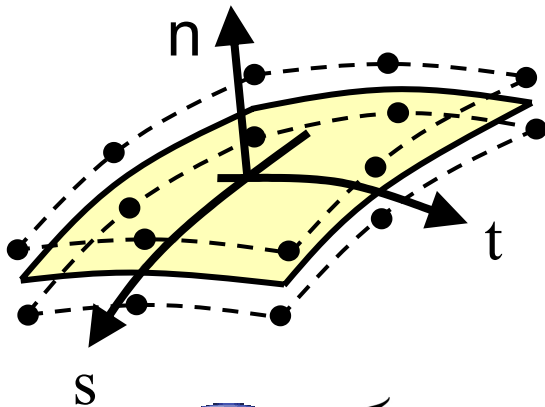
- Interface systems
 - soft normal stiffness

$$\mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$



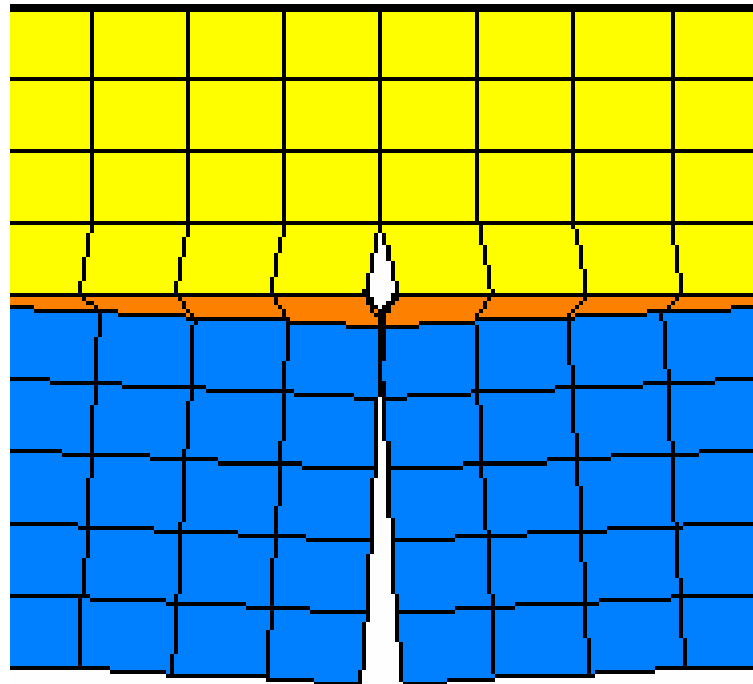
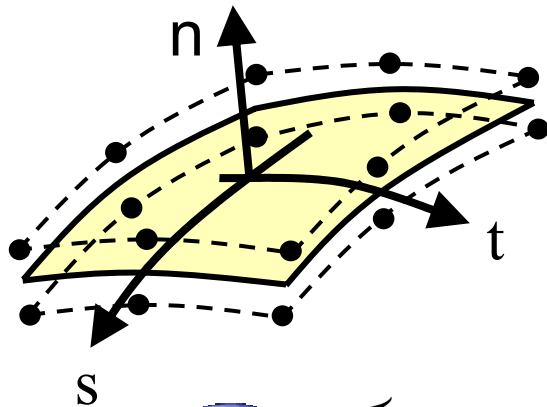
- Interface systems
 - soft normal stiffness

$$\mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$



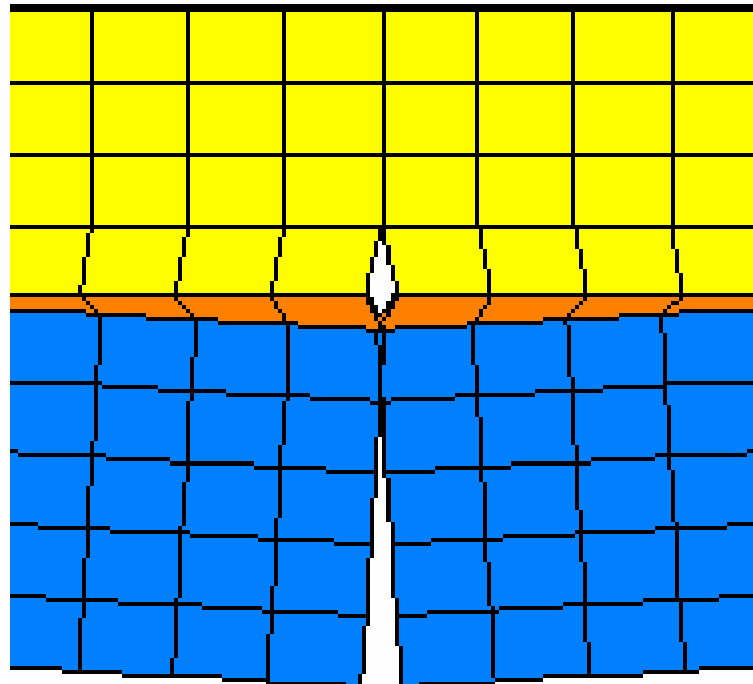
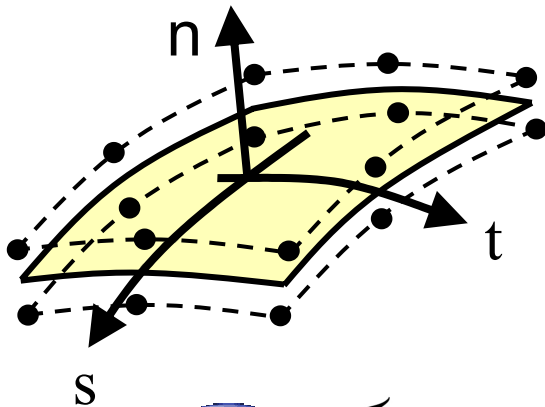
- Interface systems
 - soft normal stiffness

$$\mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$



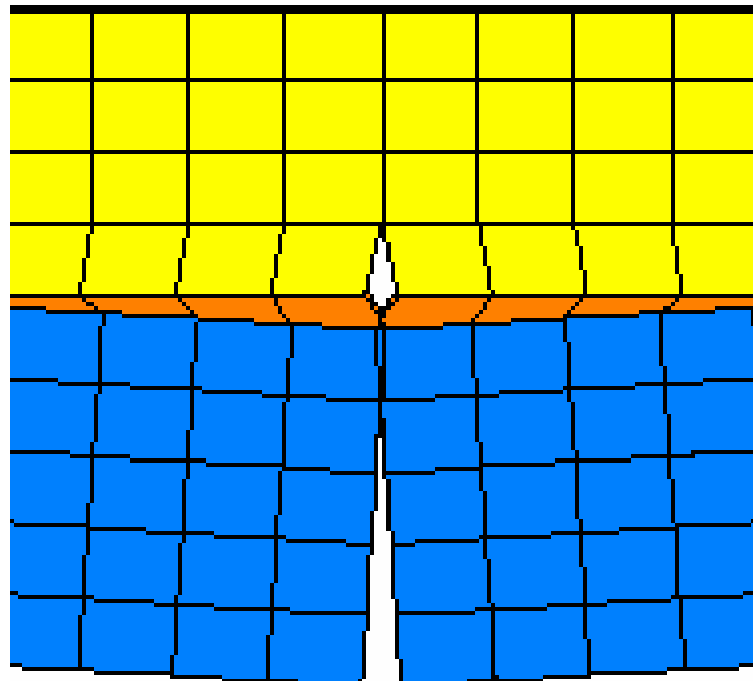
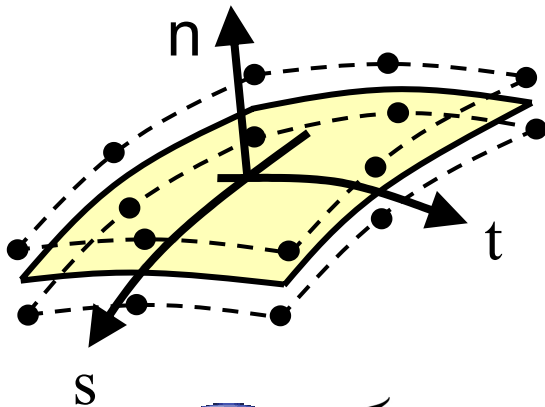
- Interface systems
 - soft normal stiffness

$$\mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$



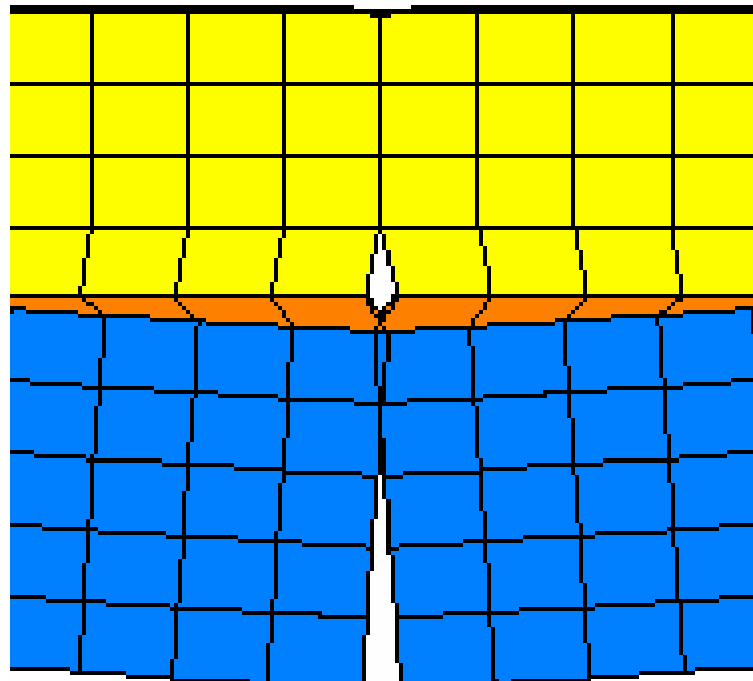
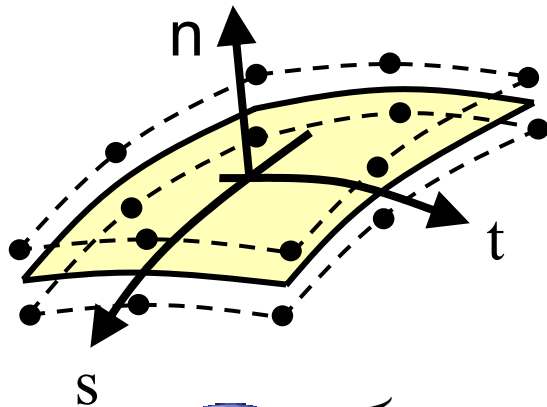
- Interface systems
 - soft normal stiffness

$$\mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$



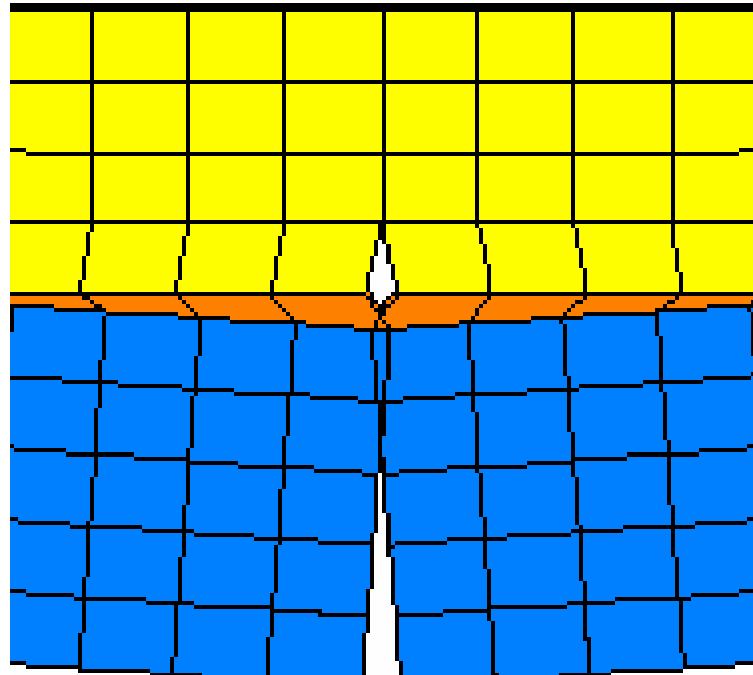
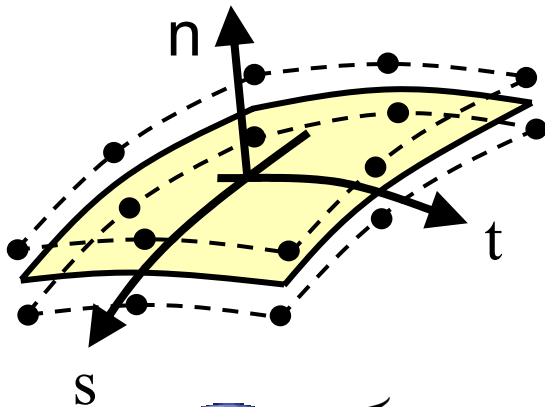
- Interface systems
 - soft normal stiffness

$$\mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$



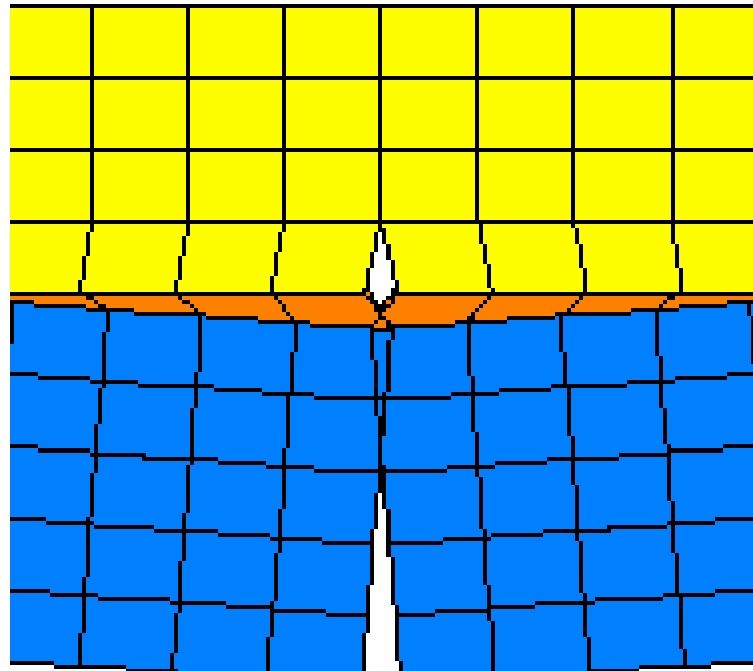
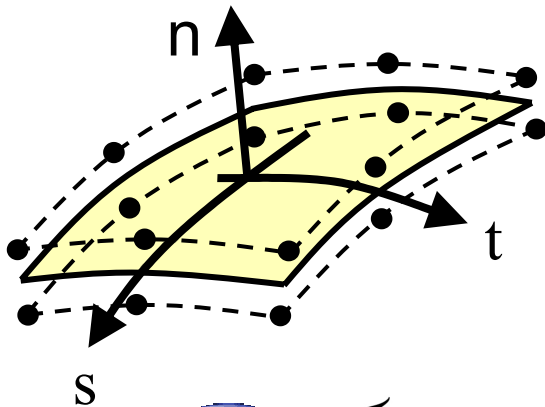
- Interface systems
 - soft normal stiffness

$$\mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$



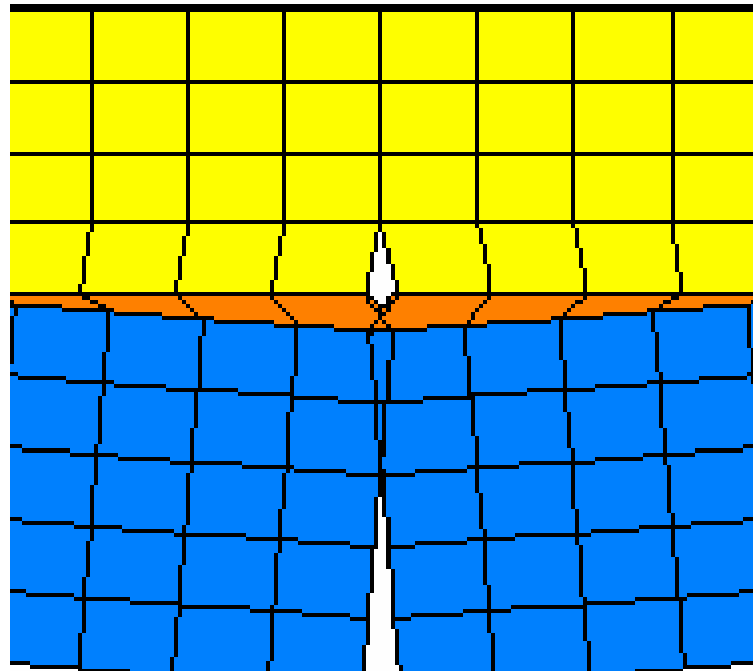
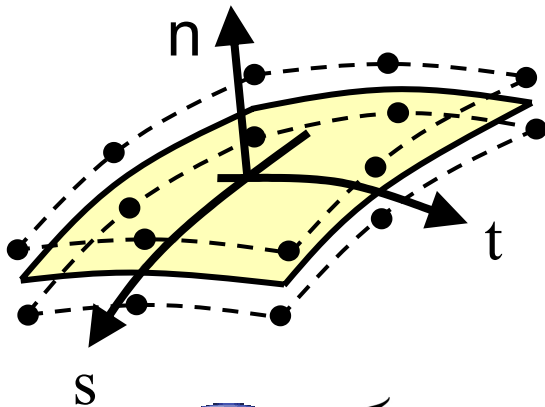
- Interface systems
 - soft normal stiffness

$$\mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$

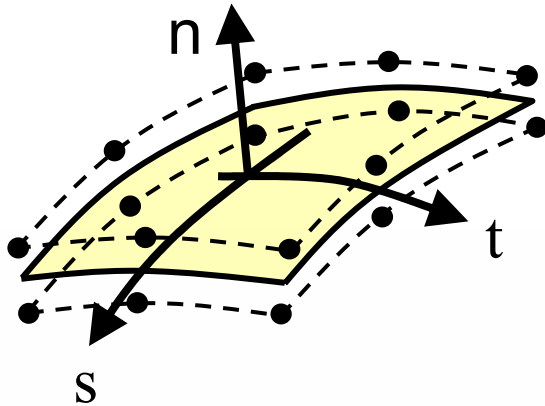


- Interface systems
 - soft normal stiffness

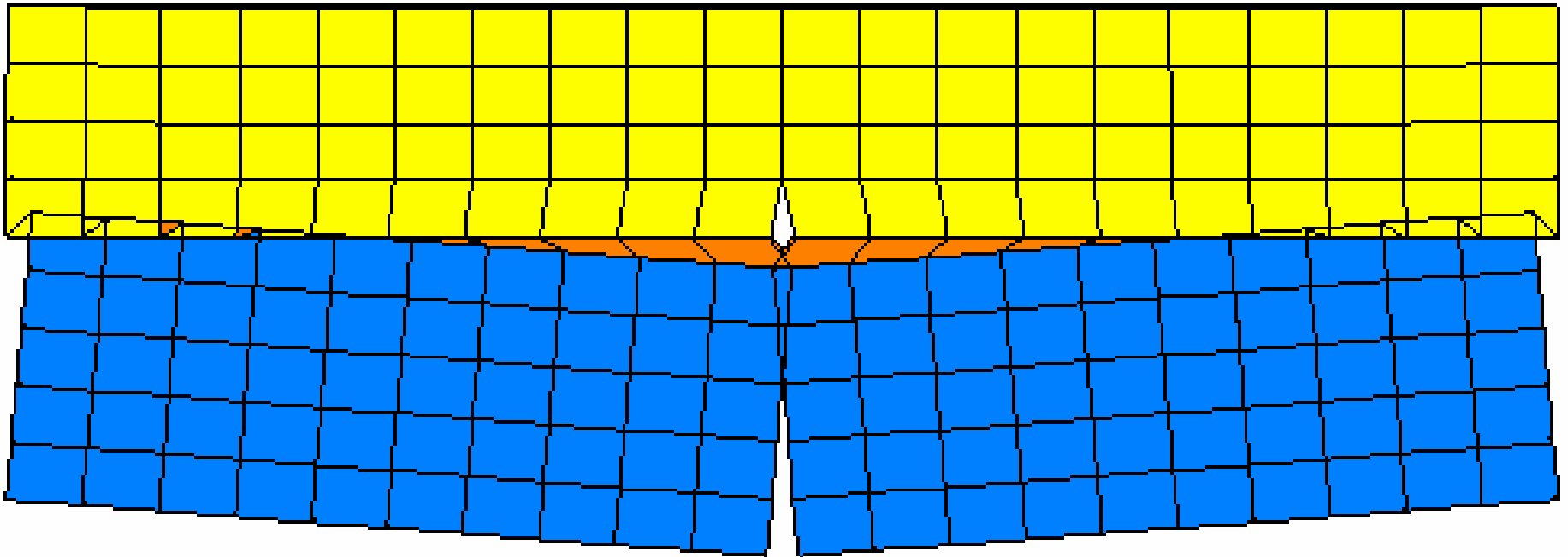
$$\mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$



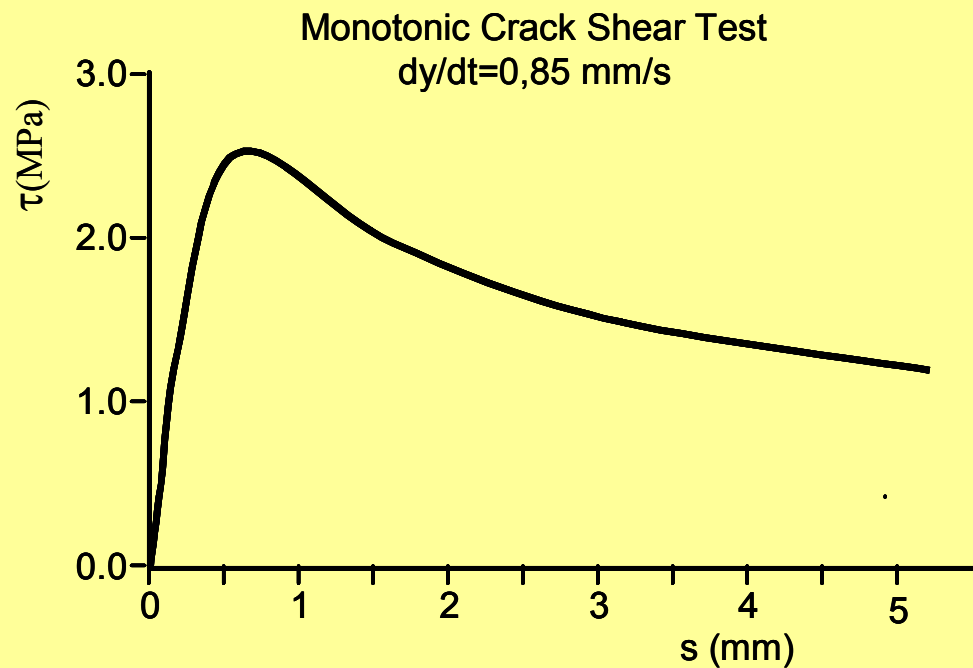
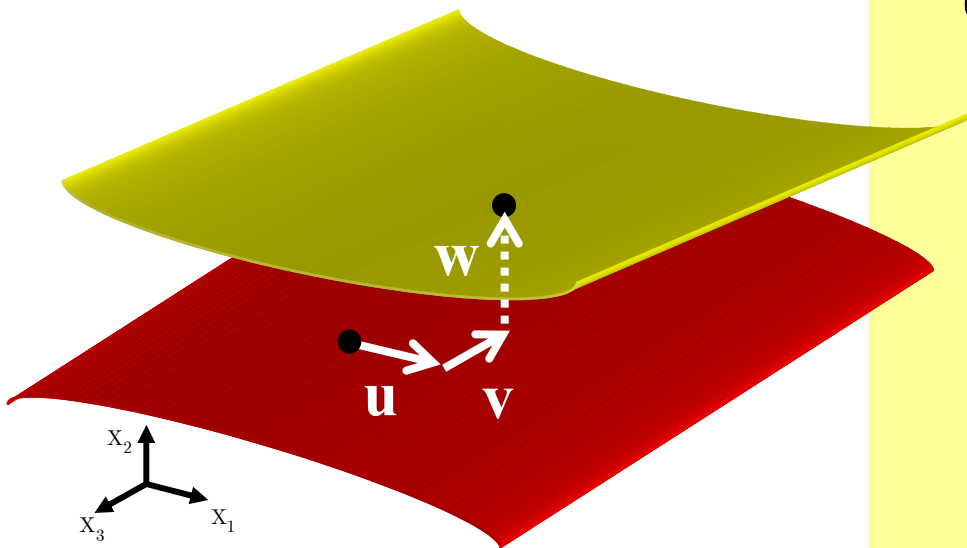
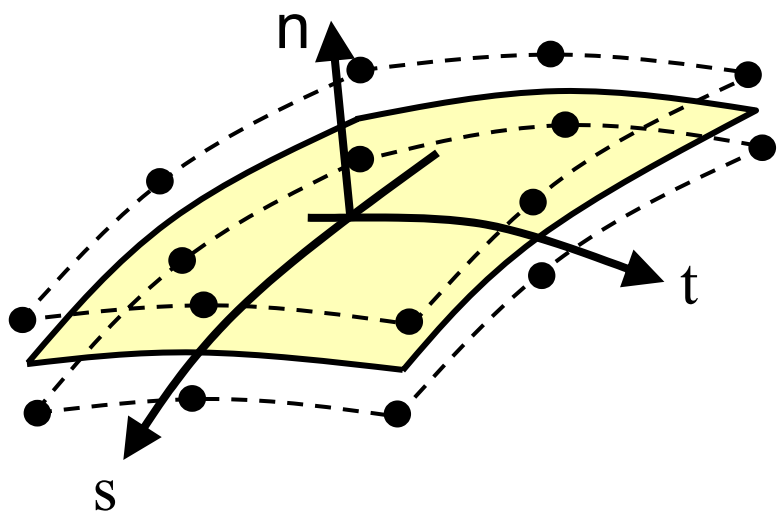
- Interface systems
 - soft normal stiffness



$$\mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$



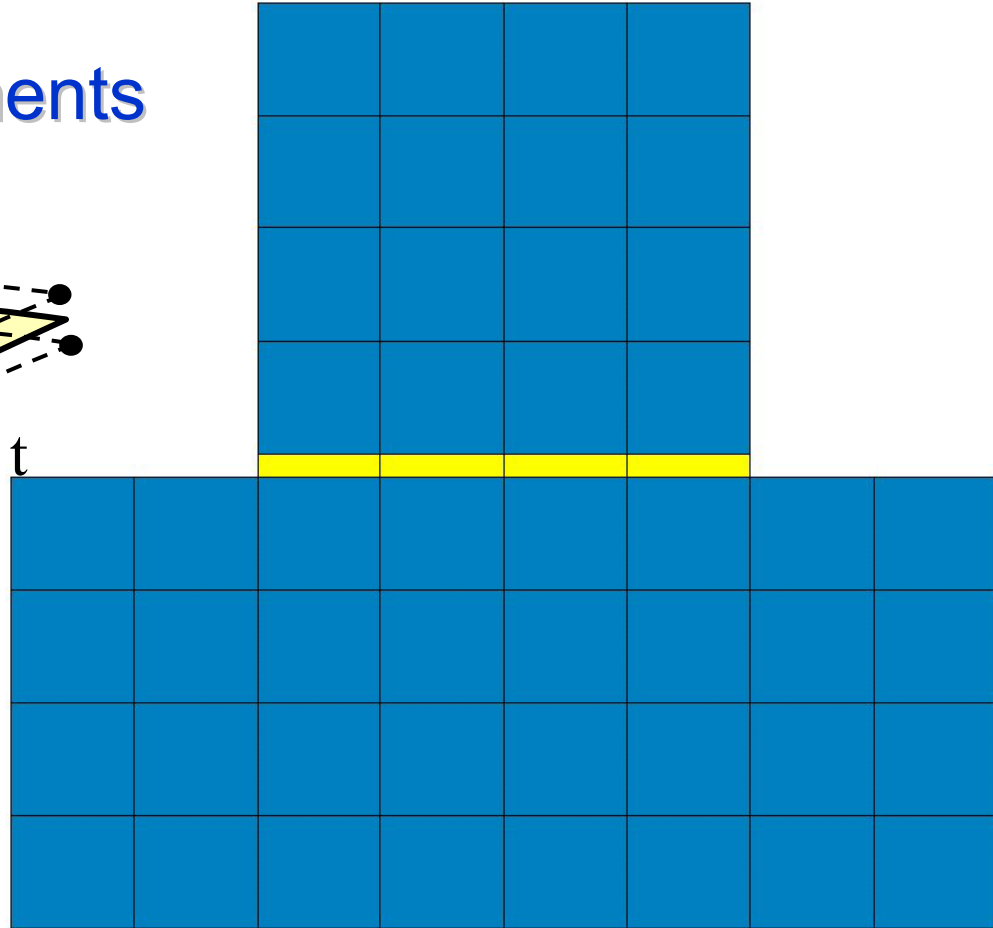
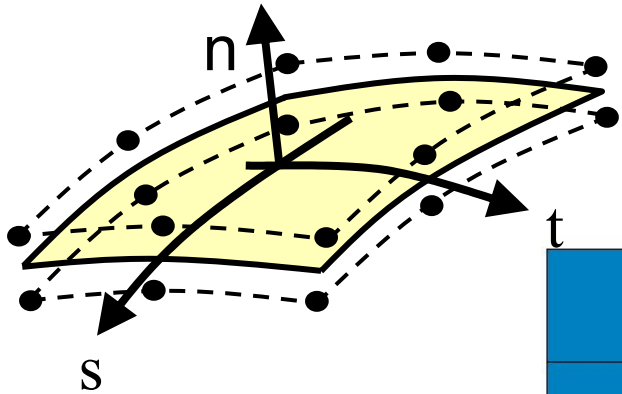
Interlayer systems: contact elements



$$w \geq 0 \quad \mathbf{D} = \begin{bmatrix} D_{nn} & 0 & 0 \\ 0 & D_{tt} & 0 \\ 0 & 0 & D_{ss} \end{bmatrix}$$

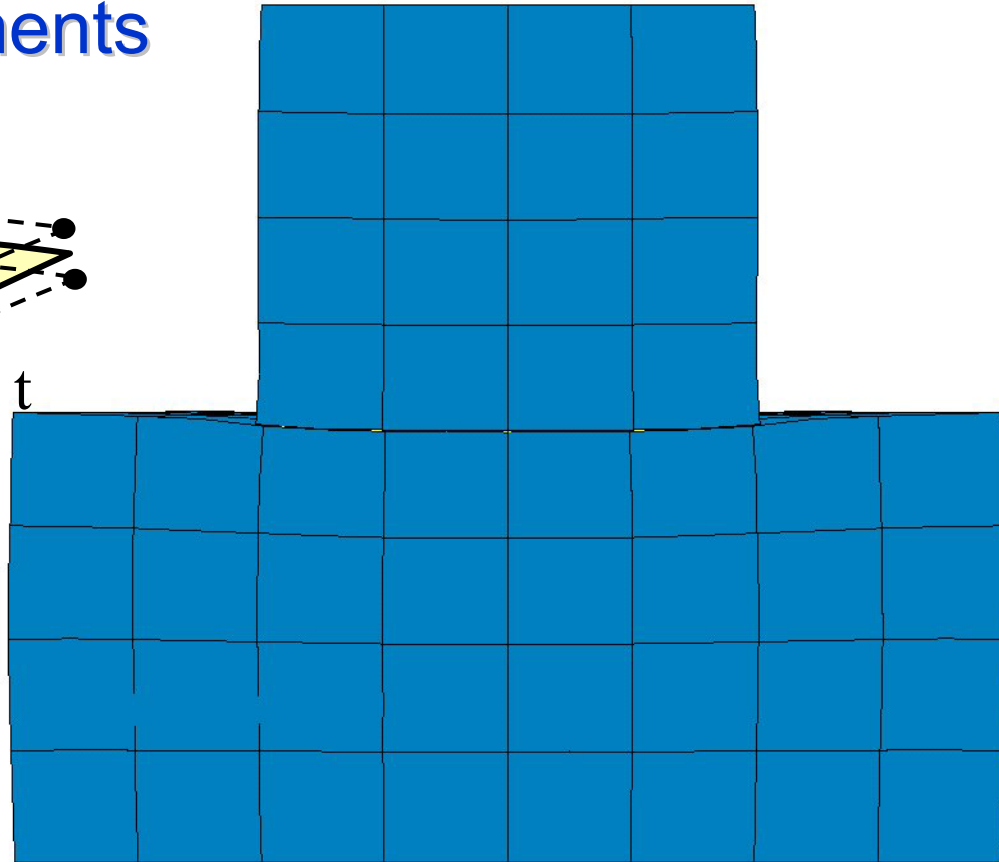
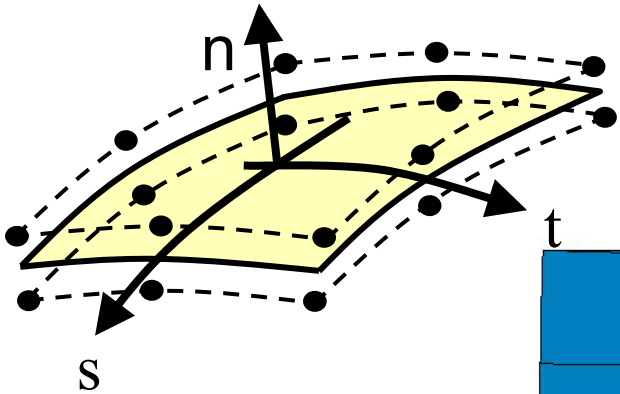
- Interlayer systems

- contact elements



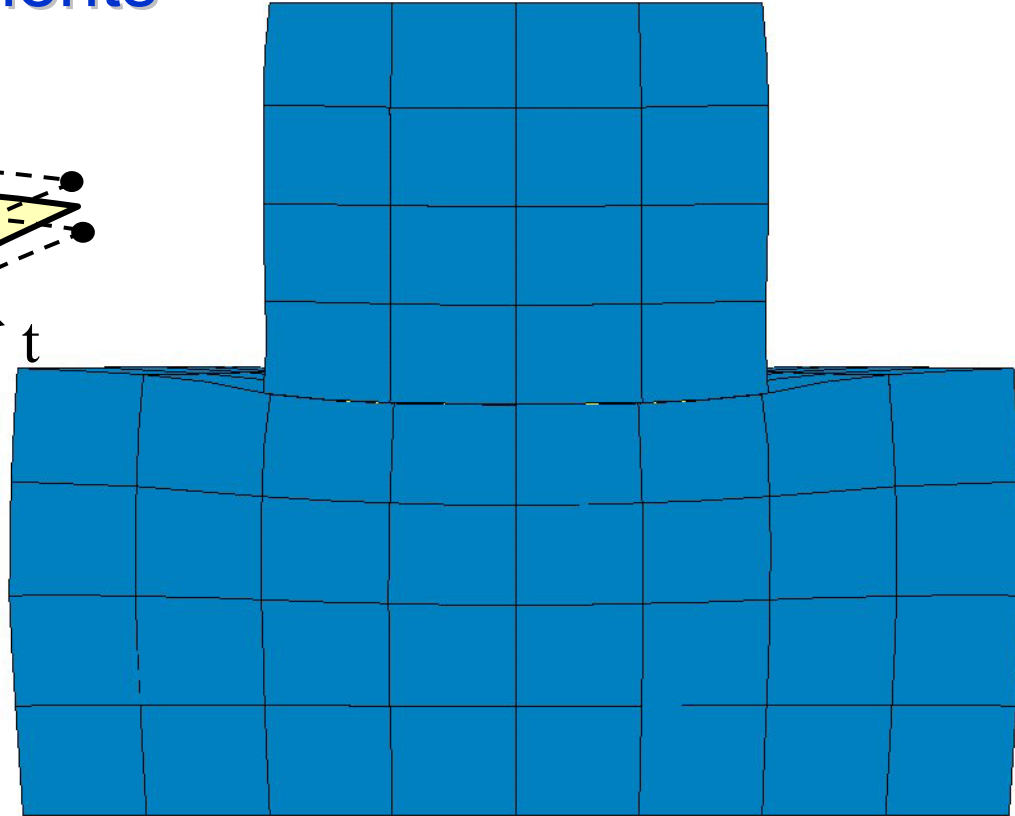
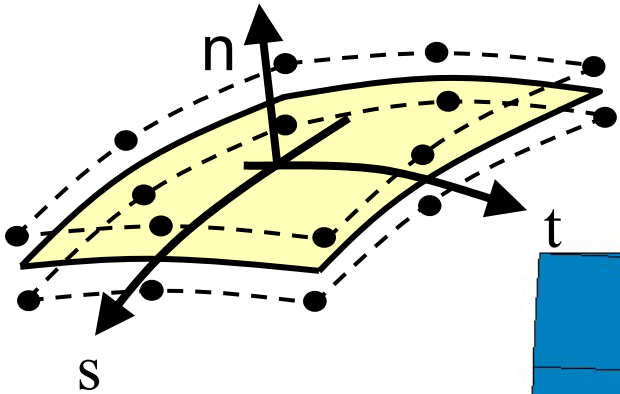
- Interlayer systems

- contact elements



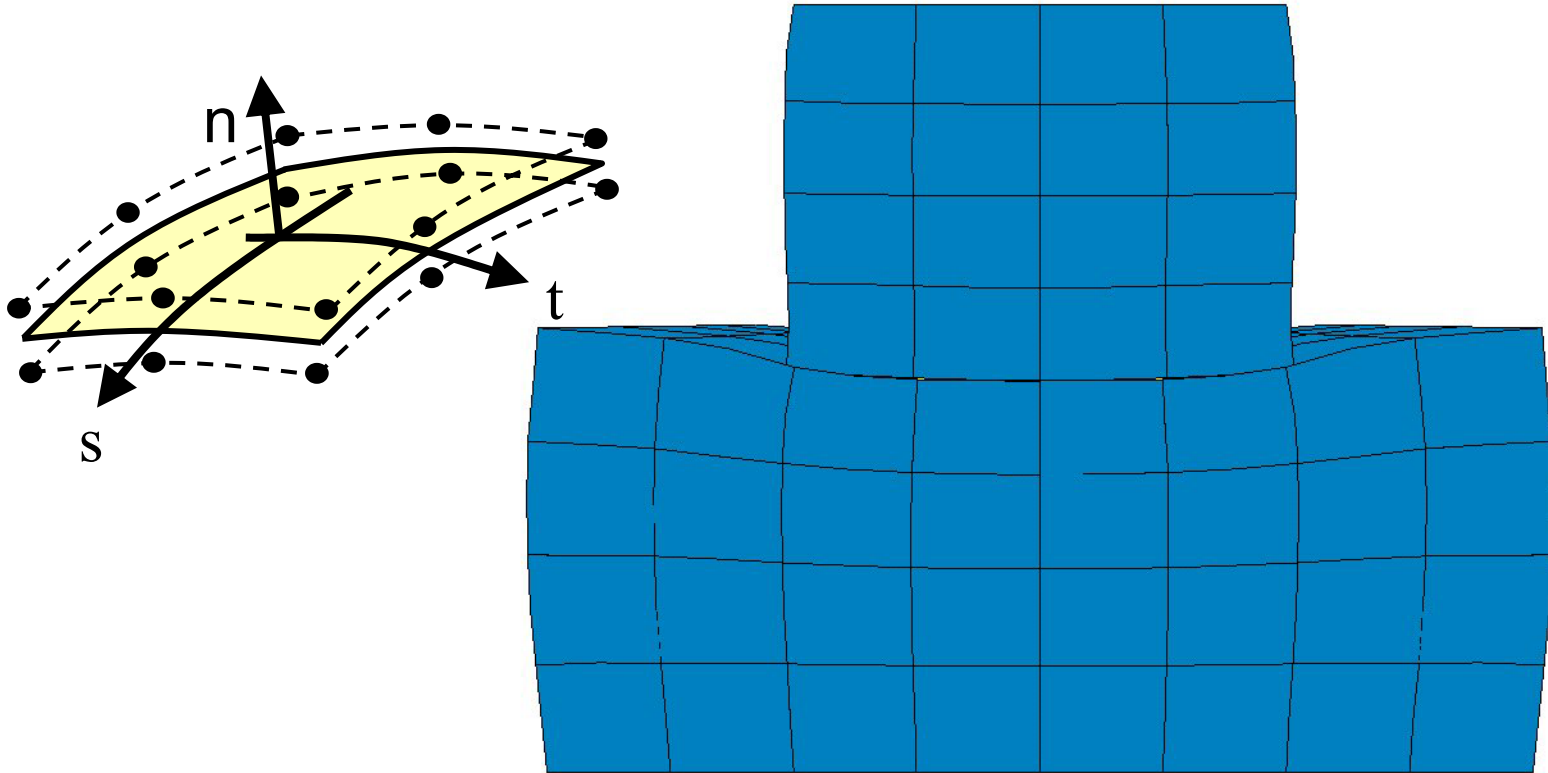
- Interlayer systems

- contact elements



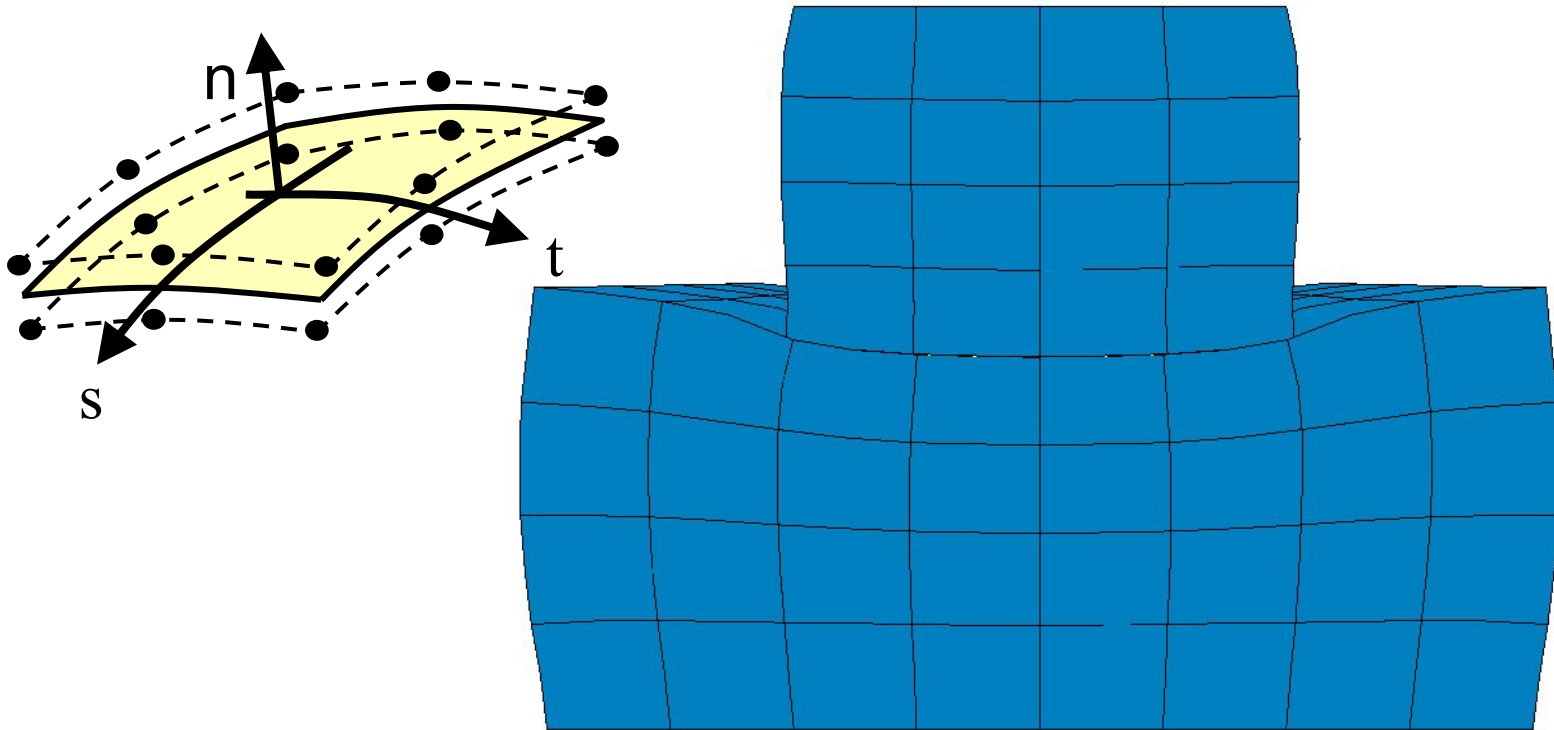
- Interlayer systems

- contact elements



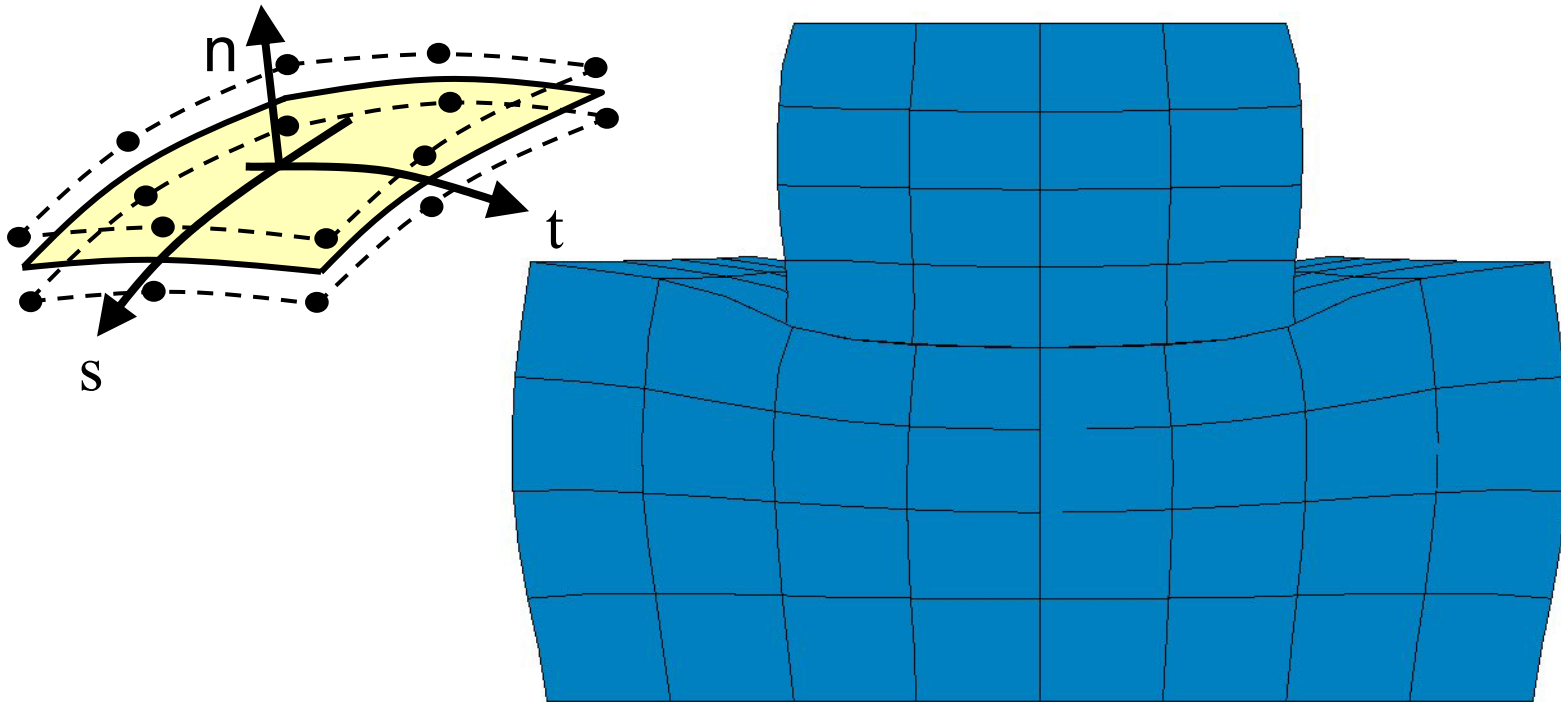
- Interlayer systems

- contact elements



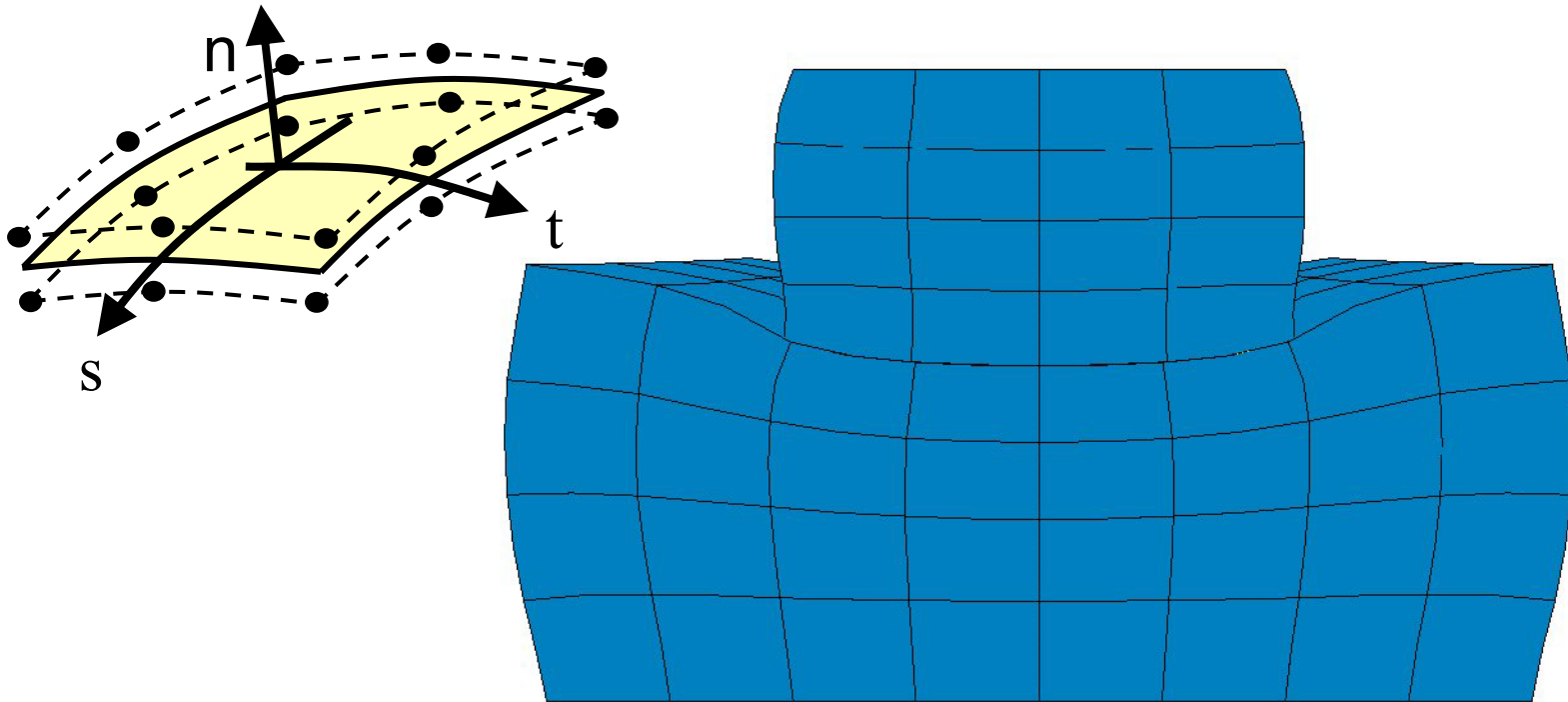
- Interlayer systems

- contact elements



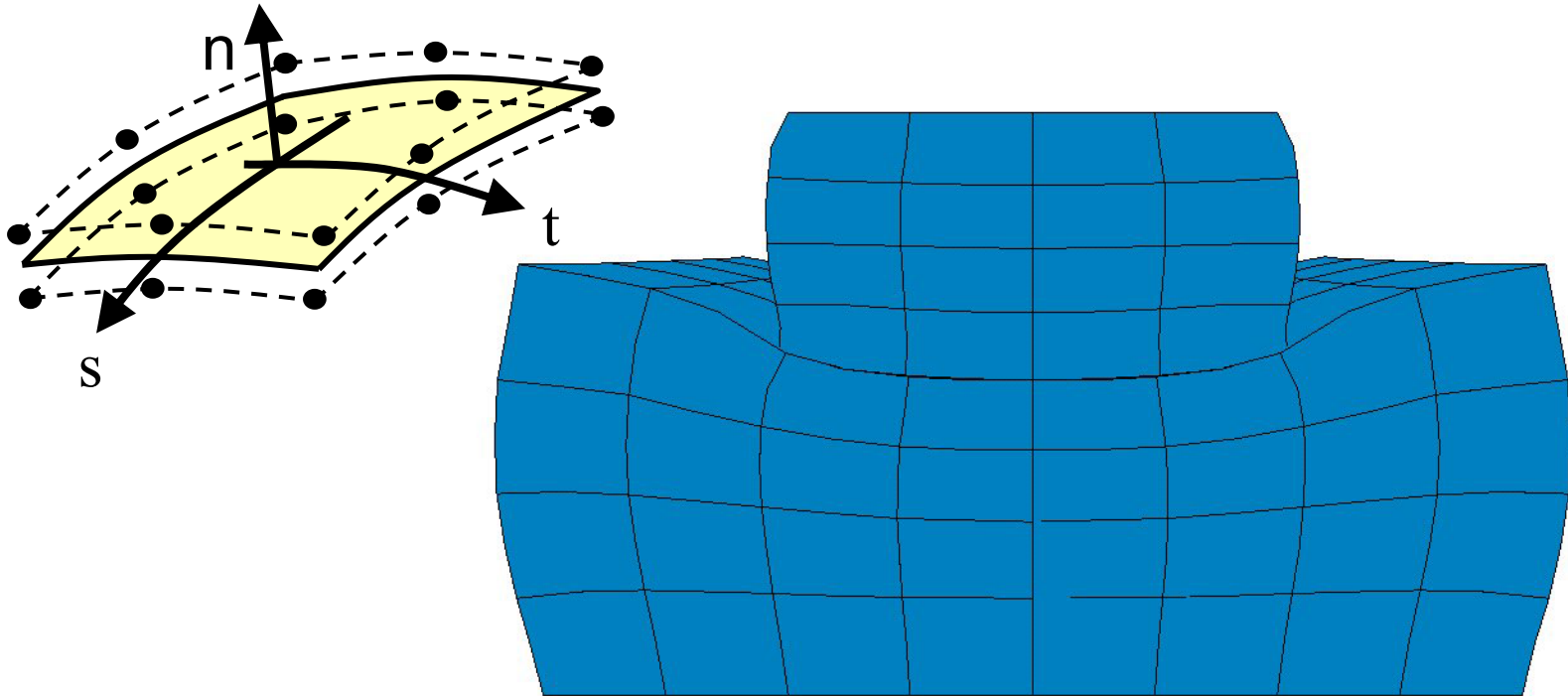
- Interlayer systems

- contact elements



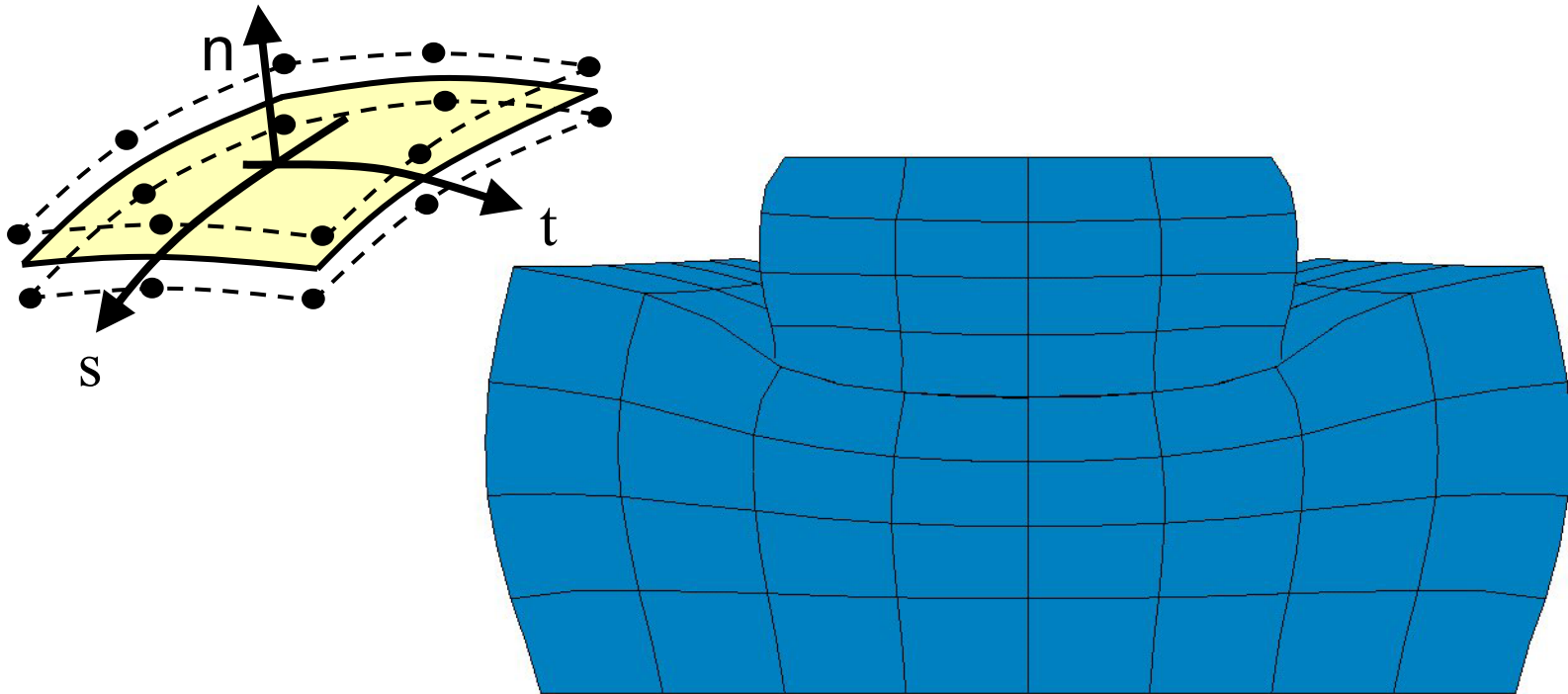
- Interlayer systems

- contact elements



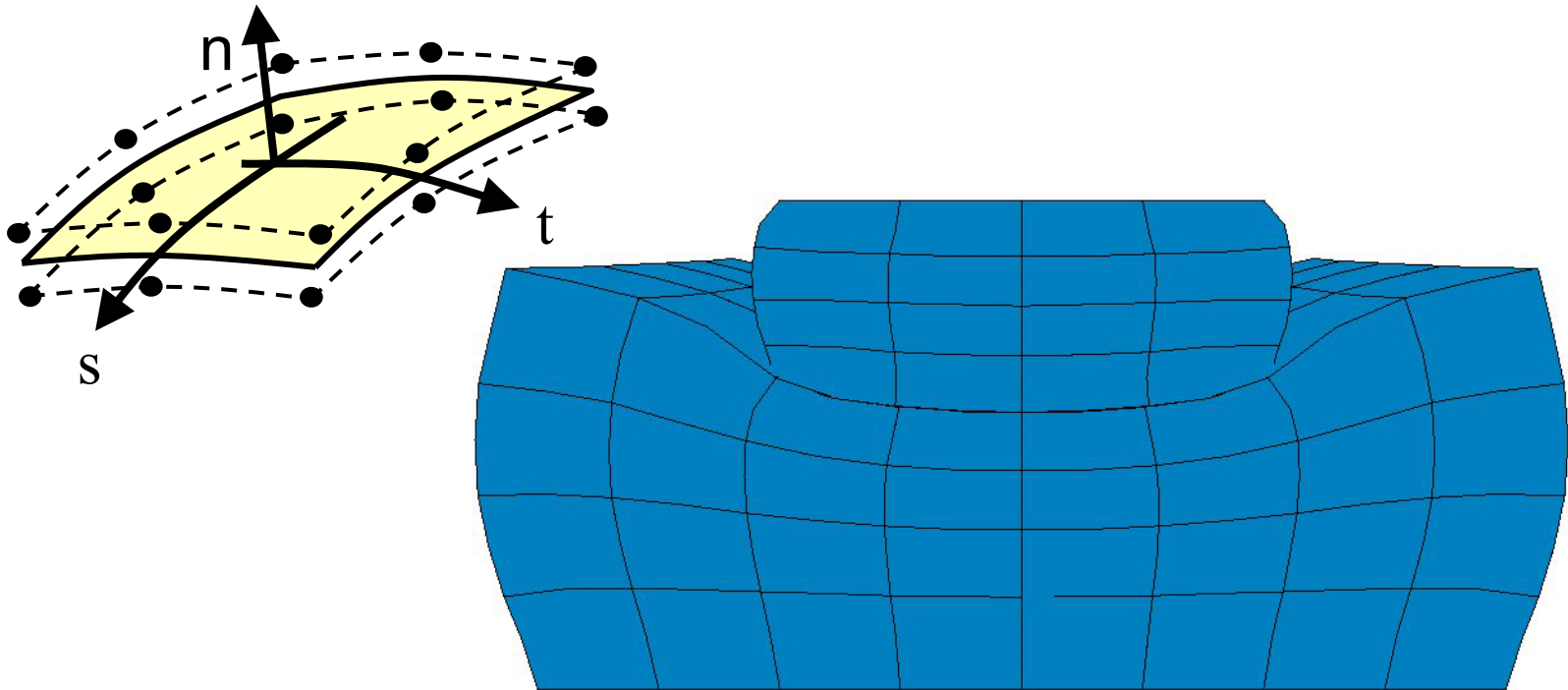
- Interlayer systems

- contact elements



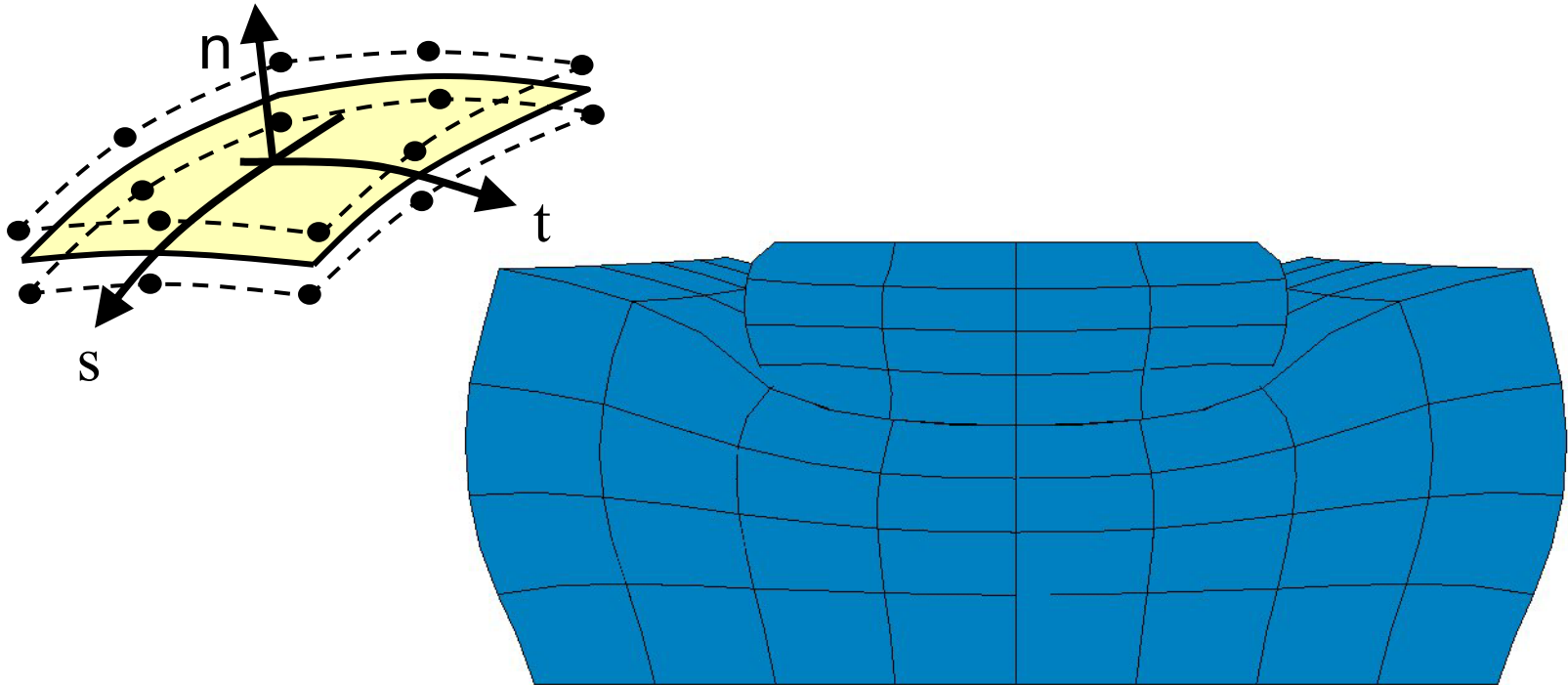
- Interlayer systems

- contact elements



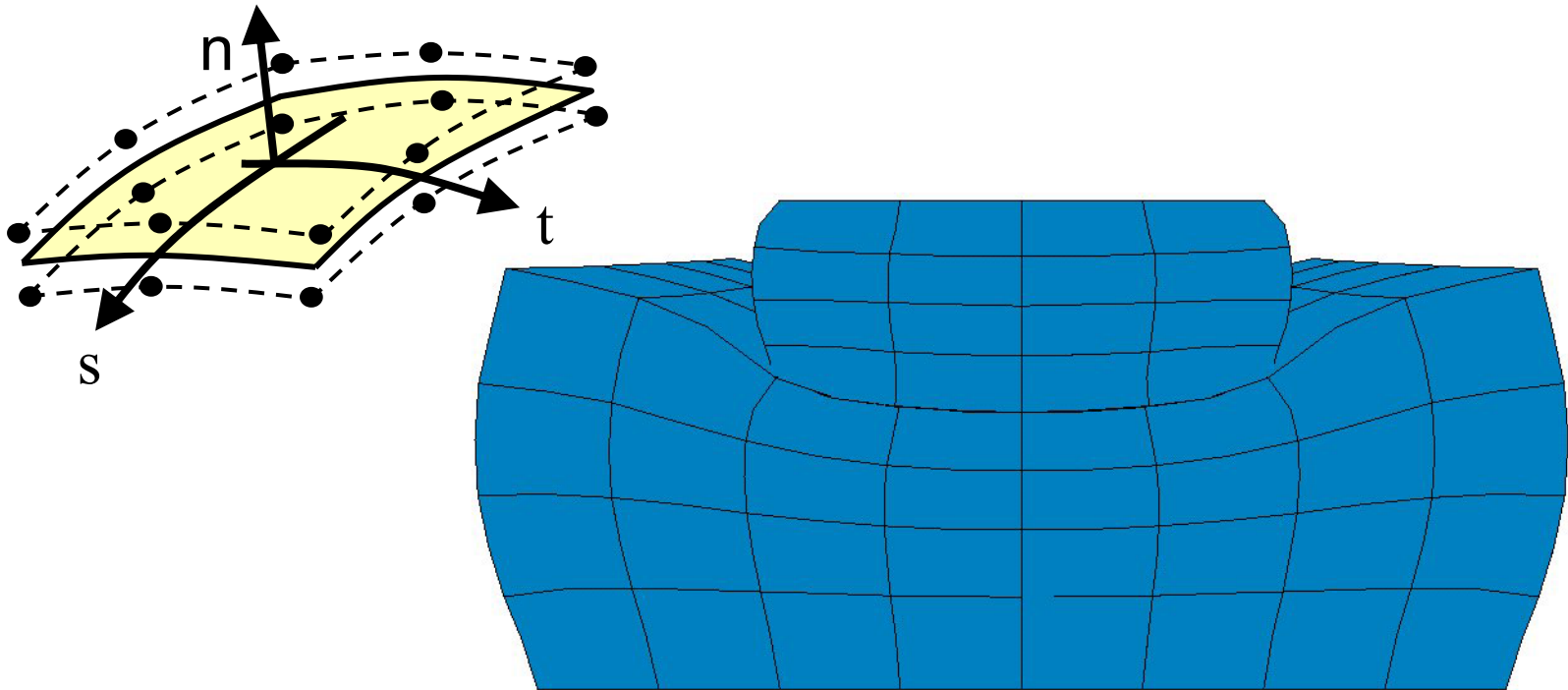
- Interlayer systems

- contact elements



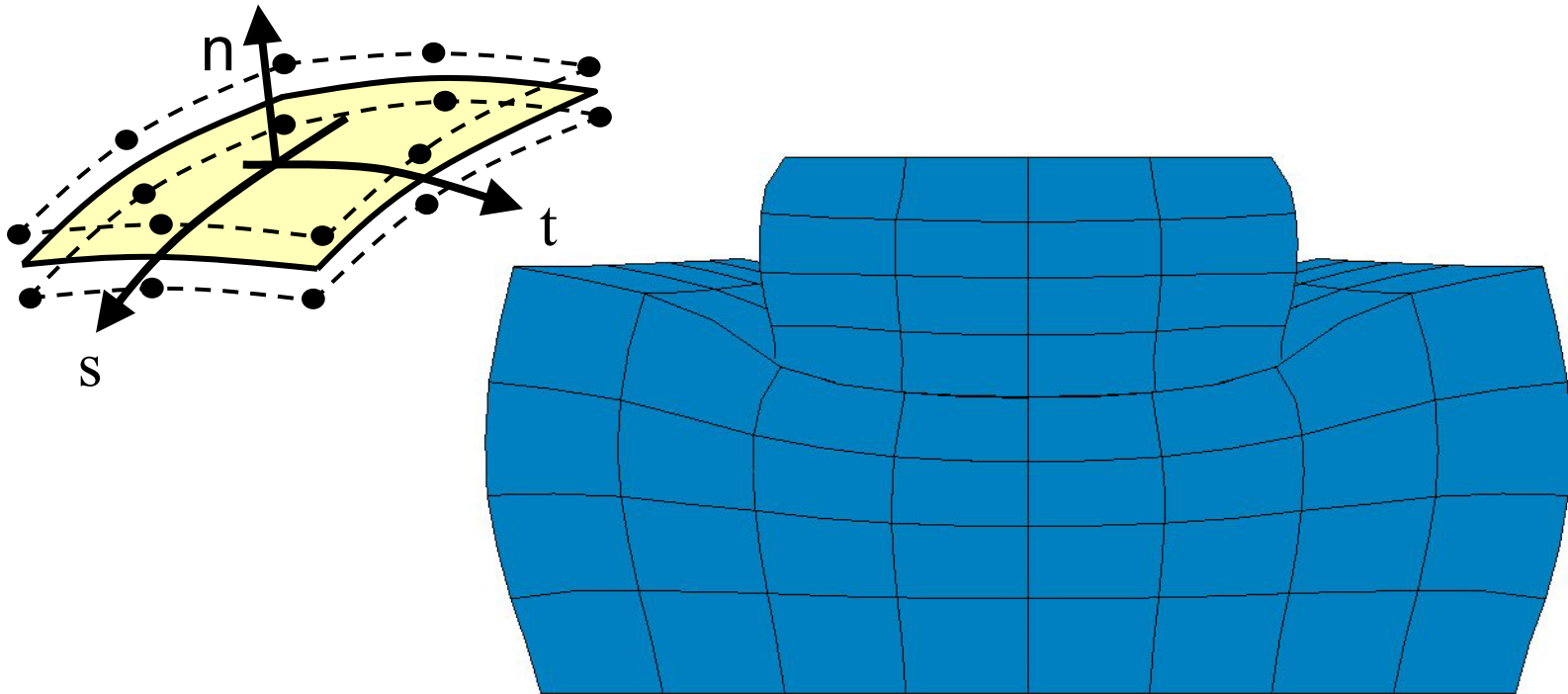
- Interlayer systems

- contact elements



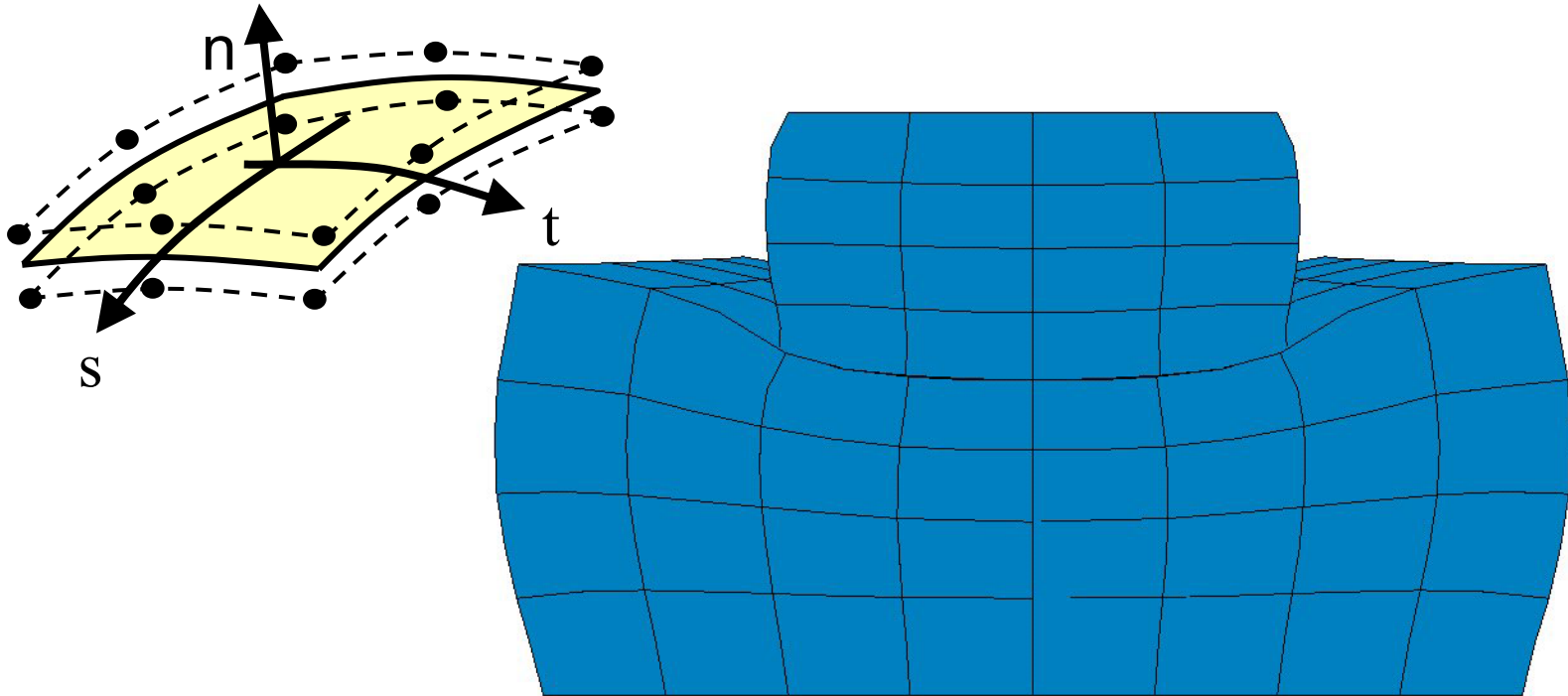
- Interlayer systems

- contact elements



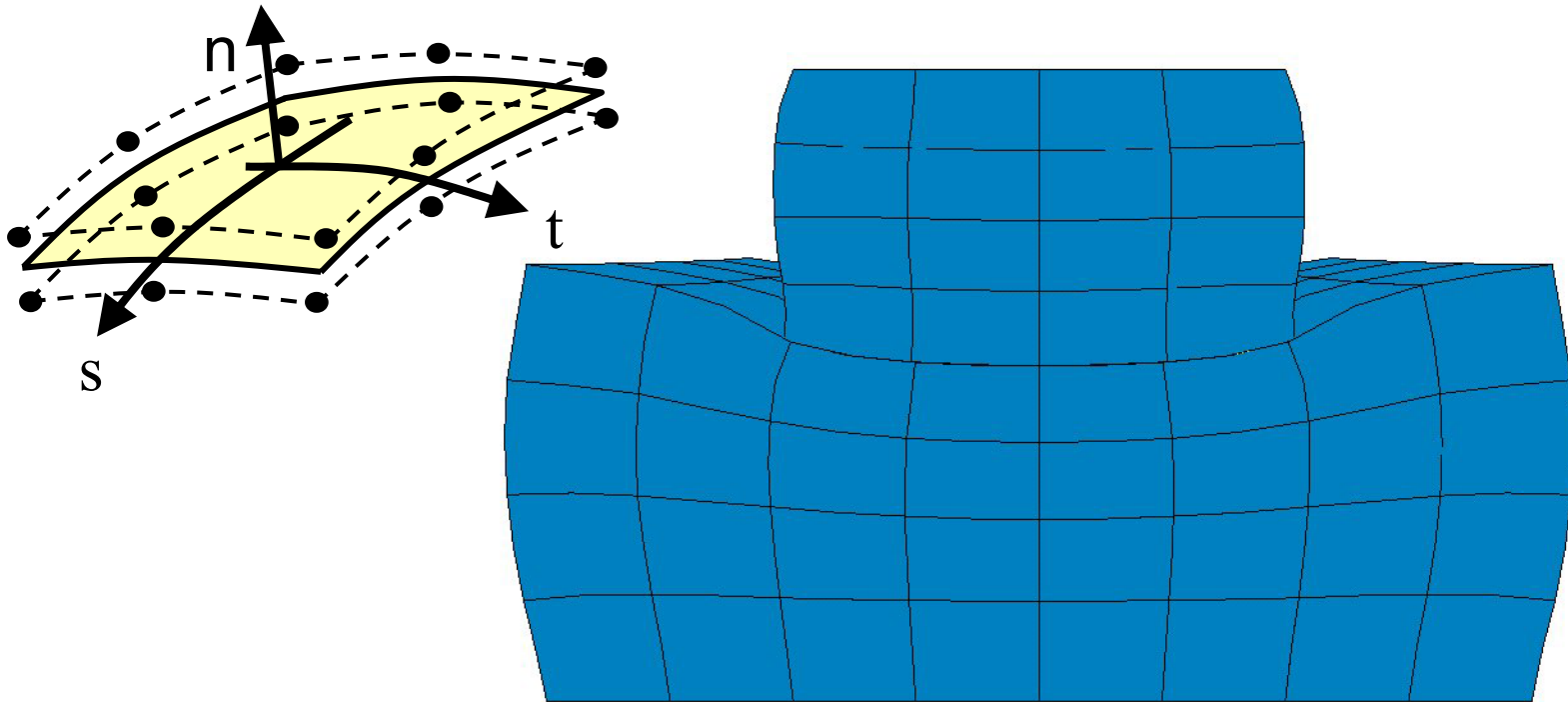
- Interlayer systems

- contact elements



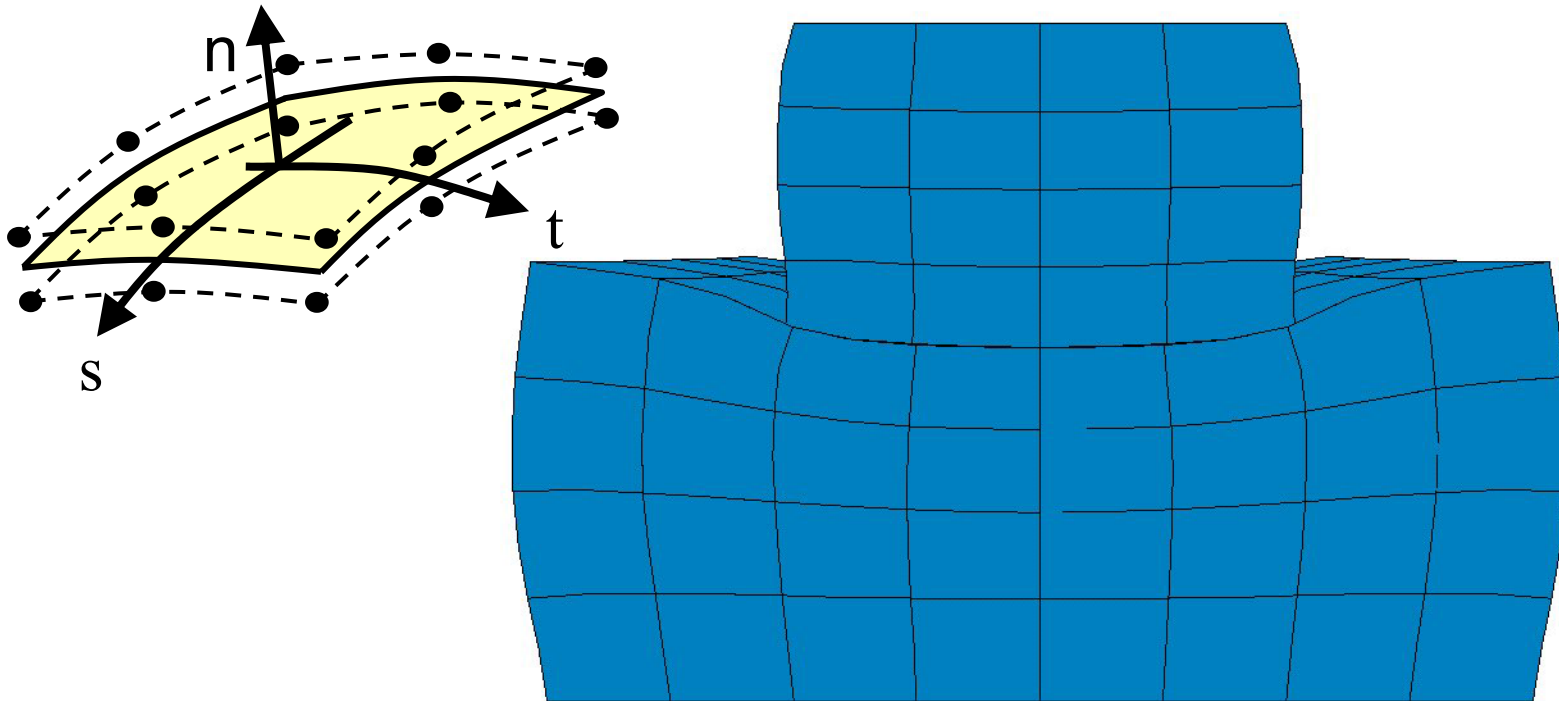
- Interlayer systems

- contact elements



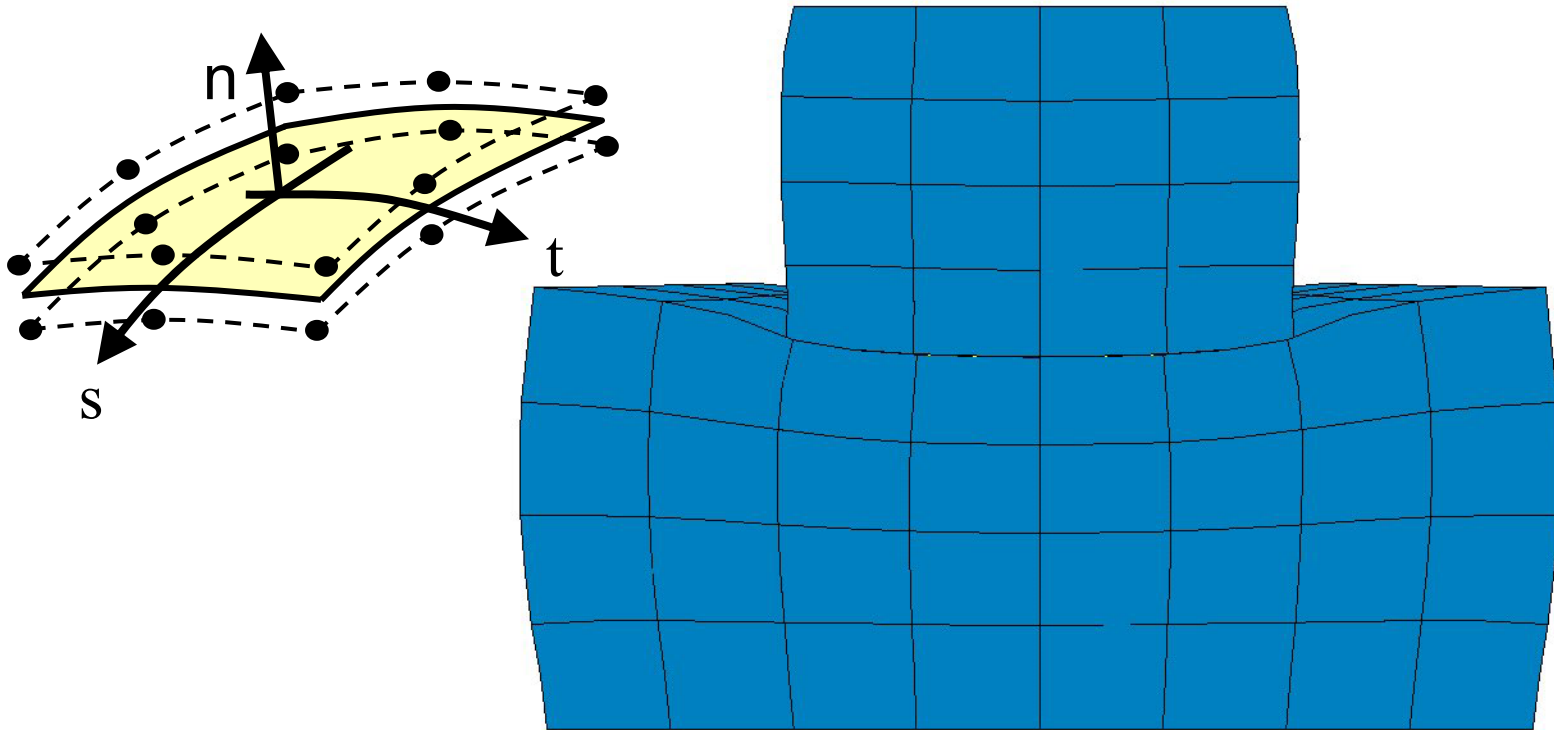
- Interlayer systems

- contact elements



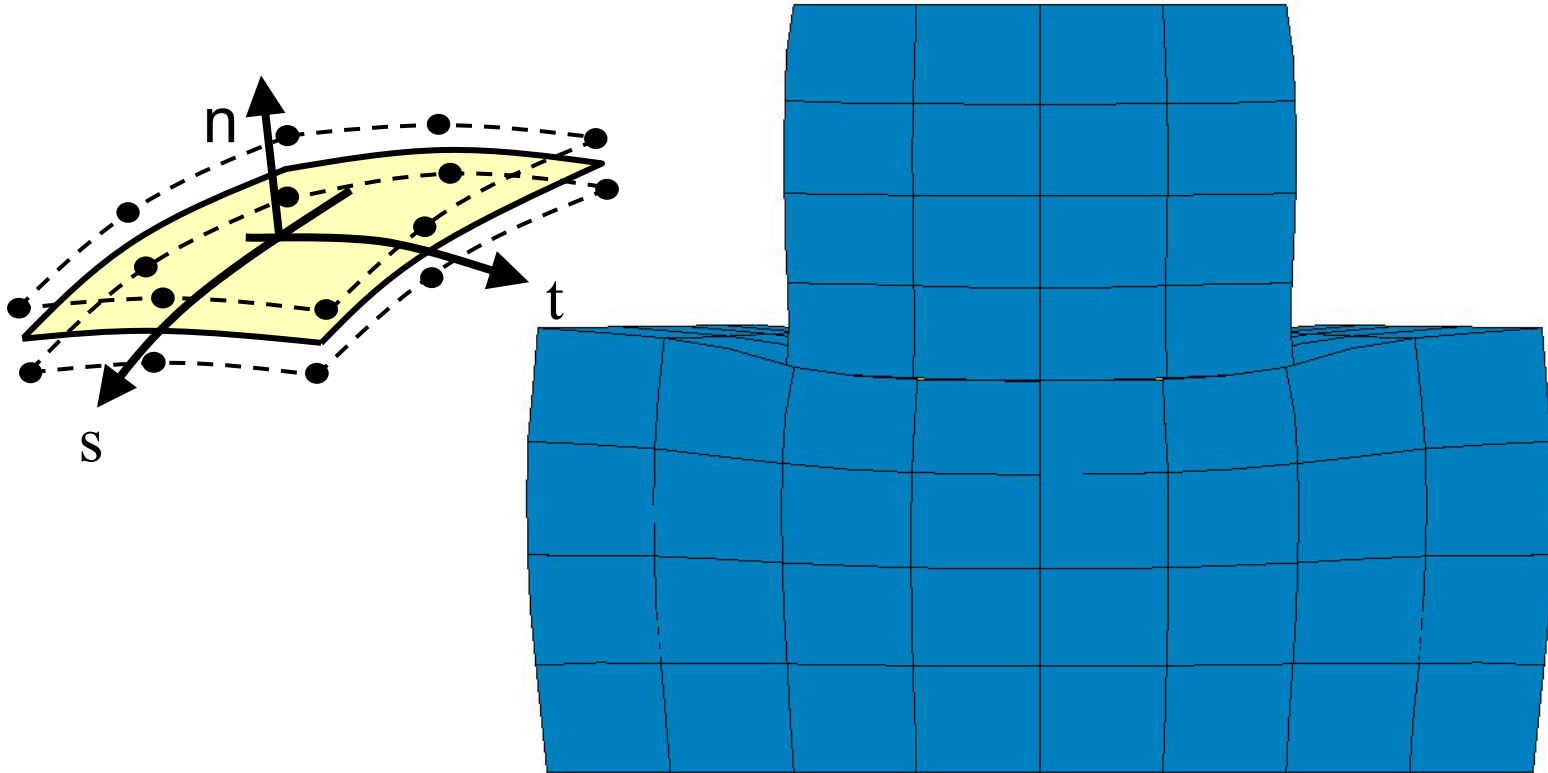
- Interlayer systems

- contact elements



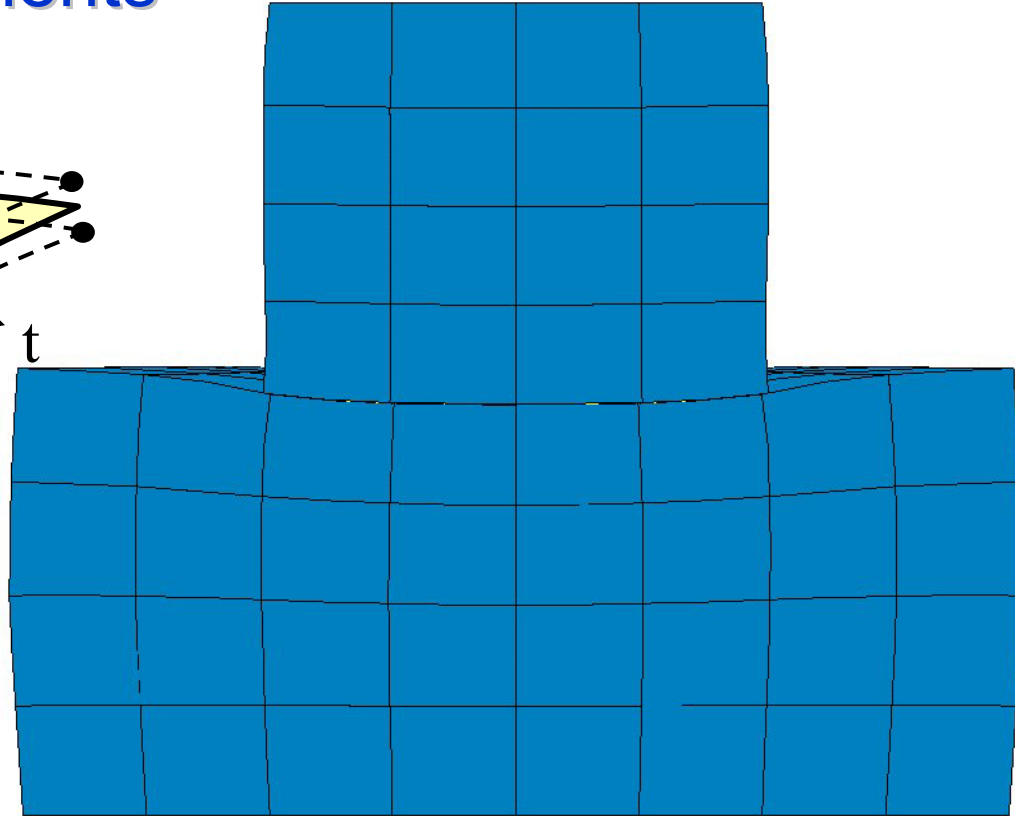
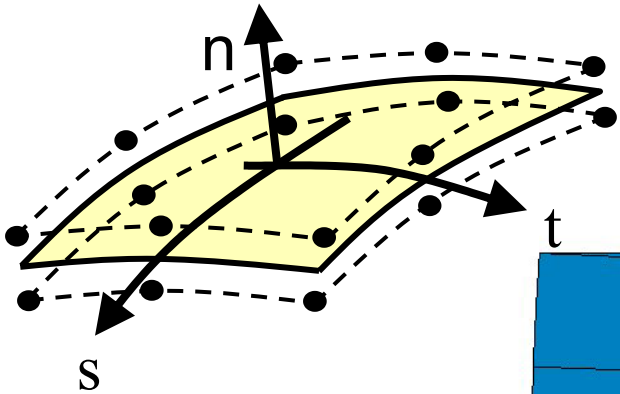
- Interlayer systems

- contact elements



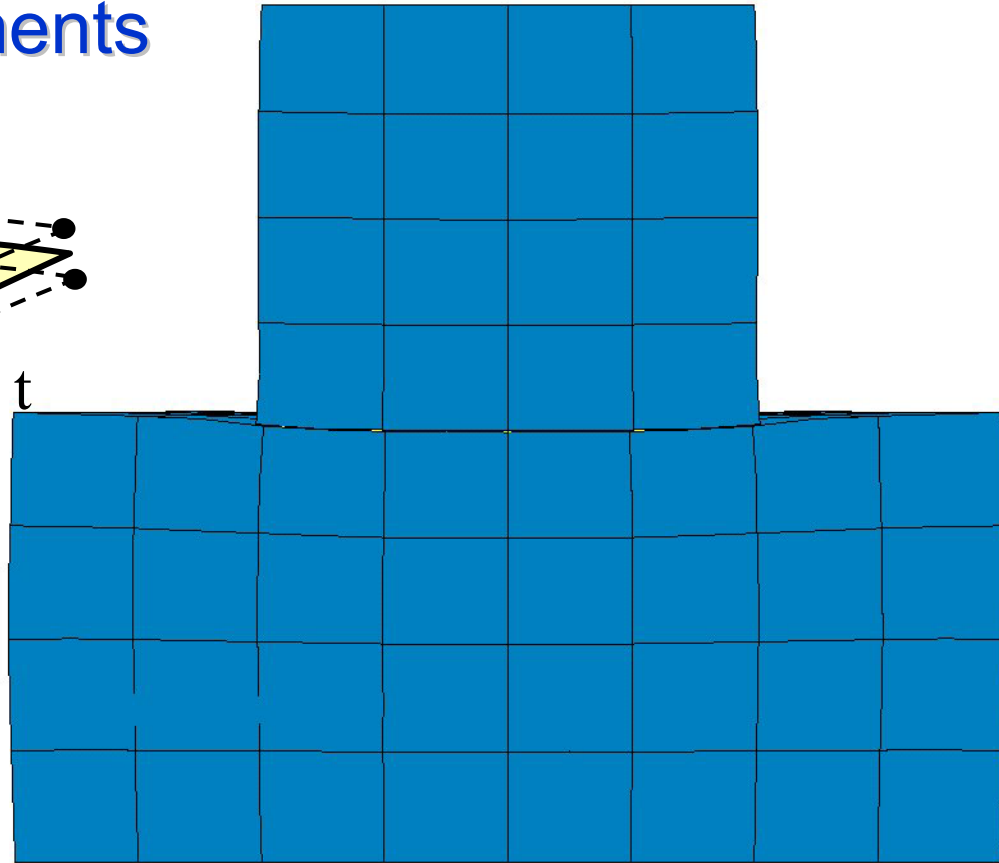
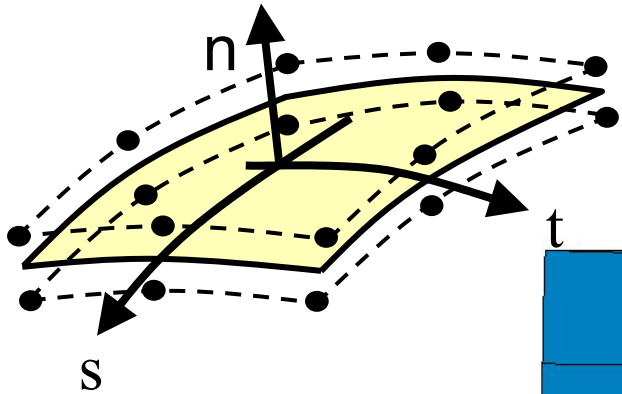
- Interlayer systems

- contact elements



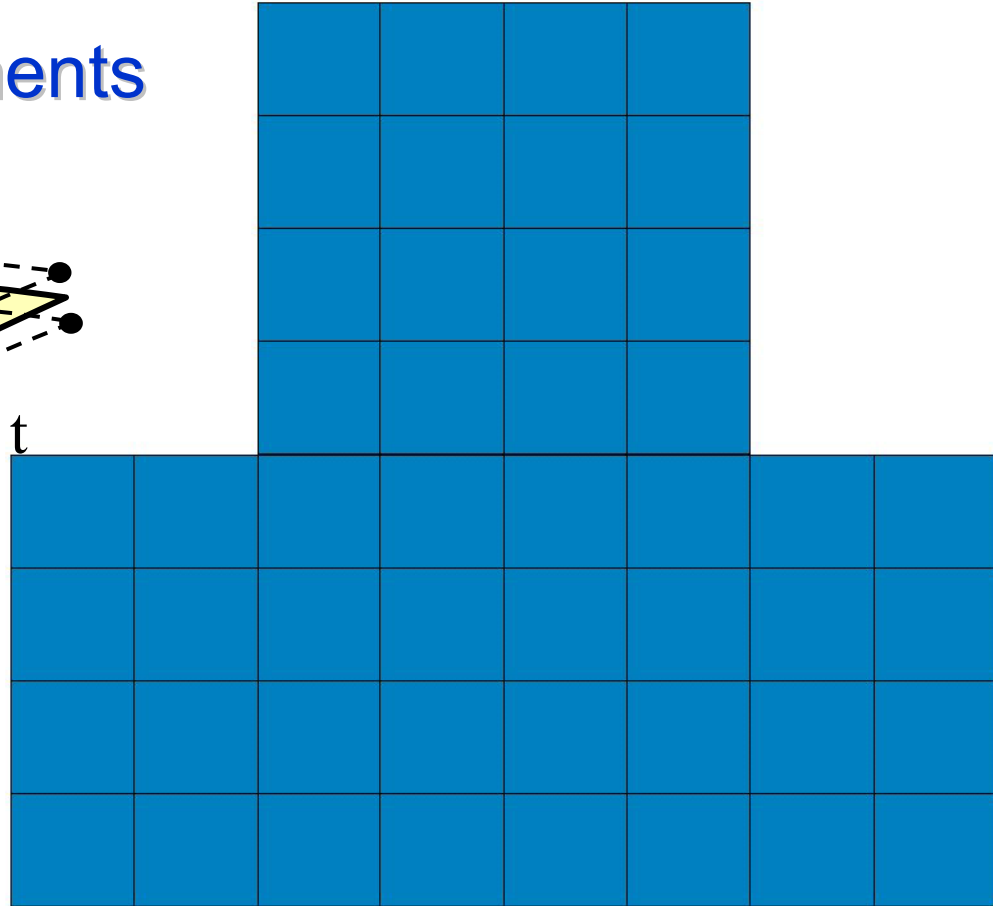
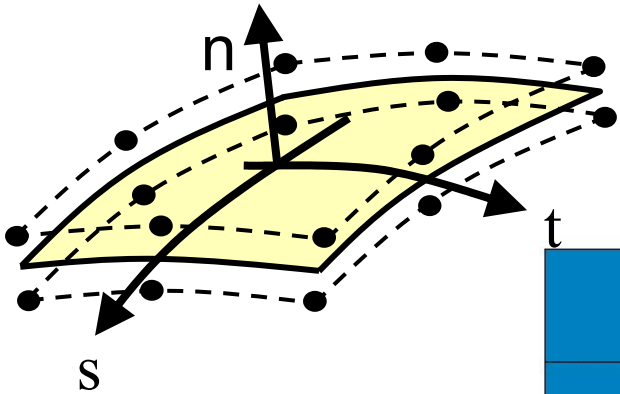
- Interlayer systems

- contact elements



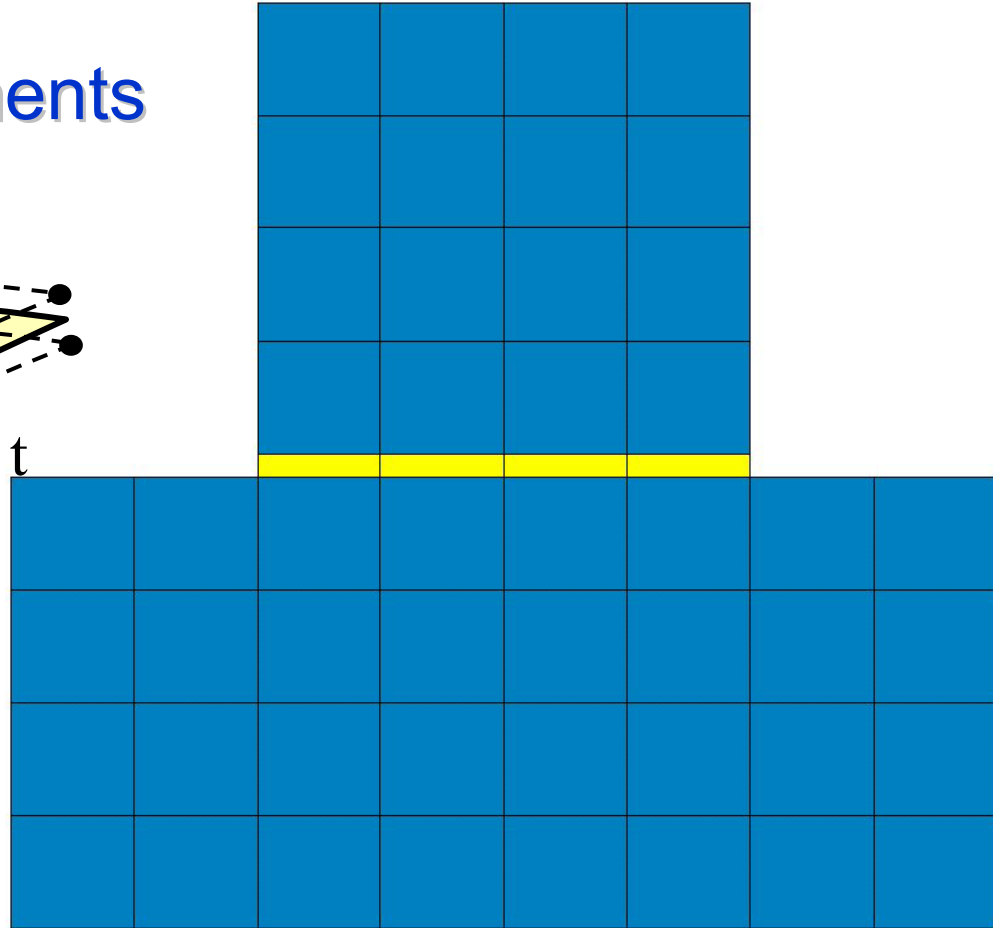
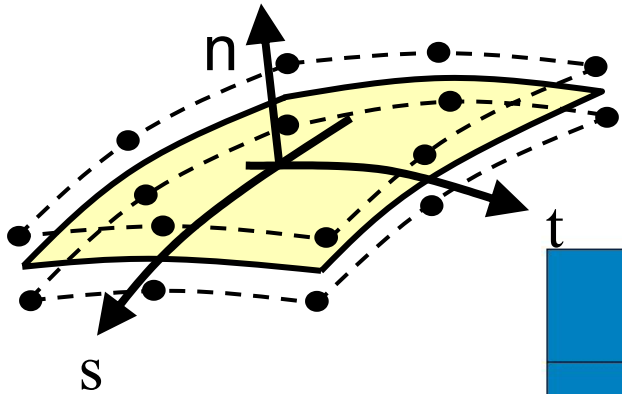
- Interlayer systems

- contact elements



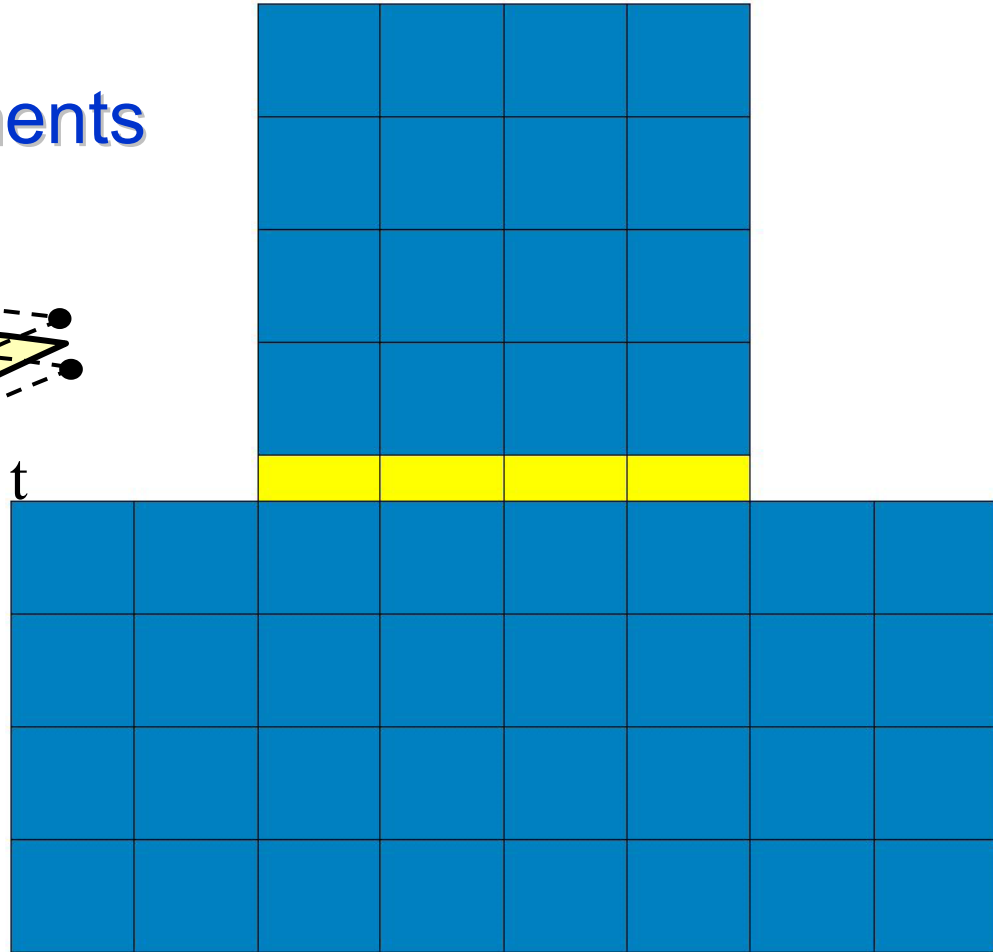
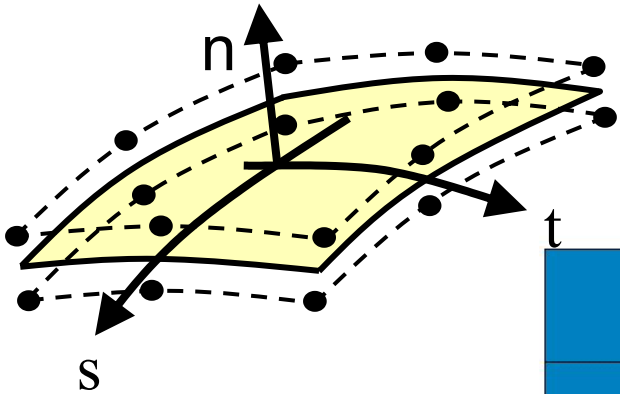
- Interlayer systems

- contact elements



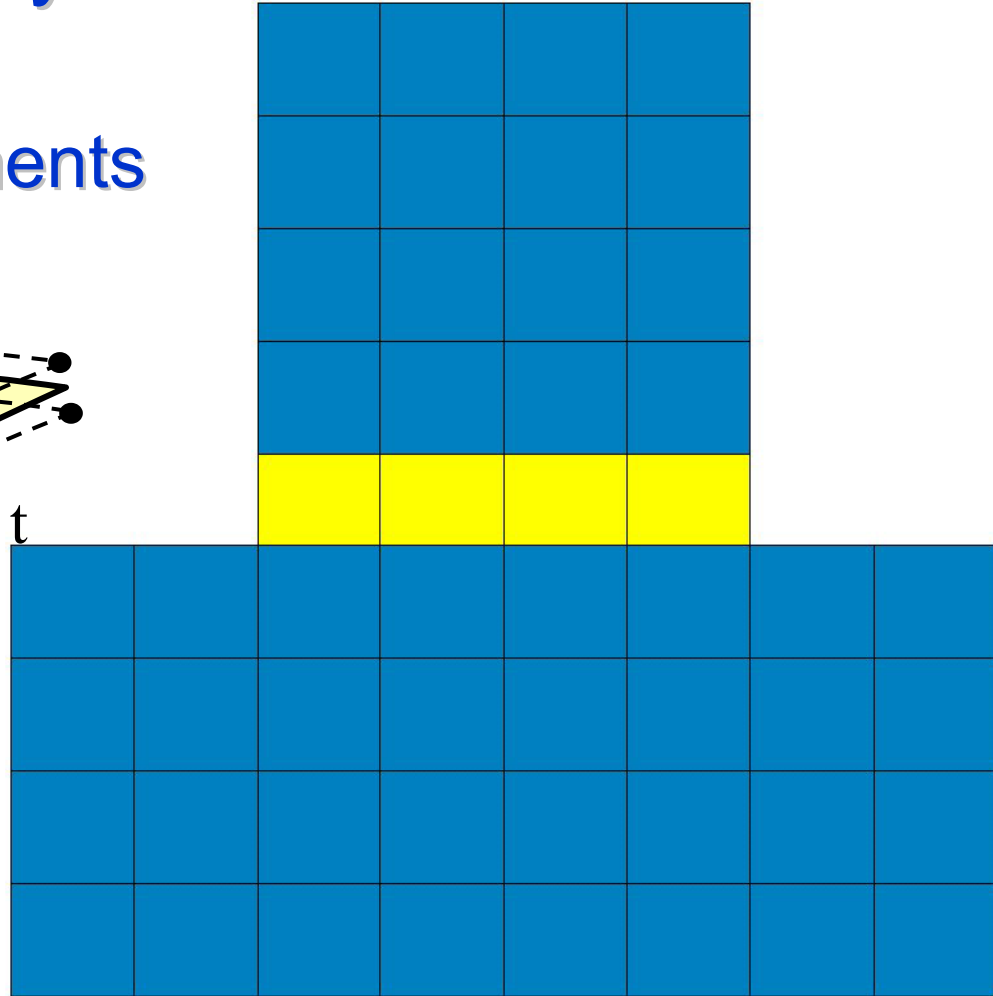
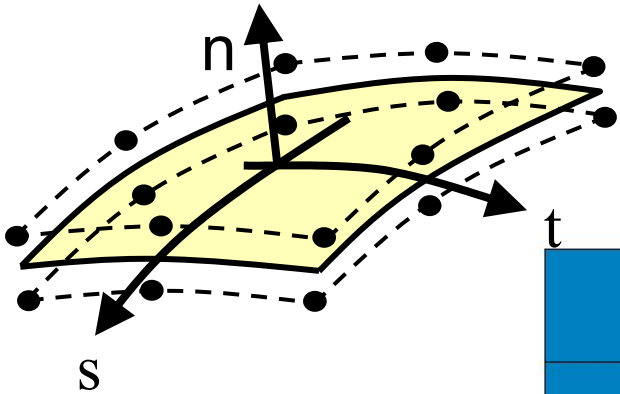
- Interlayer systems

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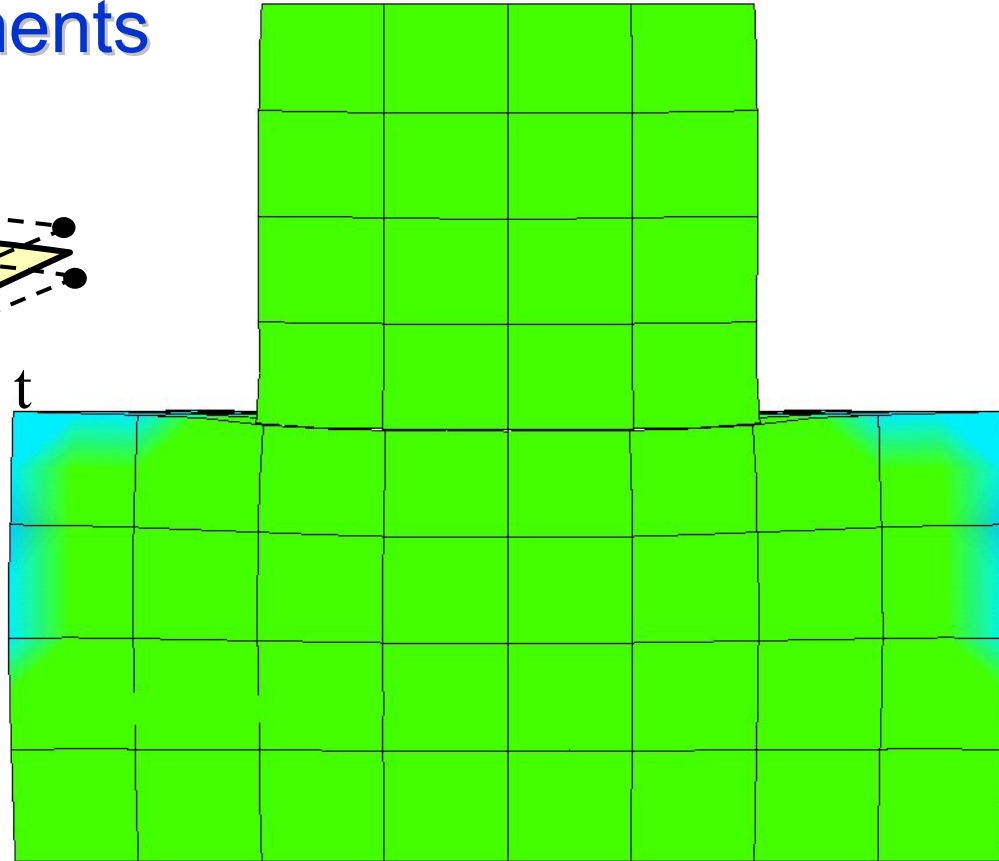
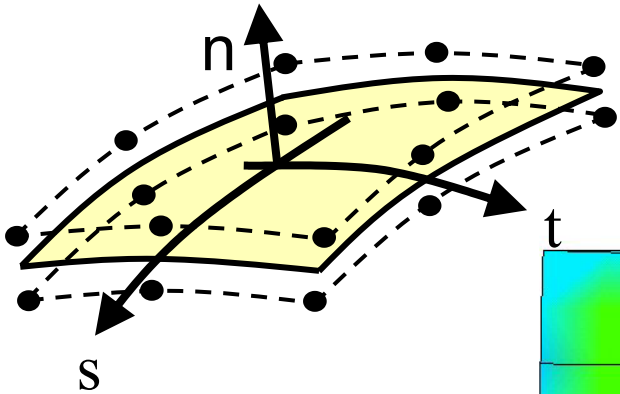
- Interlayer systems

- contact elements



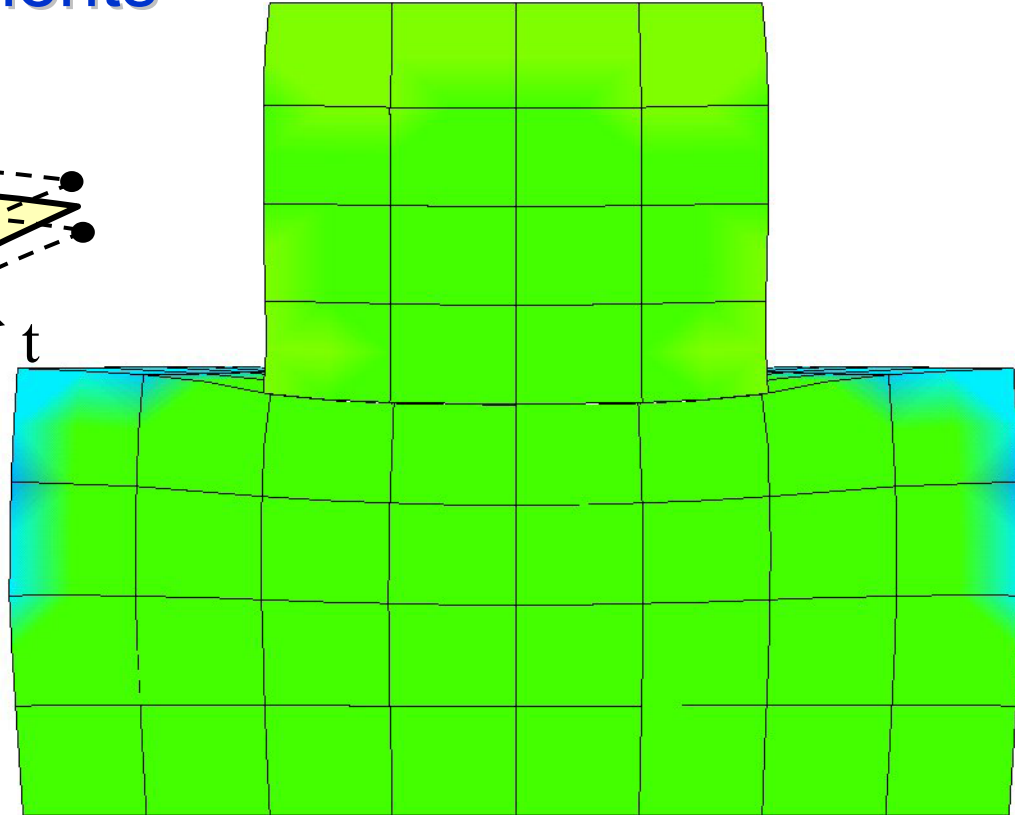
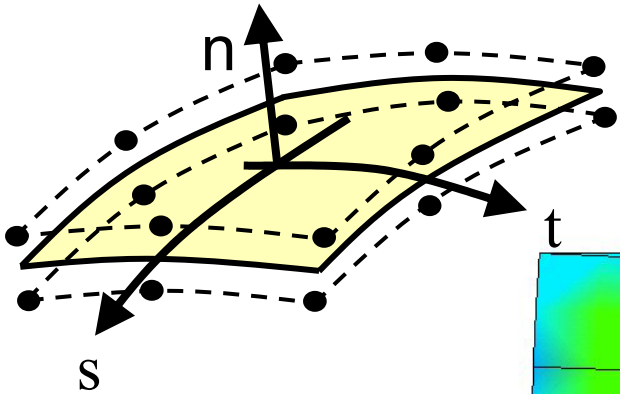
- Interlayer systems

- contact elements



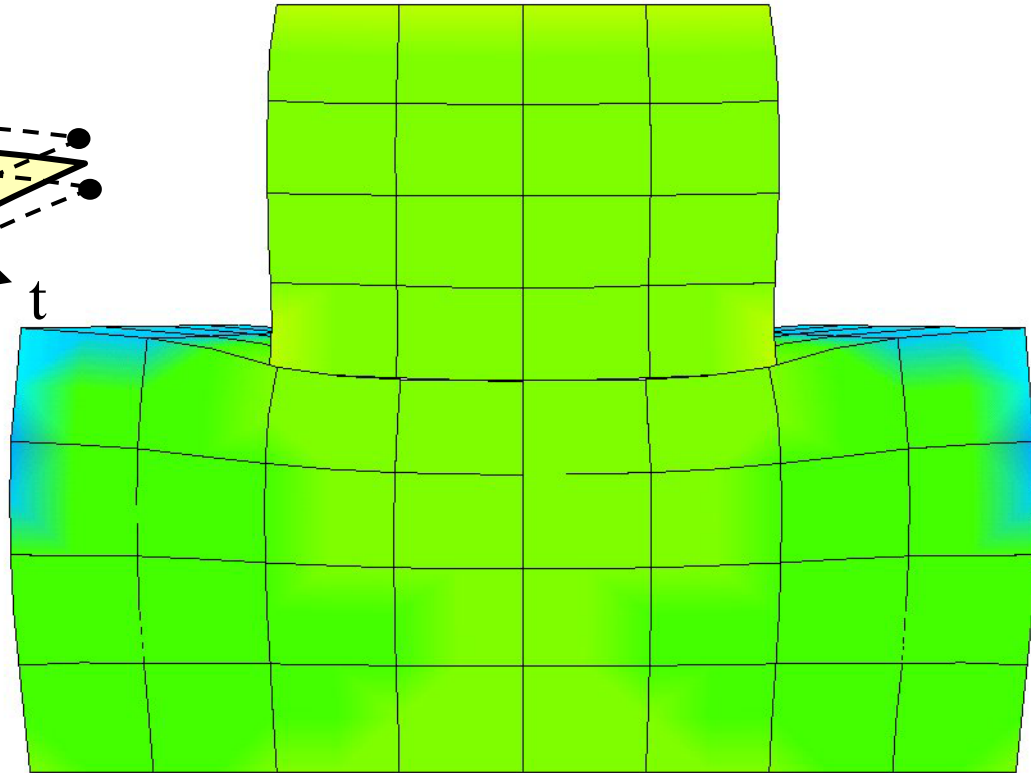
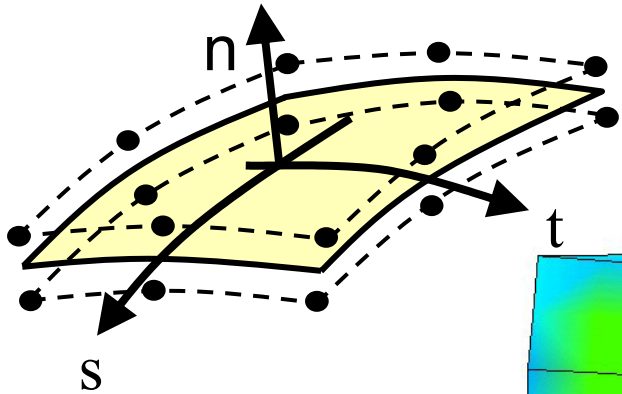
- Interlayer systems

- contact elements



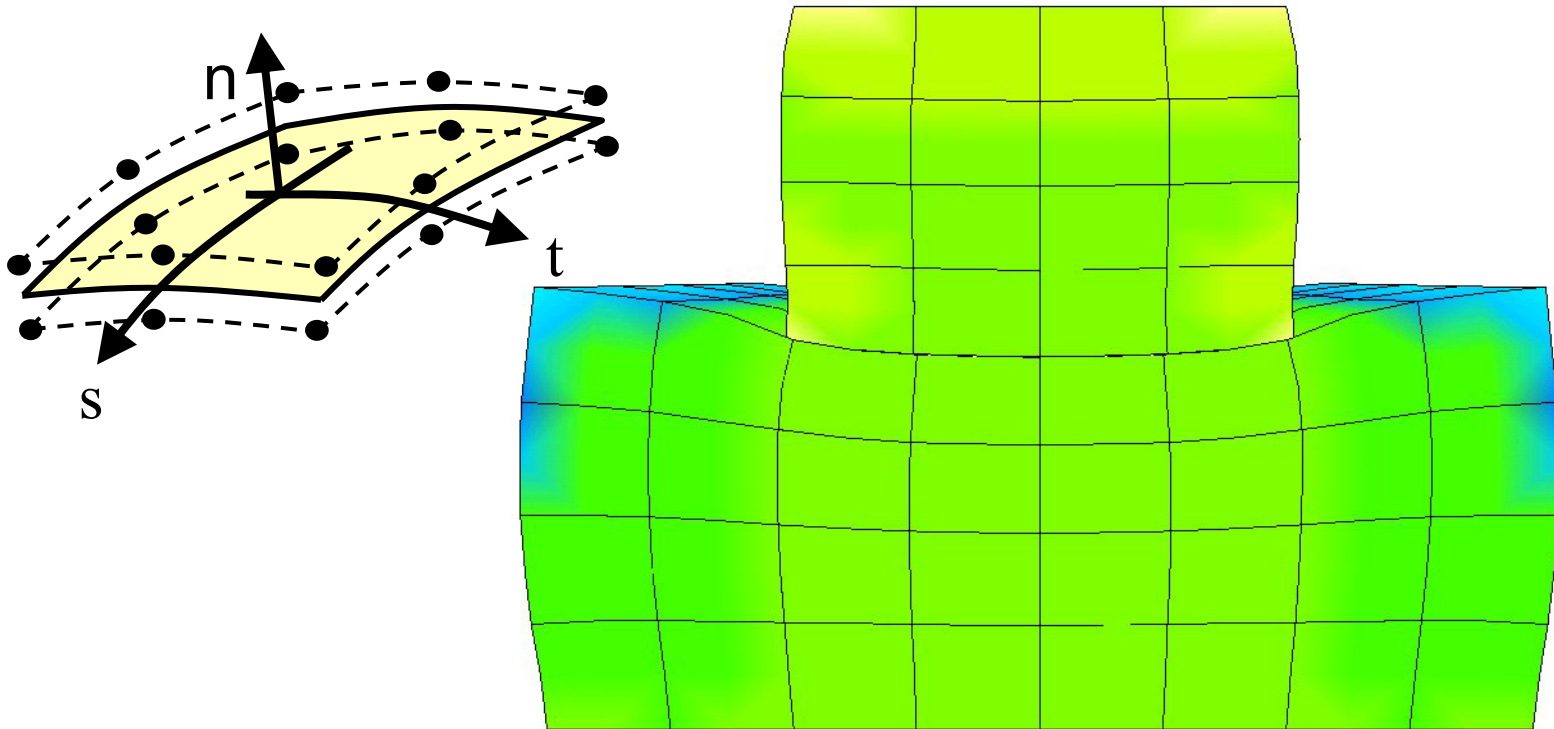
- Interlayer systems

- contact elements



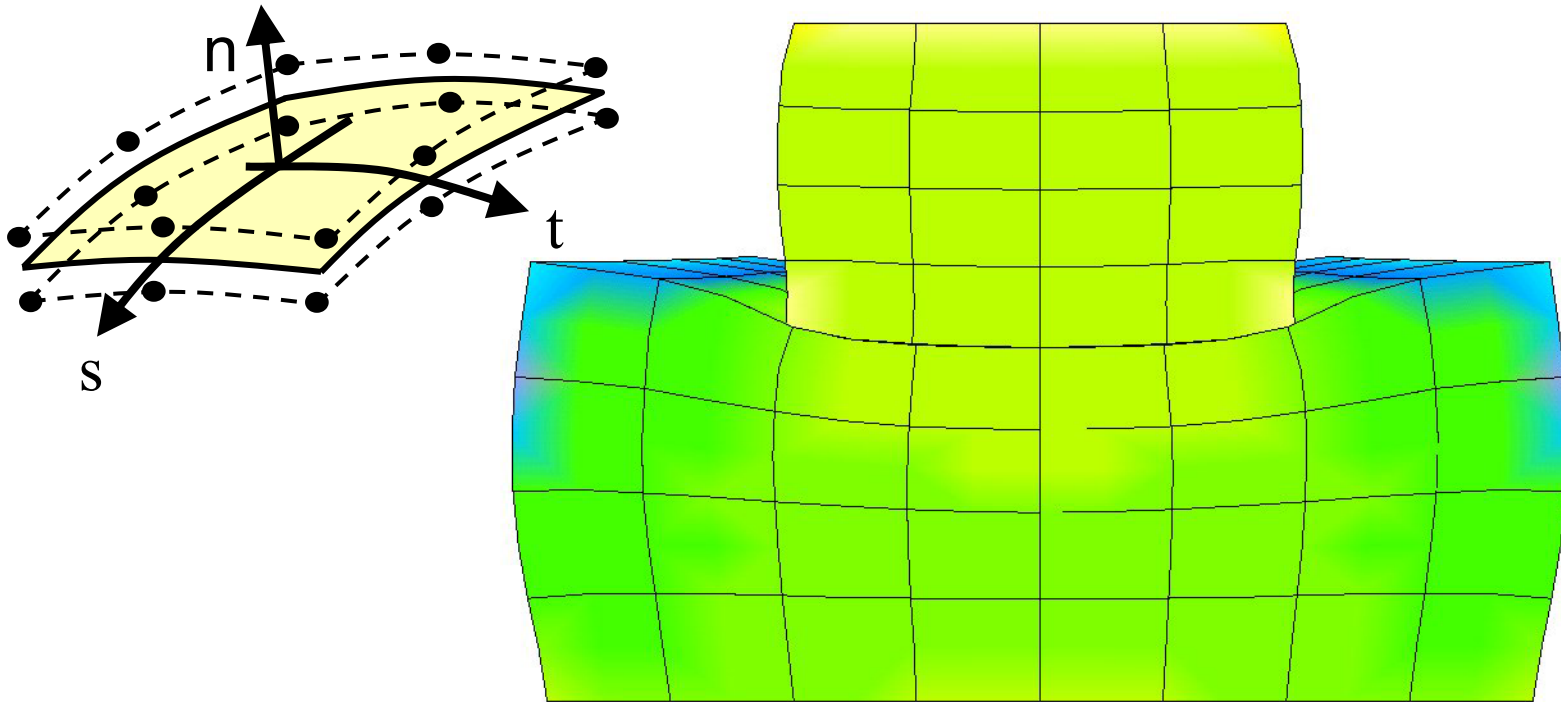
- Interlayer systems

- contact elements



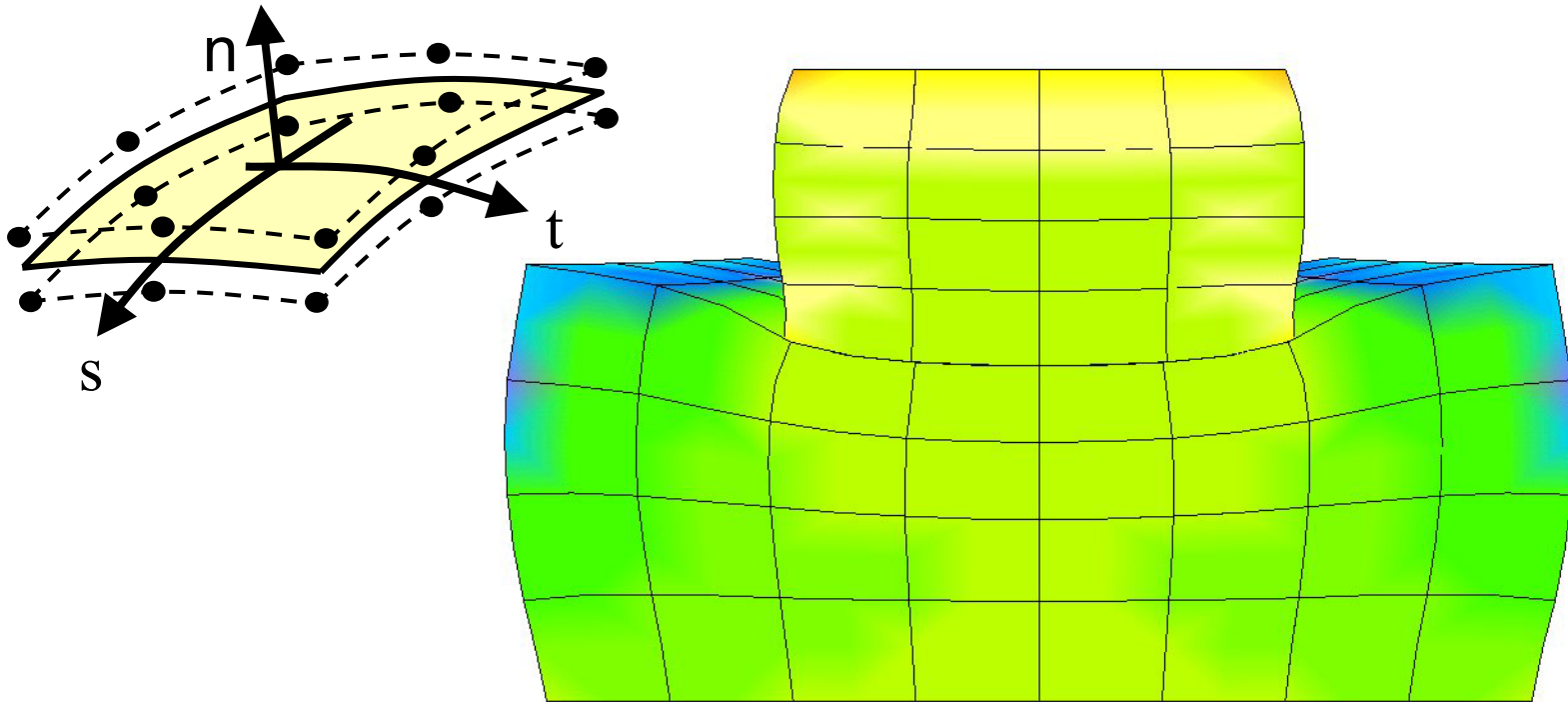
- Interlayer systems

- contact elements



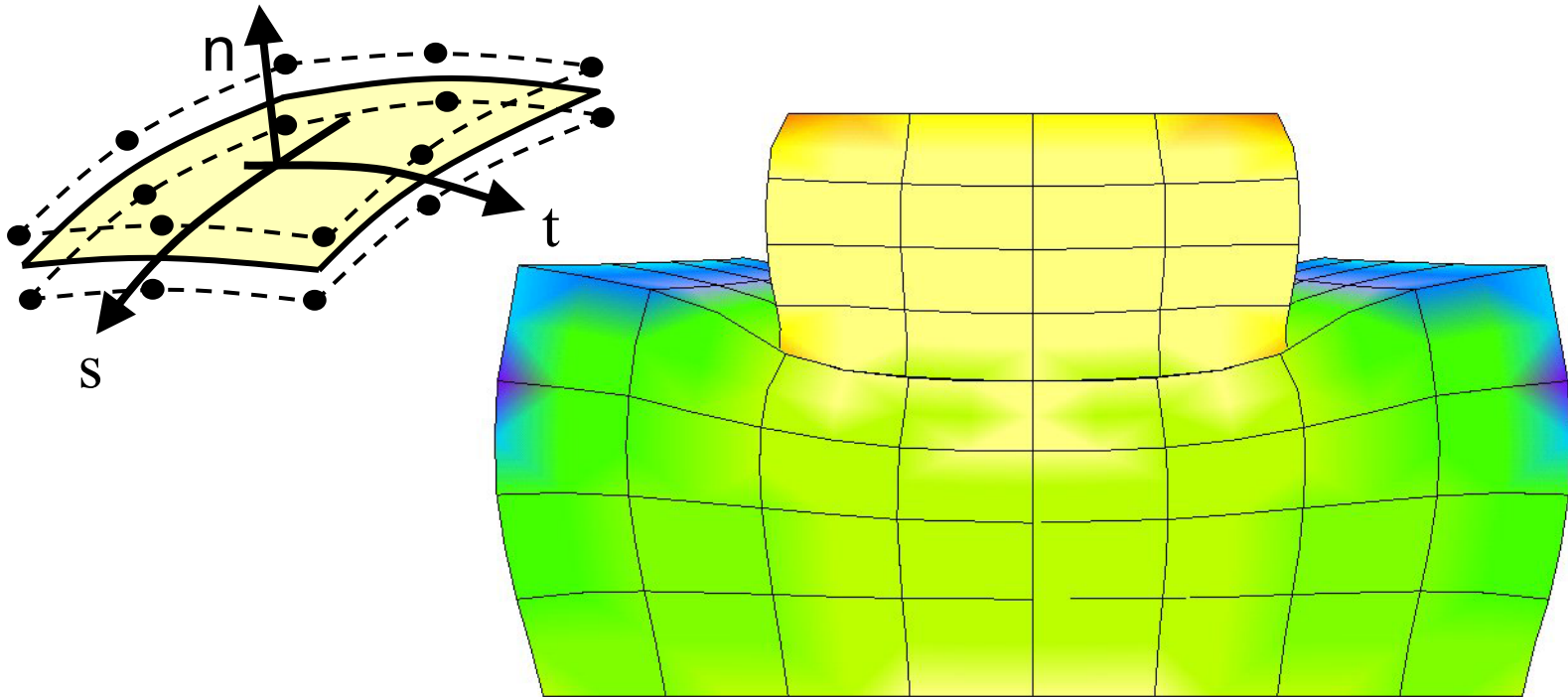
- Interlayer systems

- contact elements



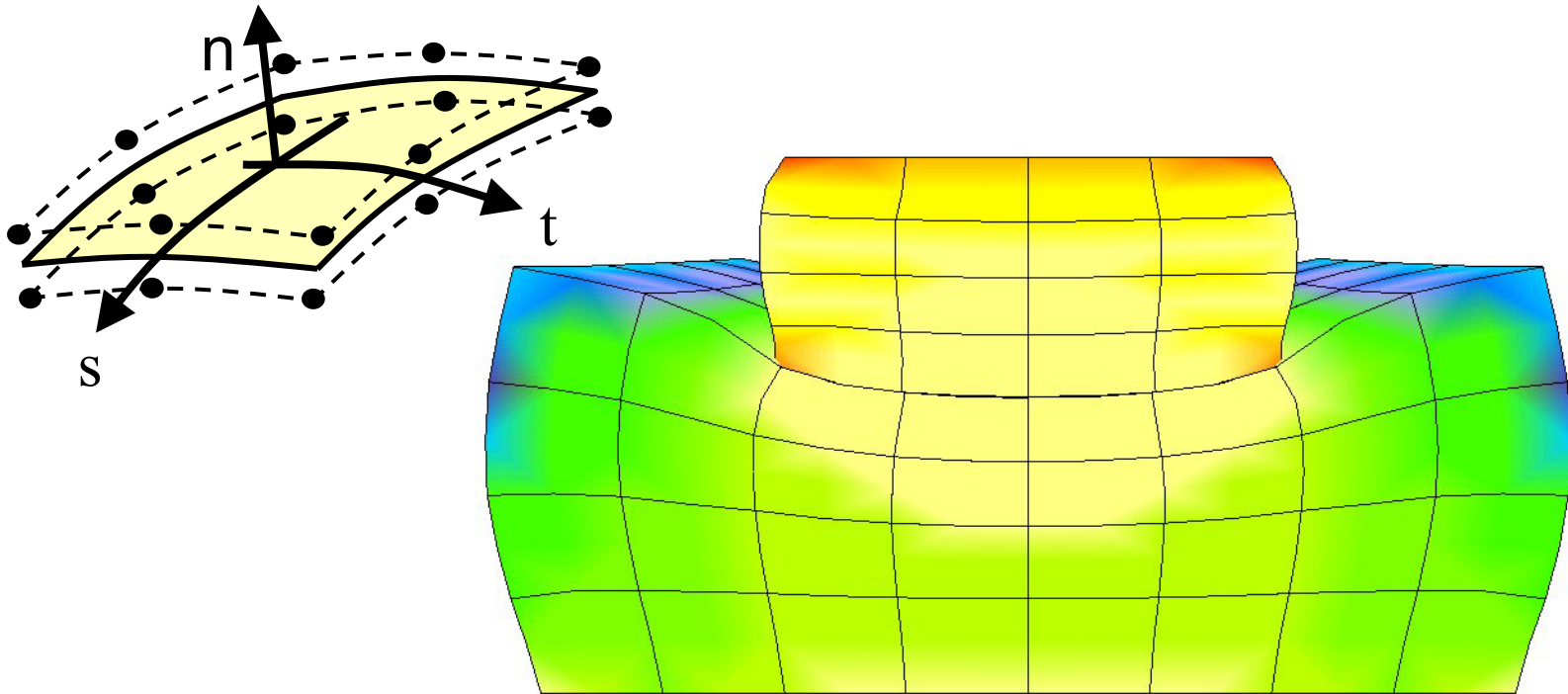
- Interlayer systems

- contact elements



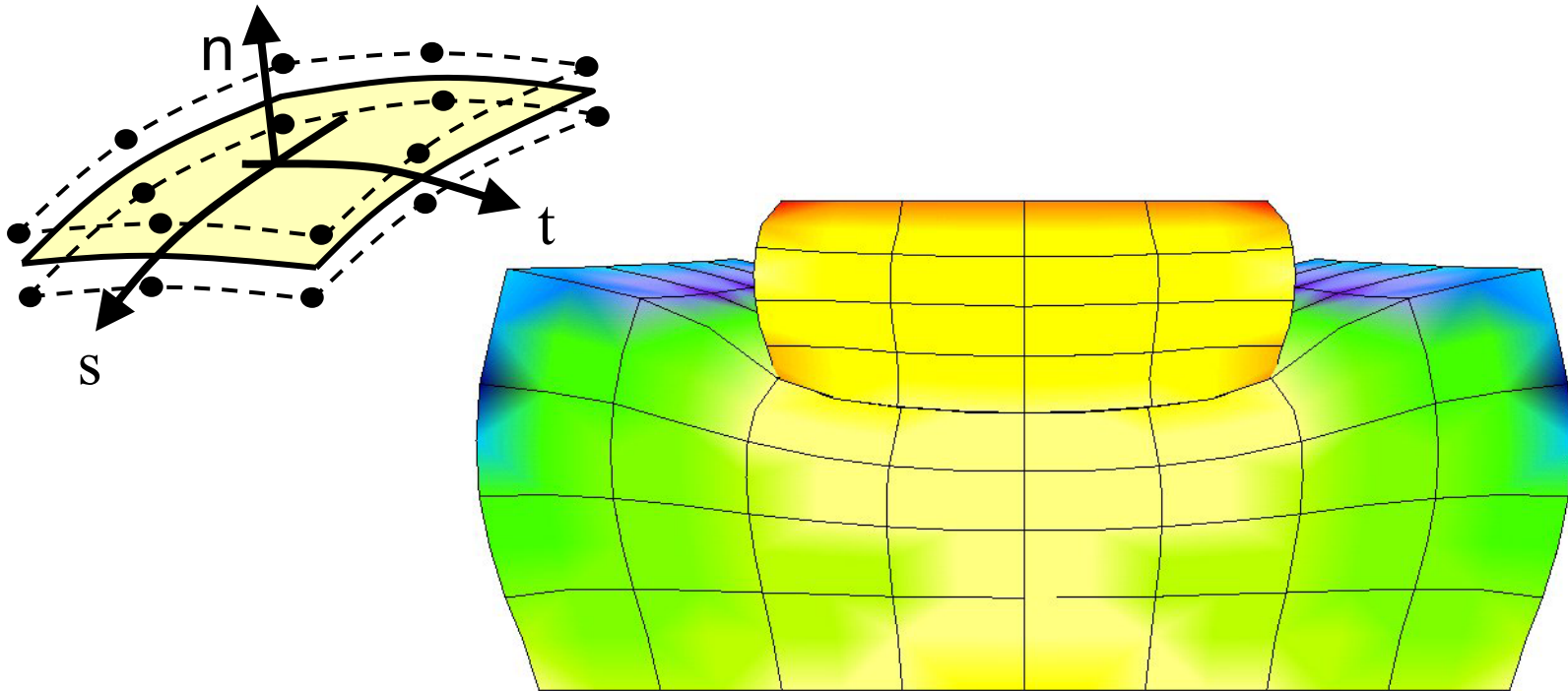
- Interlayer systems

- contact elements



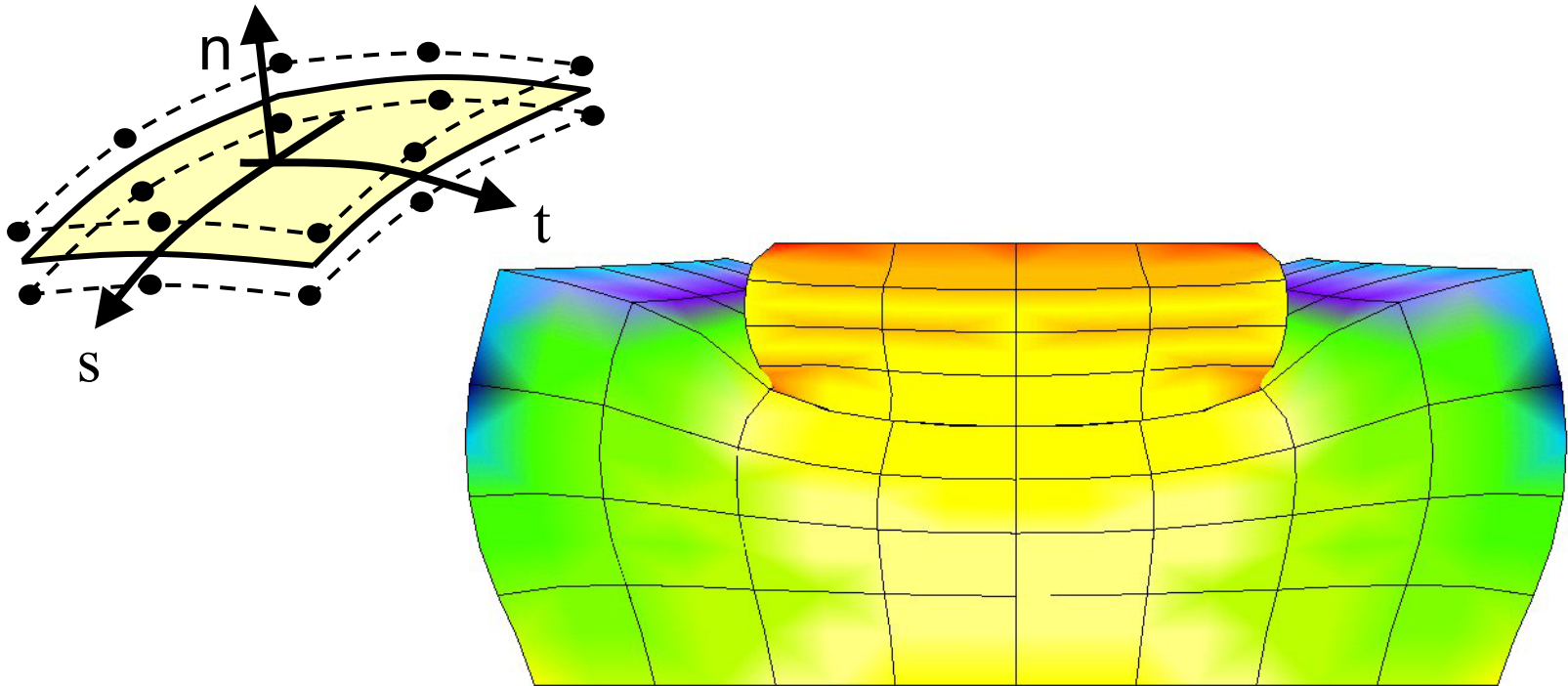
- Interlayer systems

- contact elements



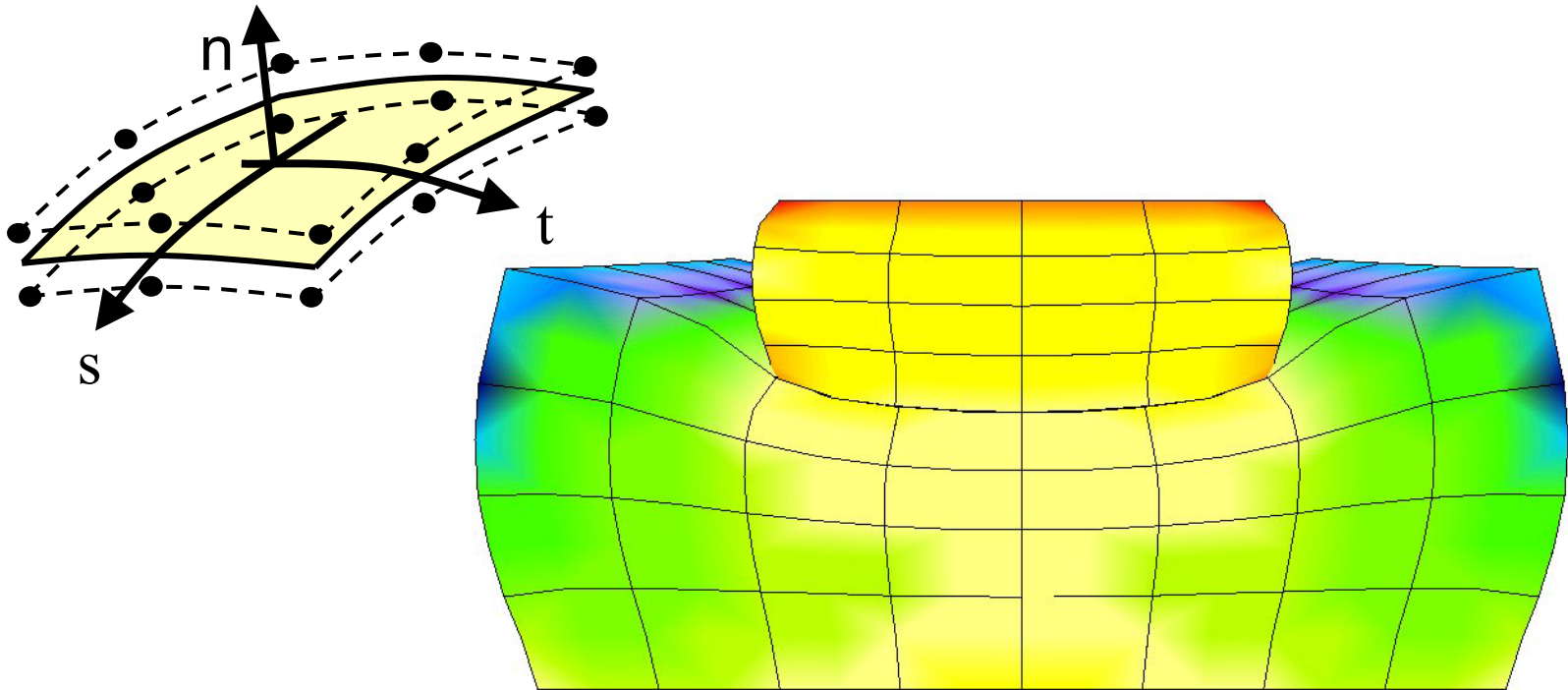
- Interlayer systems

- contact elements



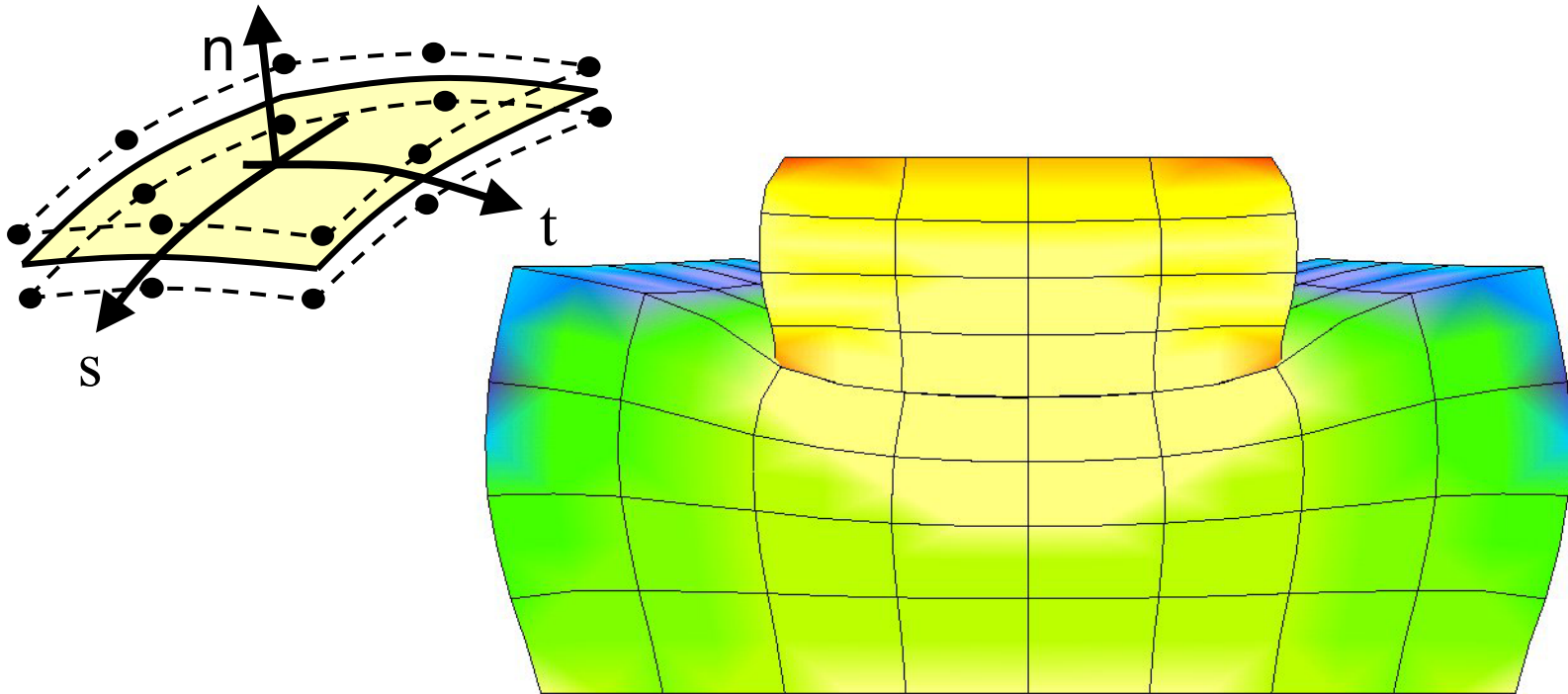
- Interlayer systems

- contact elements



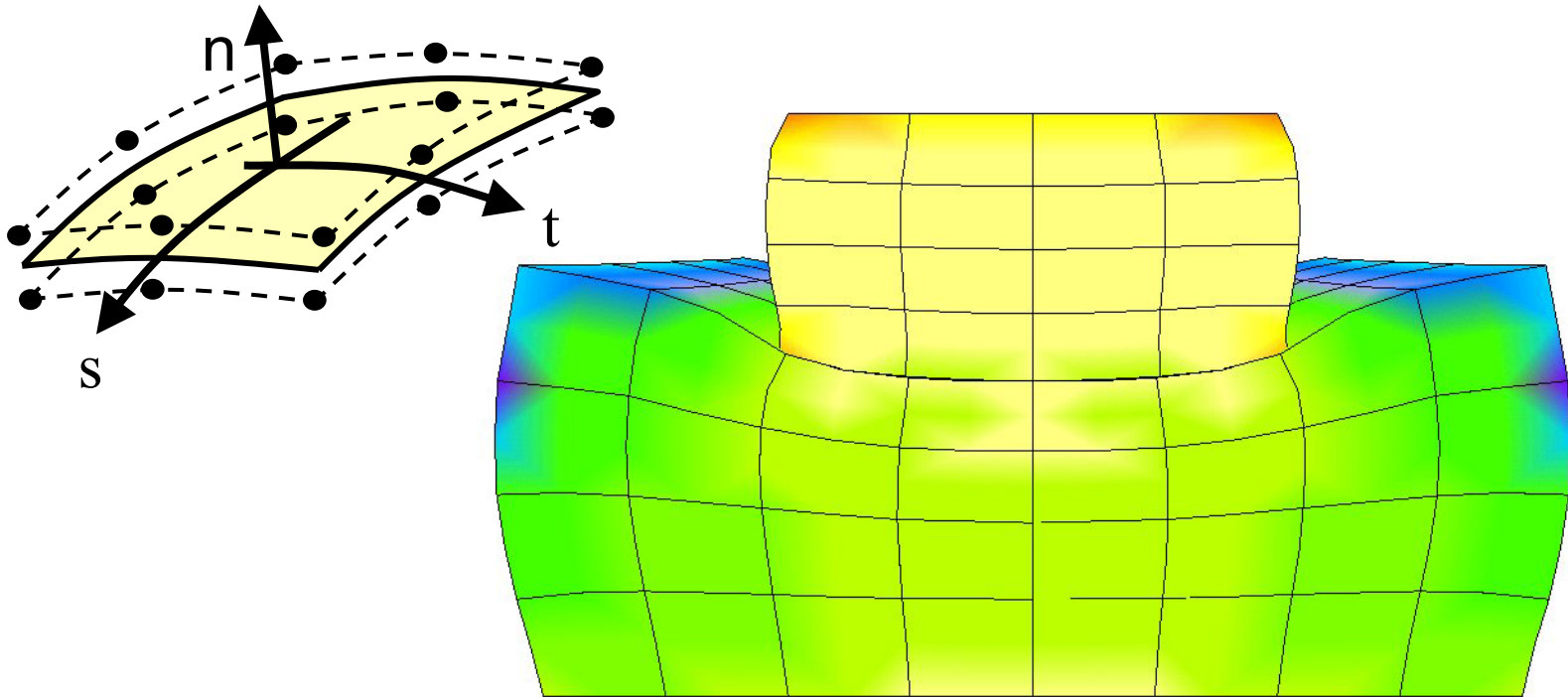
- Interlayer systems

- contact elements



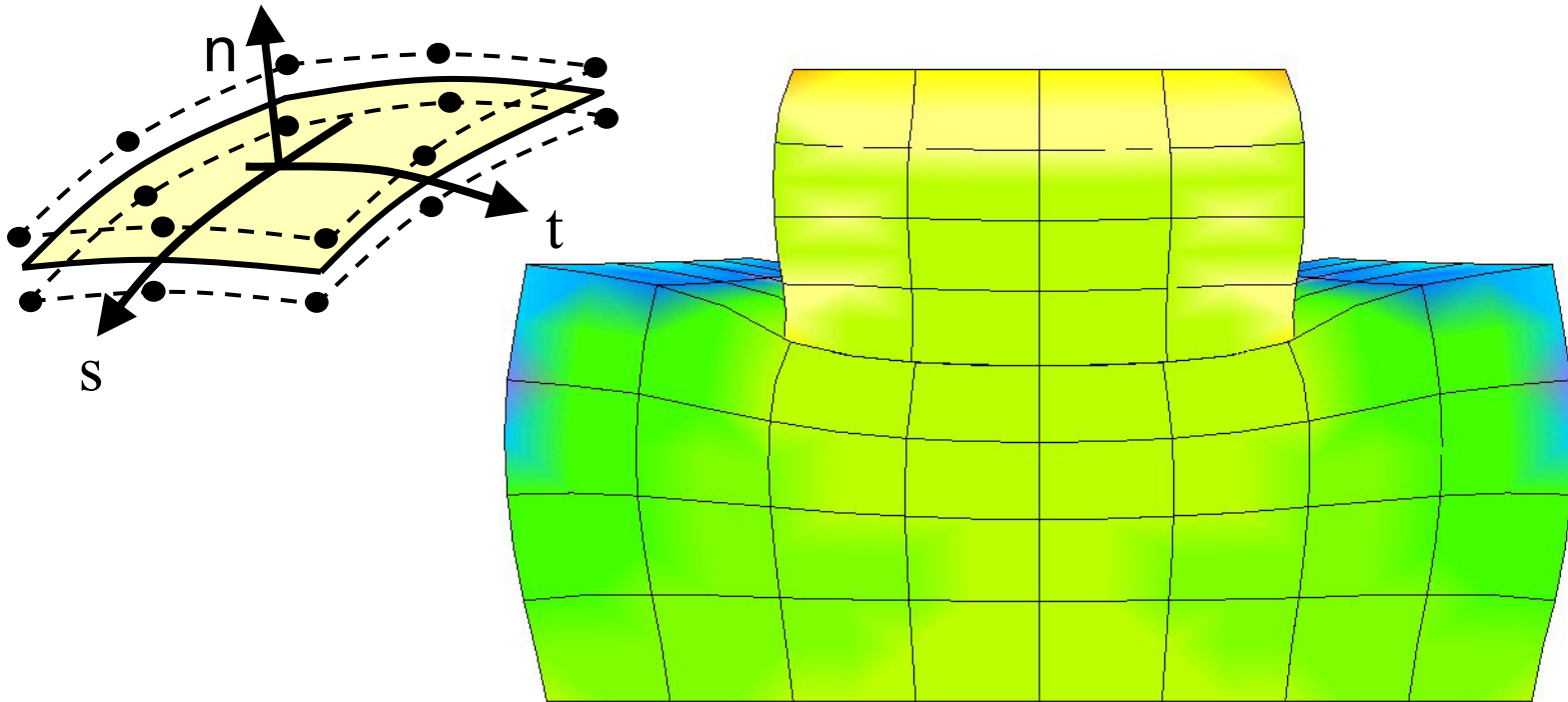
- Interlayer systems

- contact elements



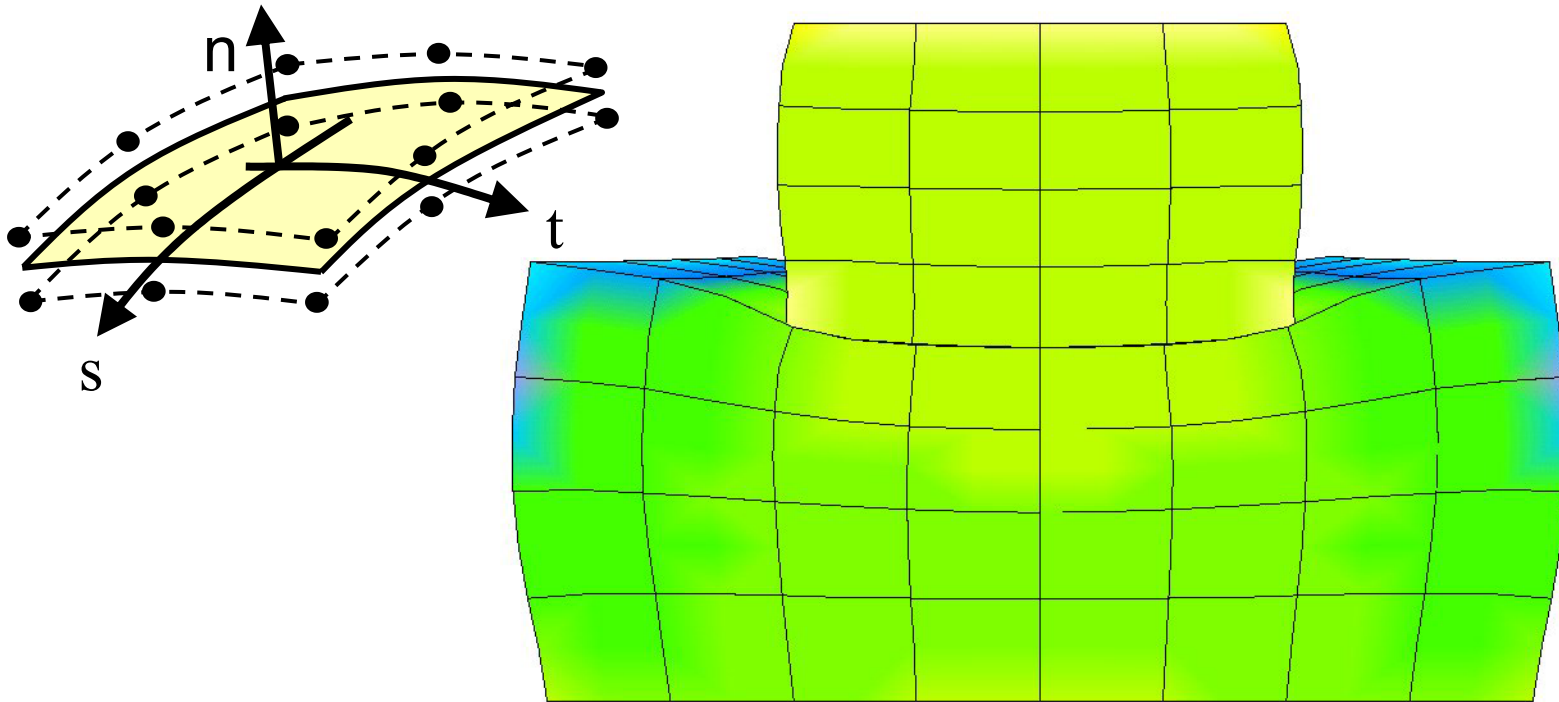
- Interlayer systems

- contact elements



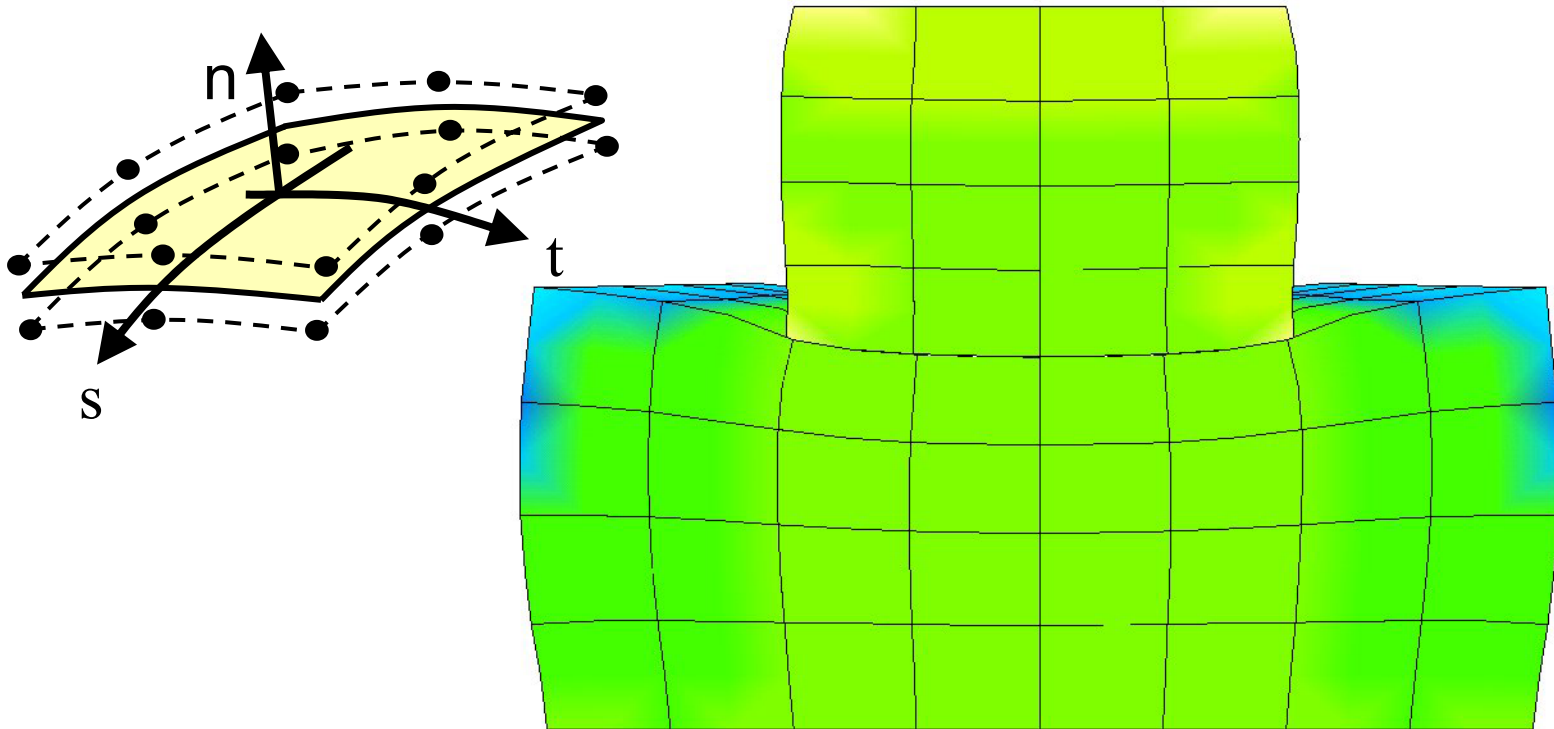
- Interlayer systems

- contact elements



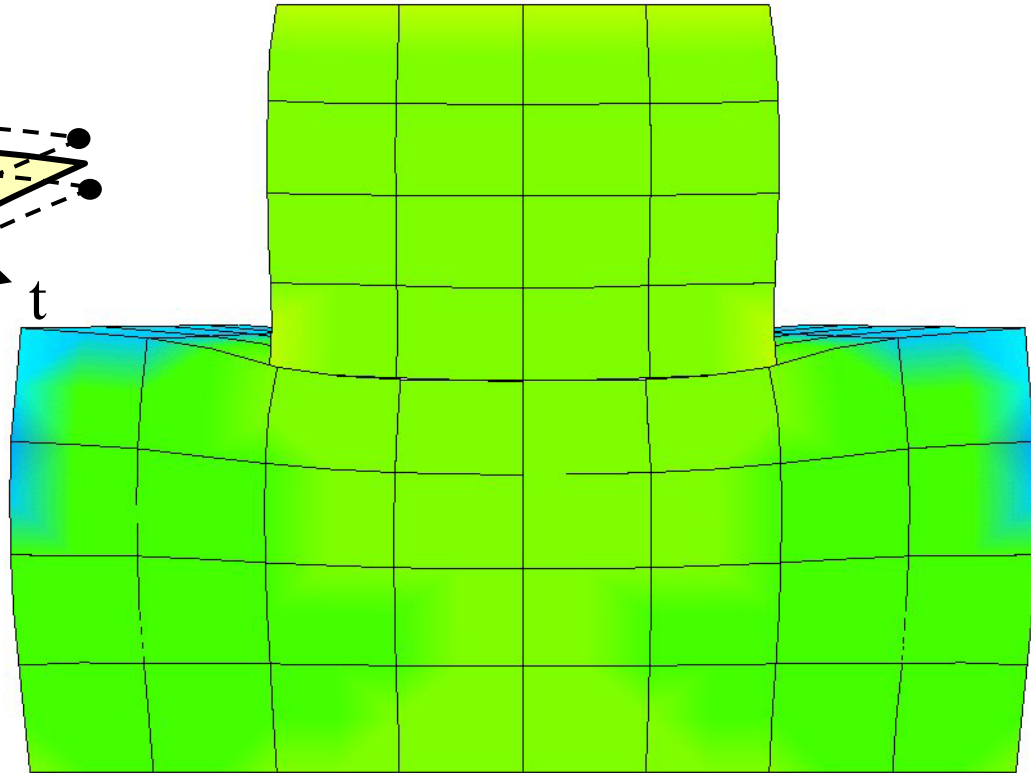
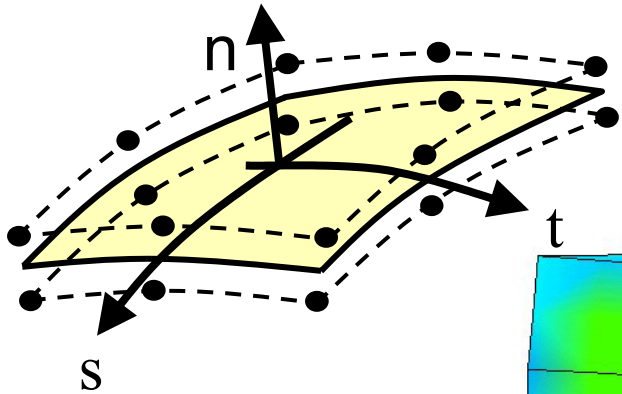
- Interlayer systems

- contact elements



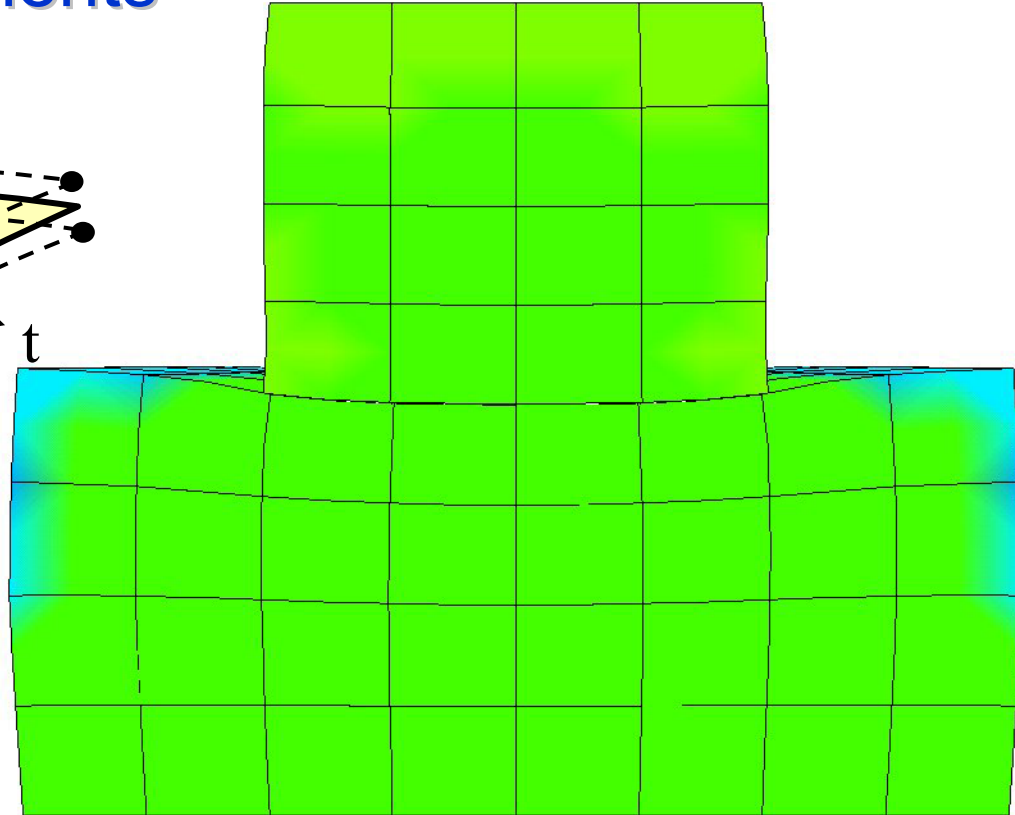
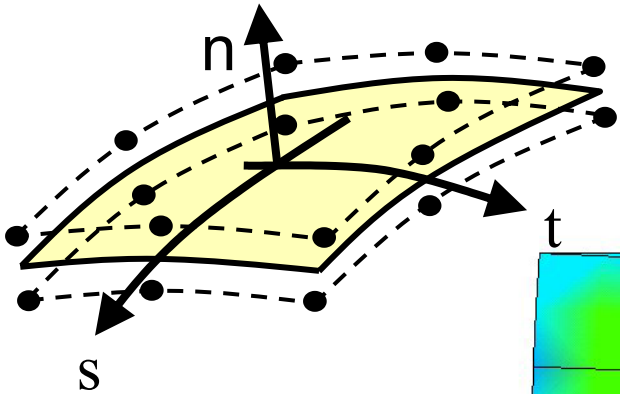
- Interlayer systems

- contact elements



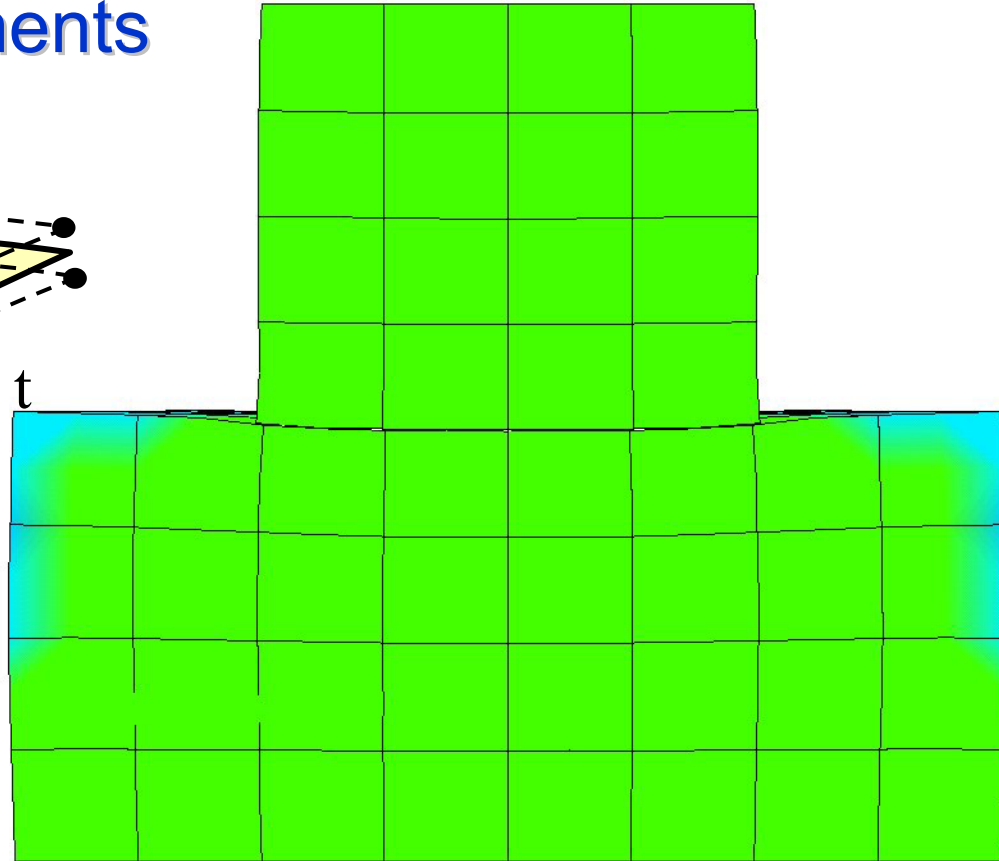
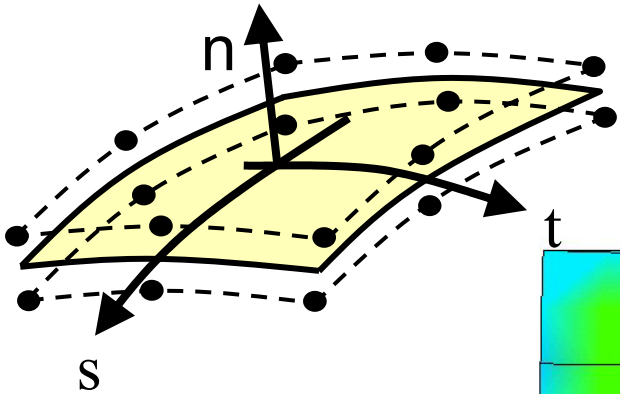
- Interlayer systems

- contact elements



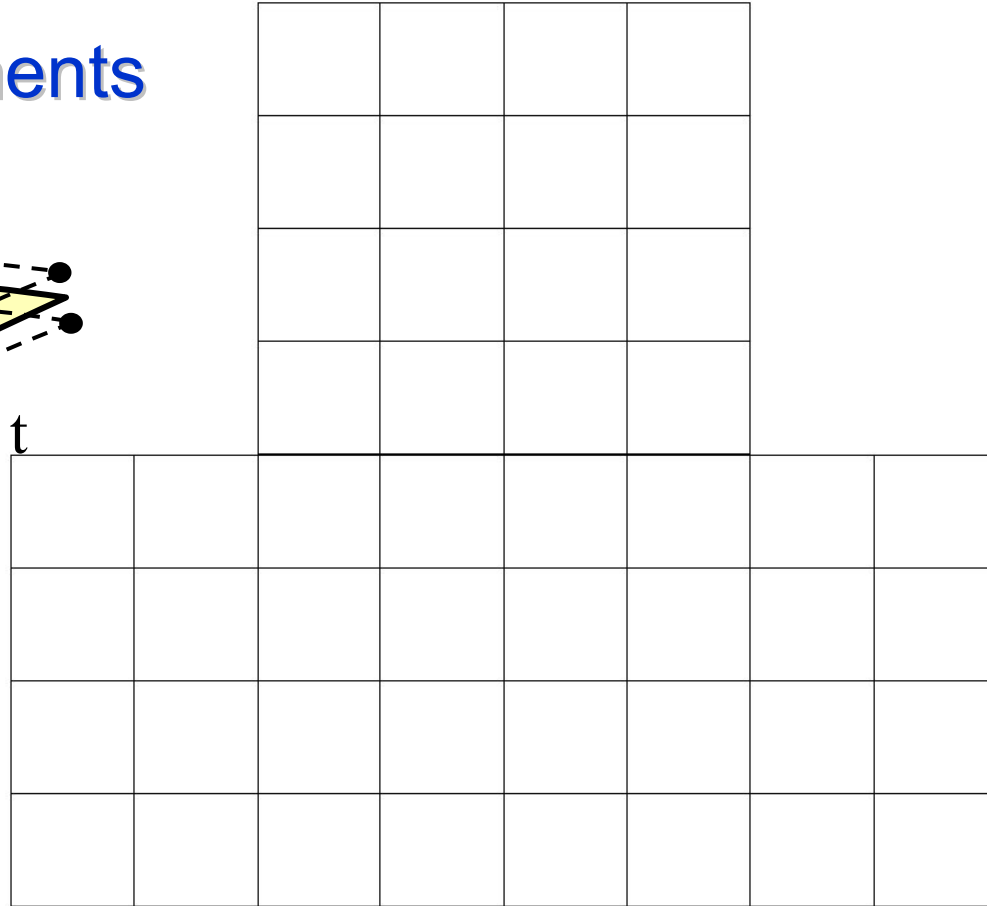
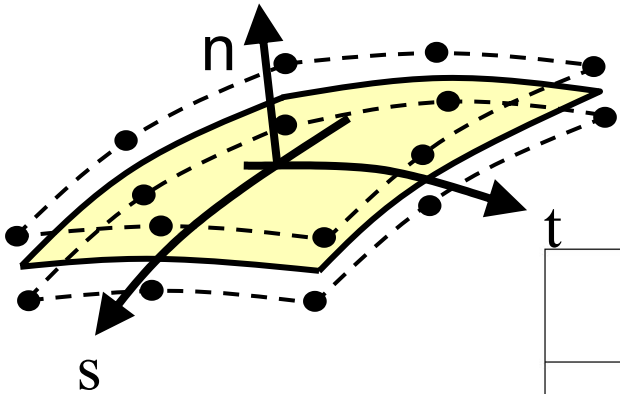
- Interlayer systems

- contact elements



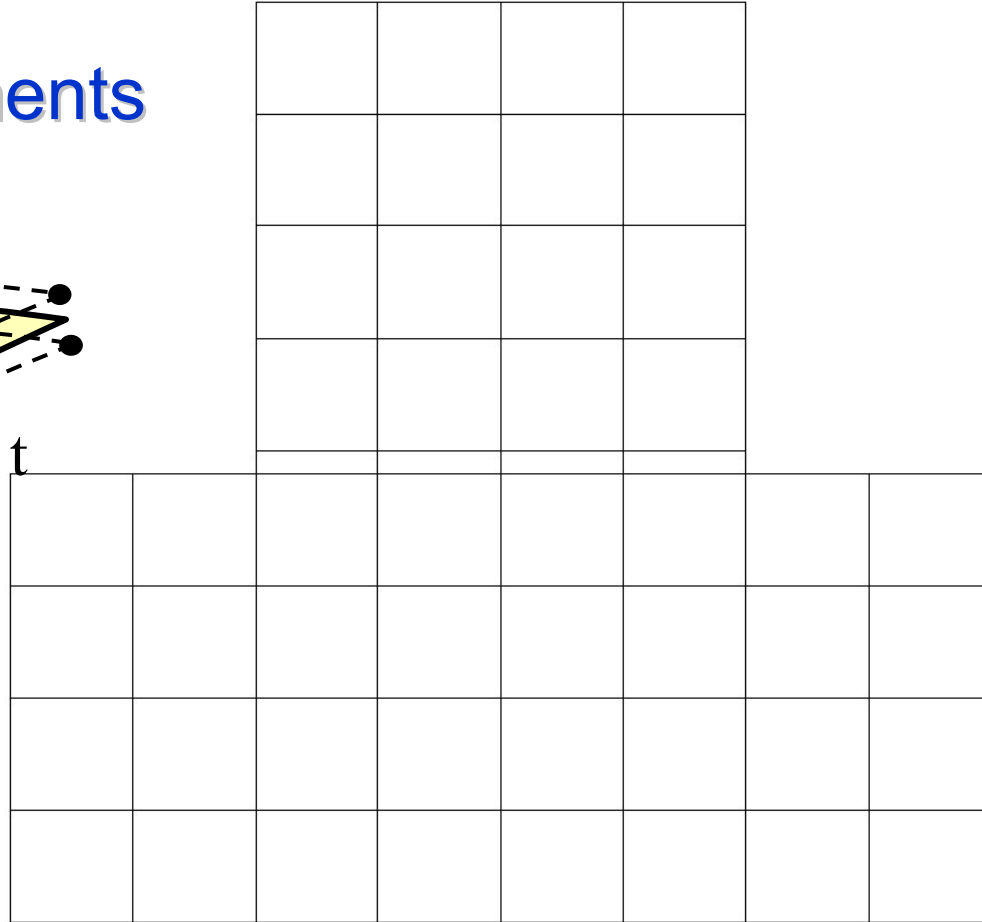
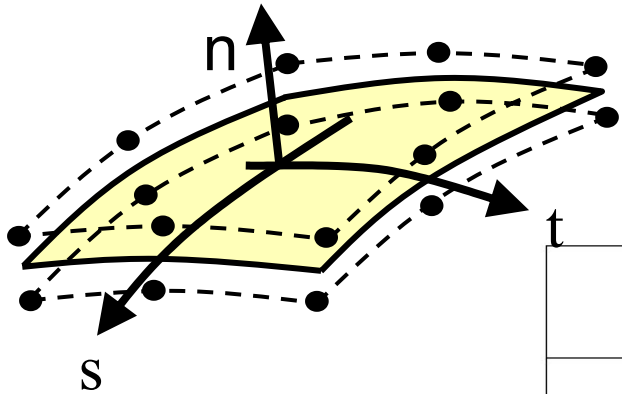
- Interlayer systems

- contact elements



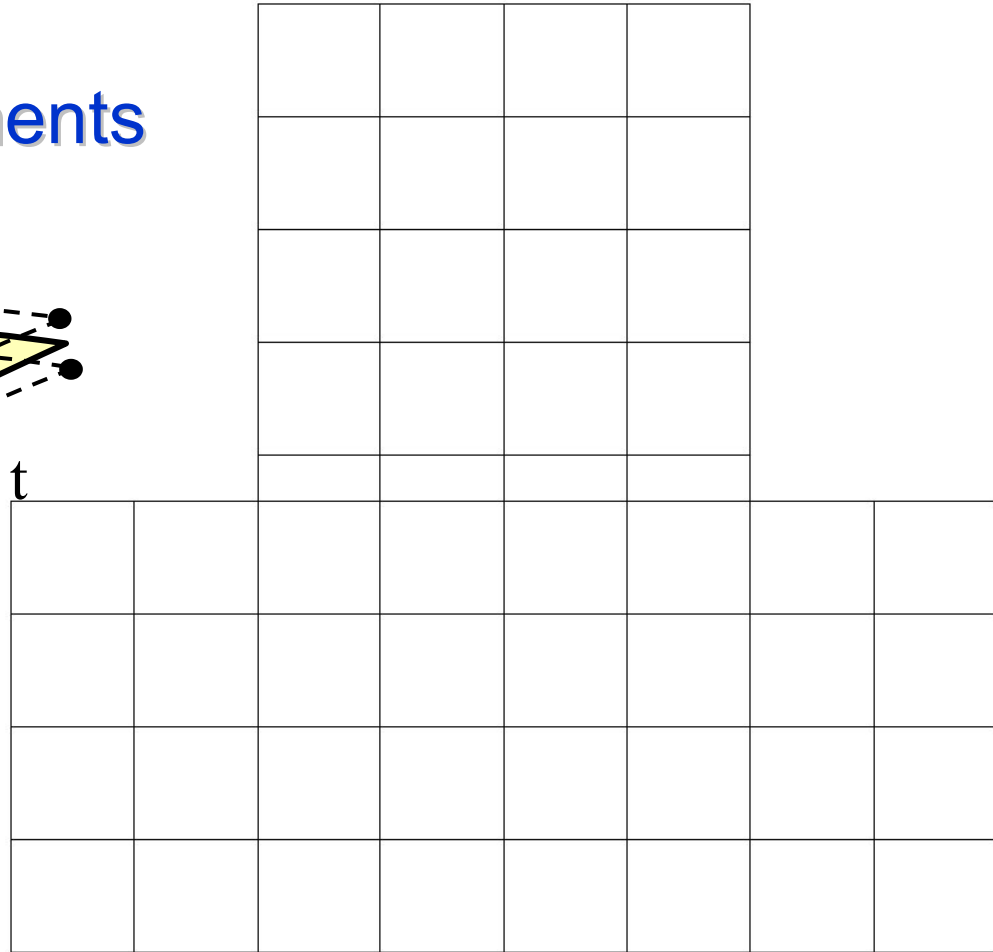
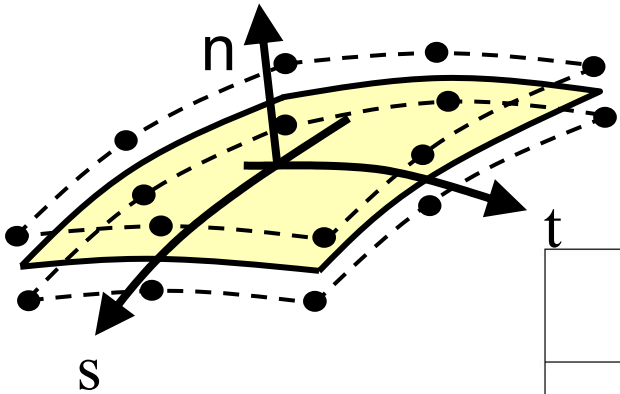
- Interlayer systems

- contact elements



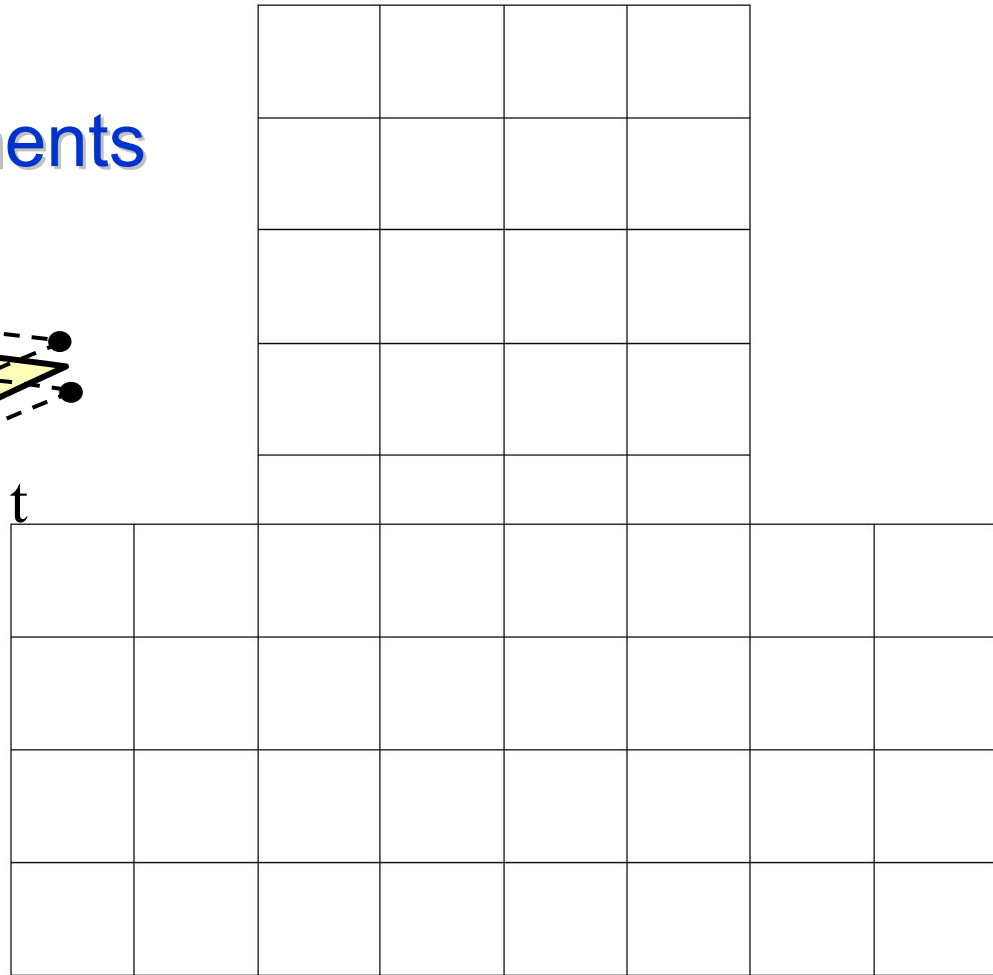
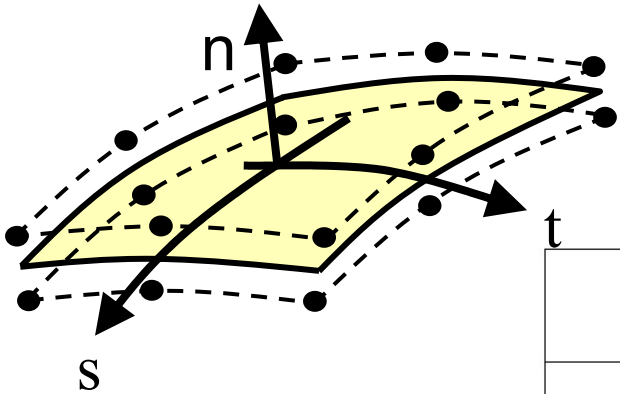
- Interlayer systems

- contact elements

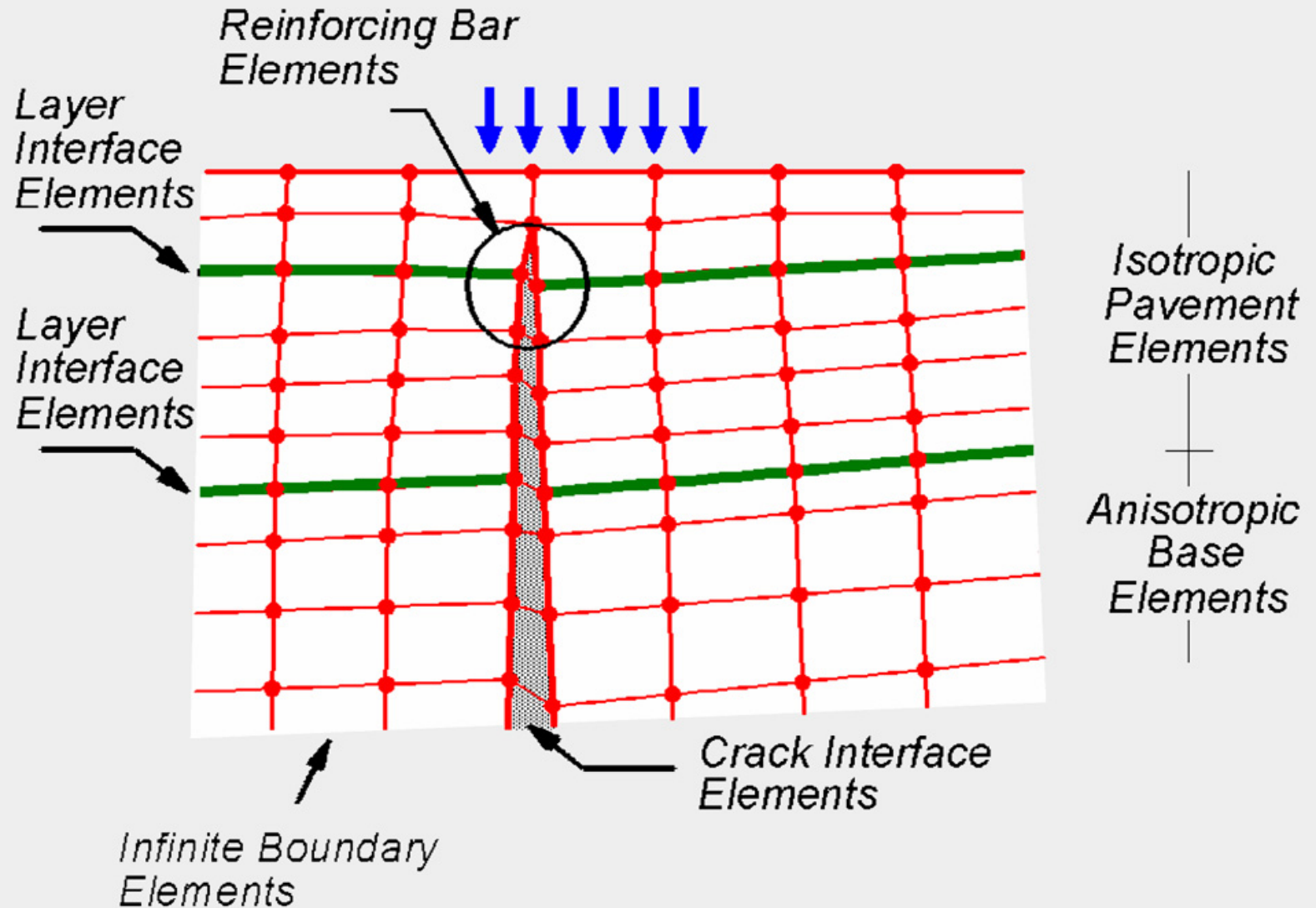


- Interlayer systems

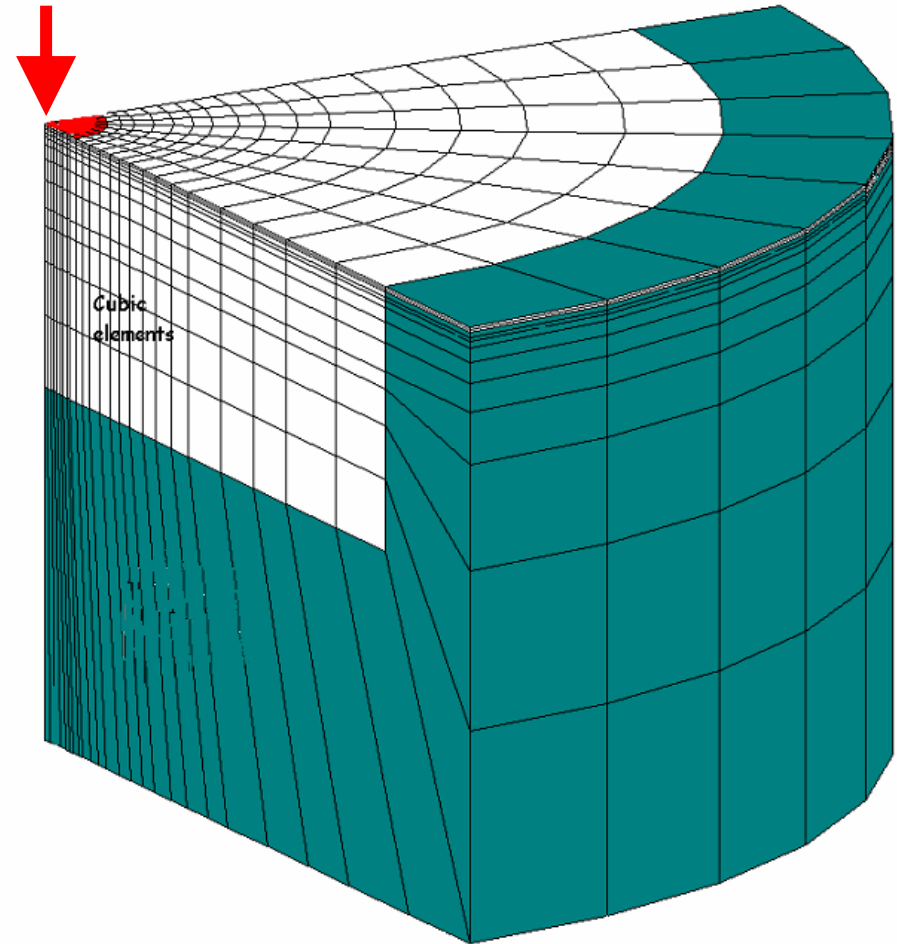
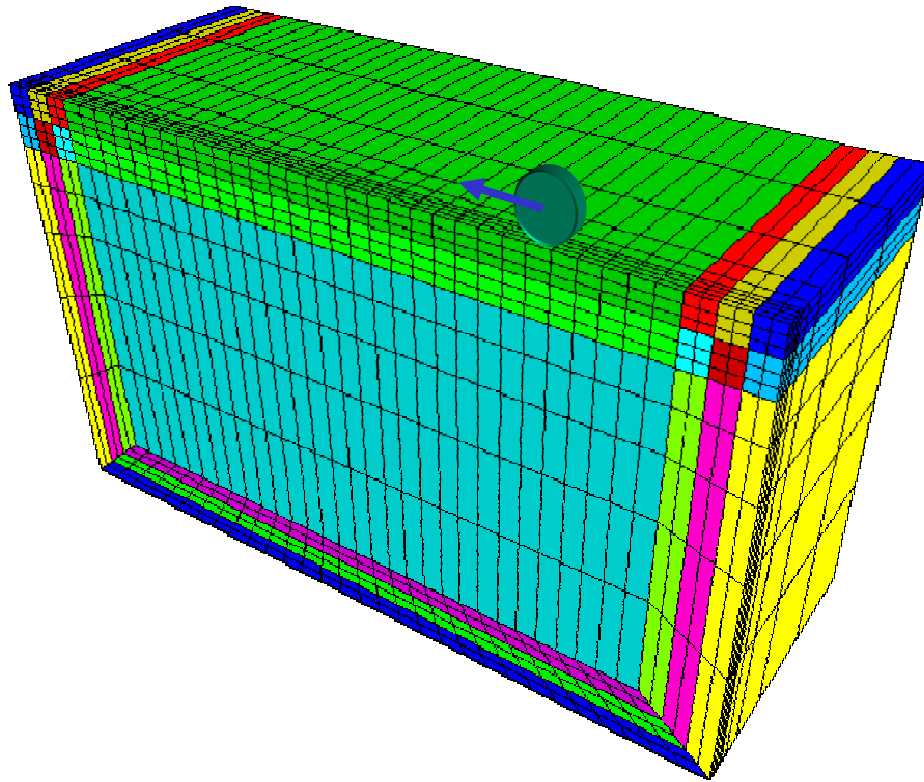
- contact elements



- the simulation problem: infinite systems

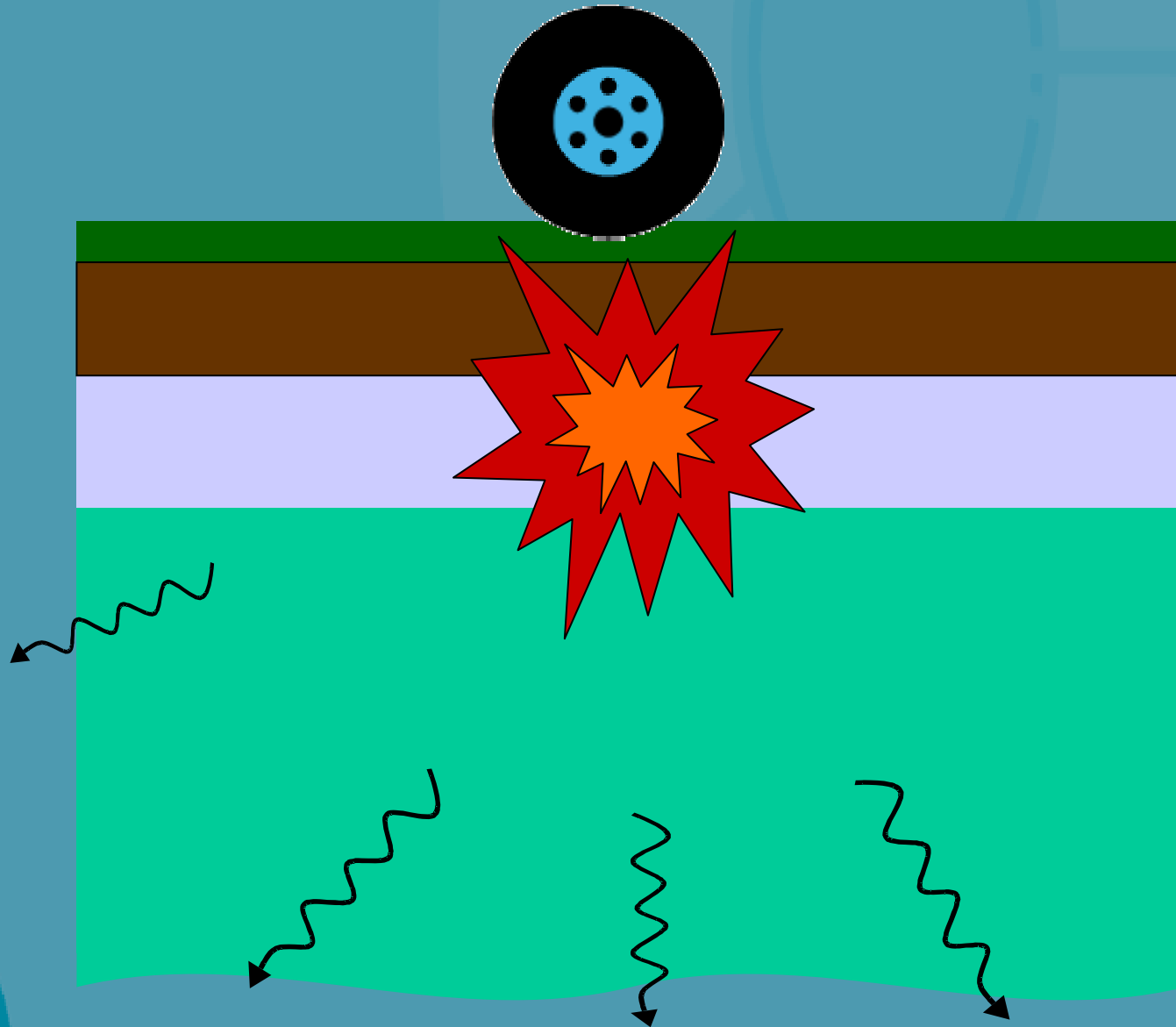


- infinite systems

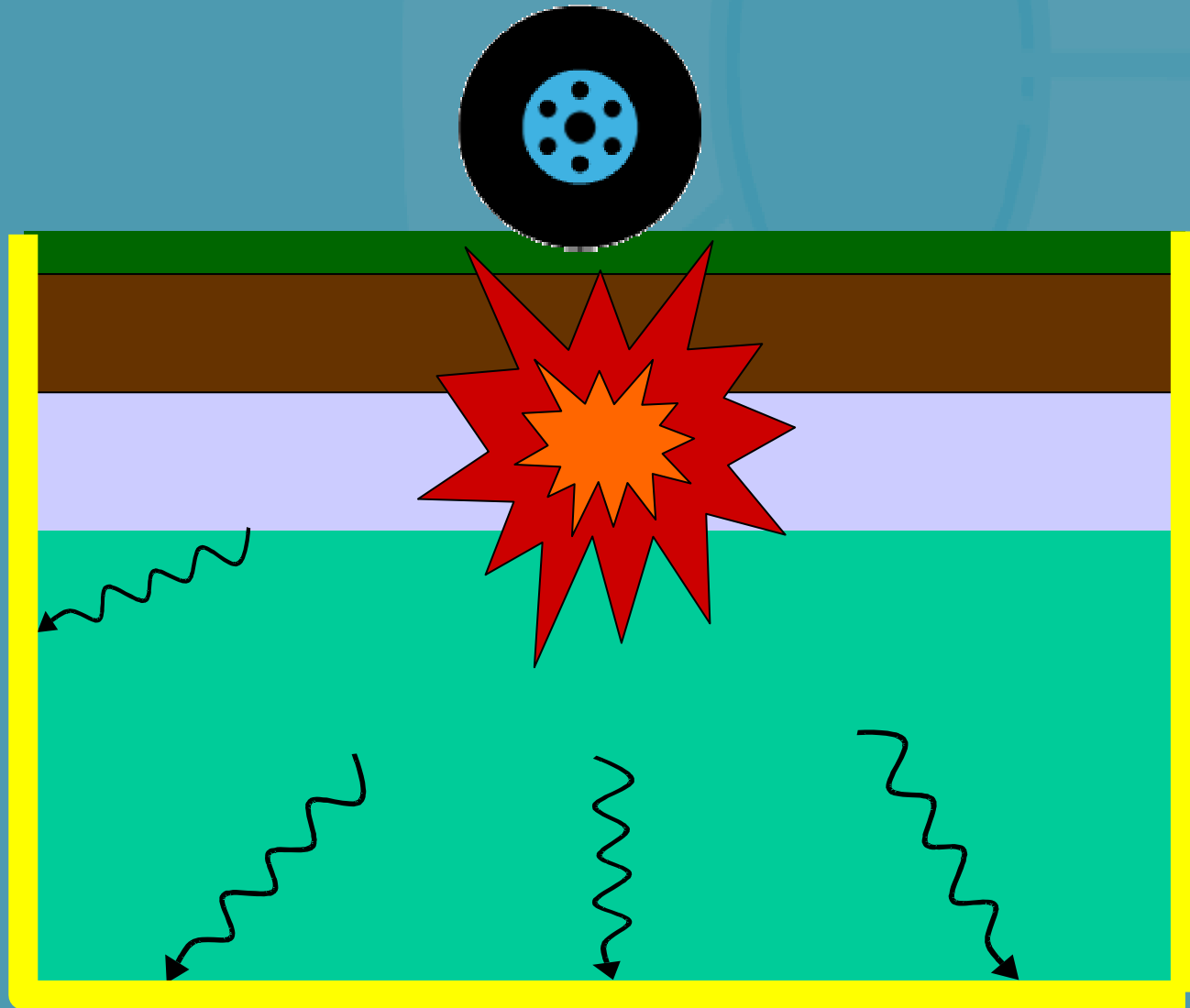


- moving load problem - falling weight simulation

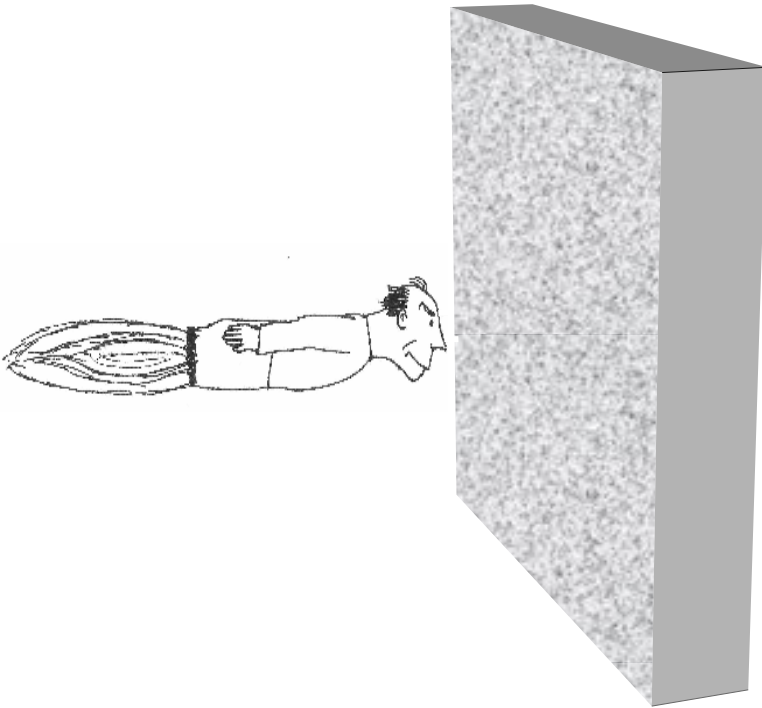
- infinite systems



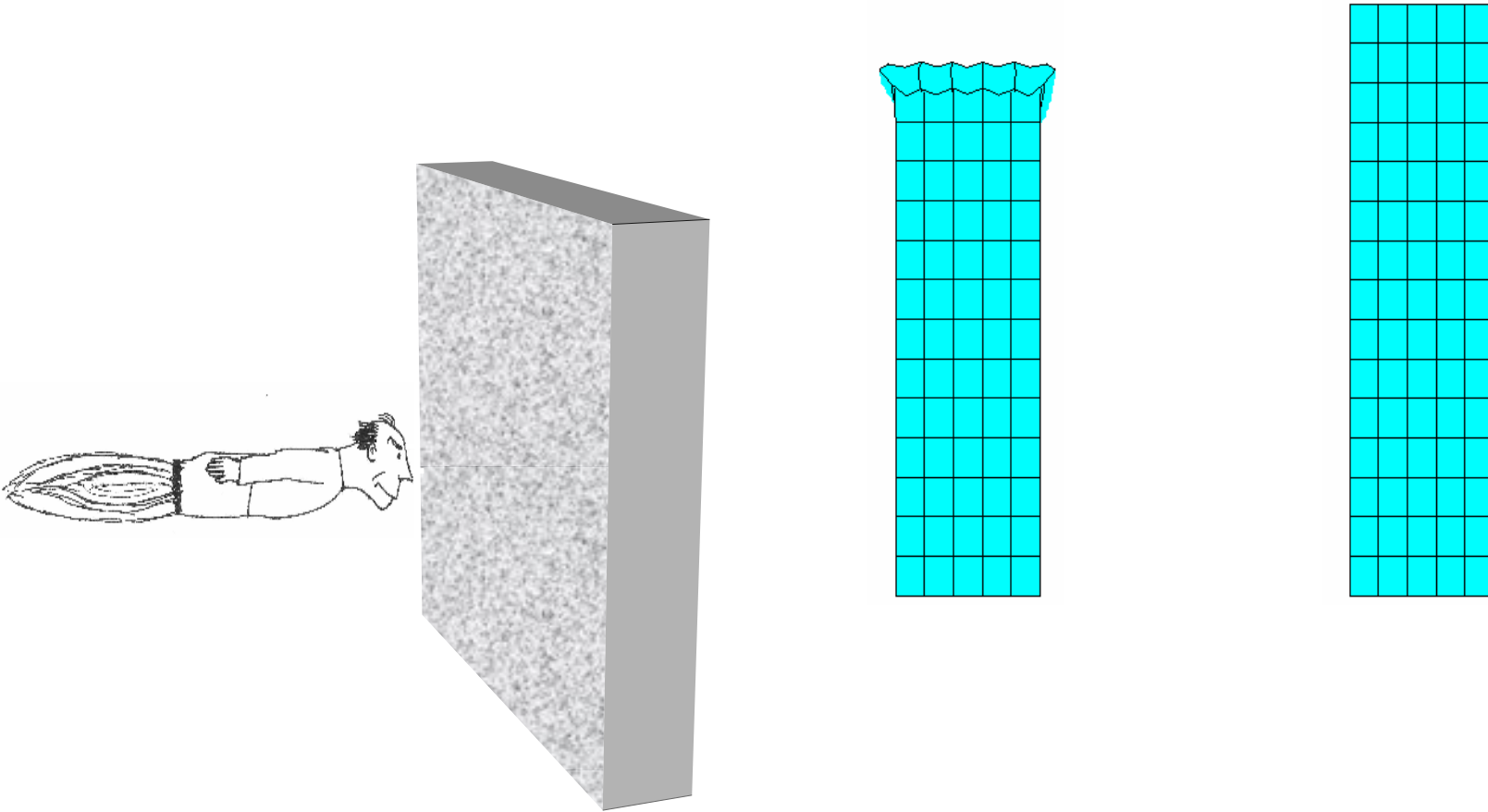
- infinite systems



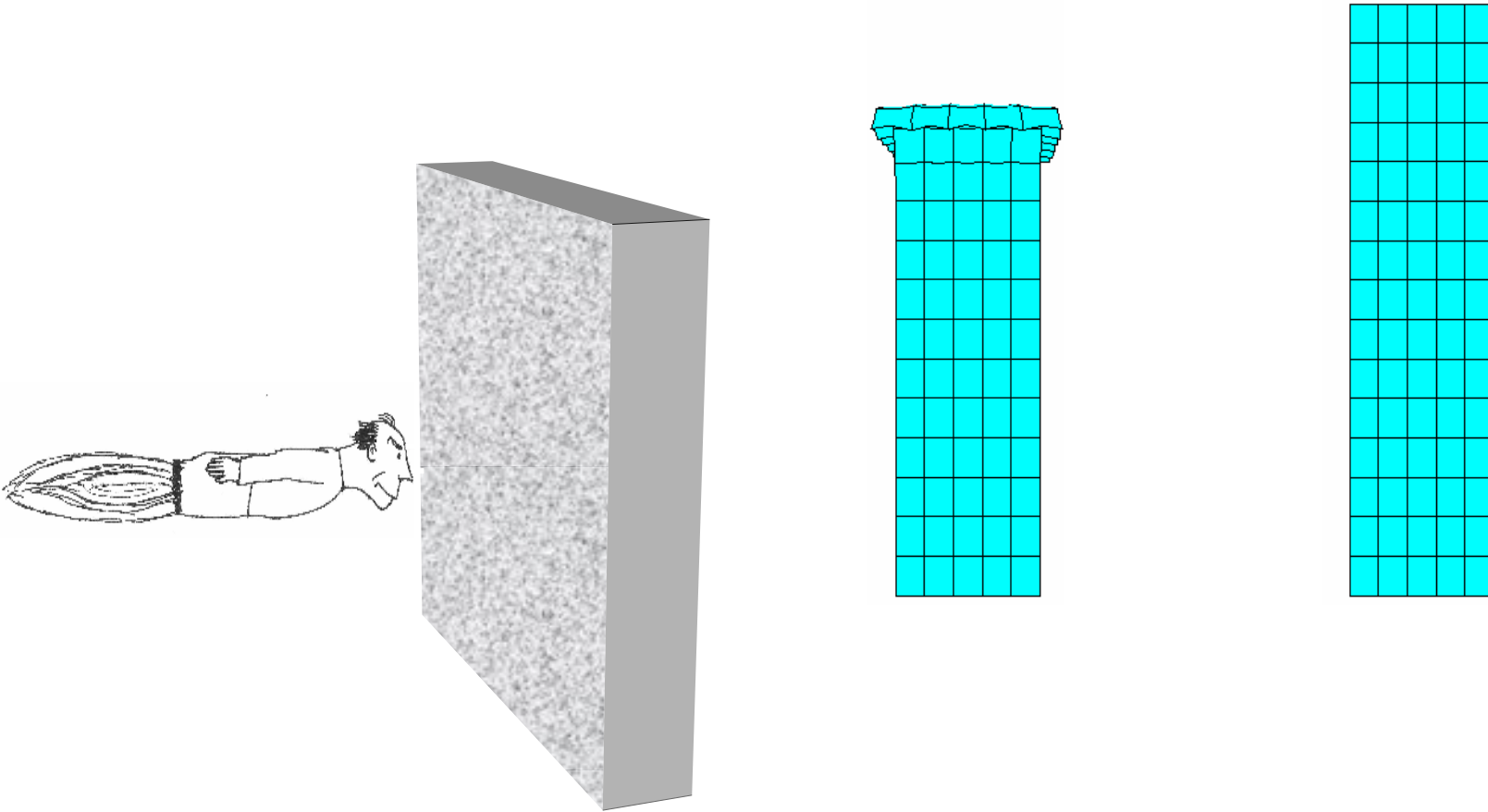
- Wave dissipation techniques
 - rigid boundaries



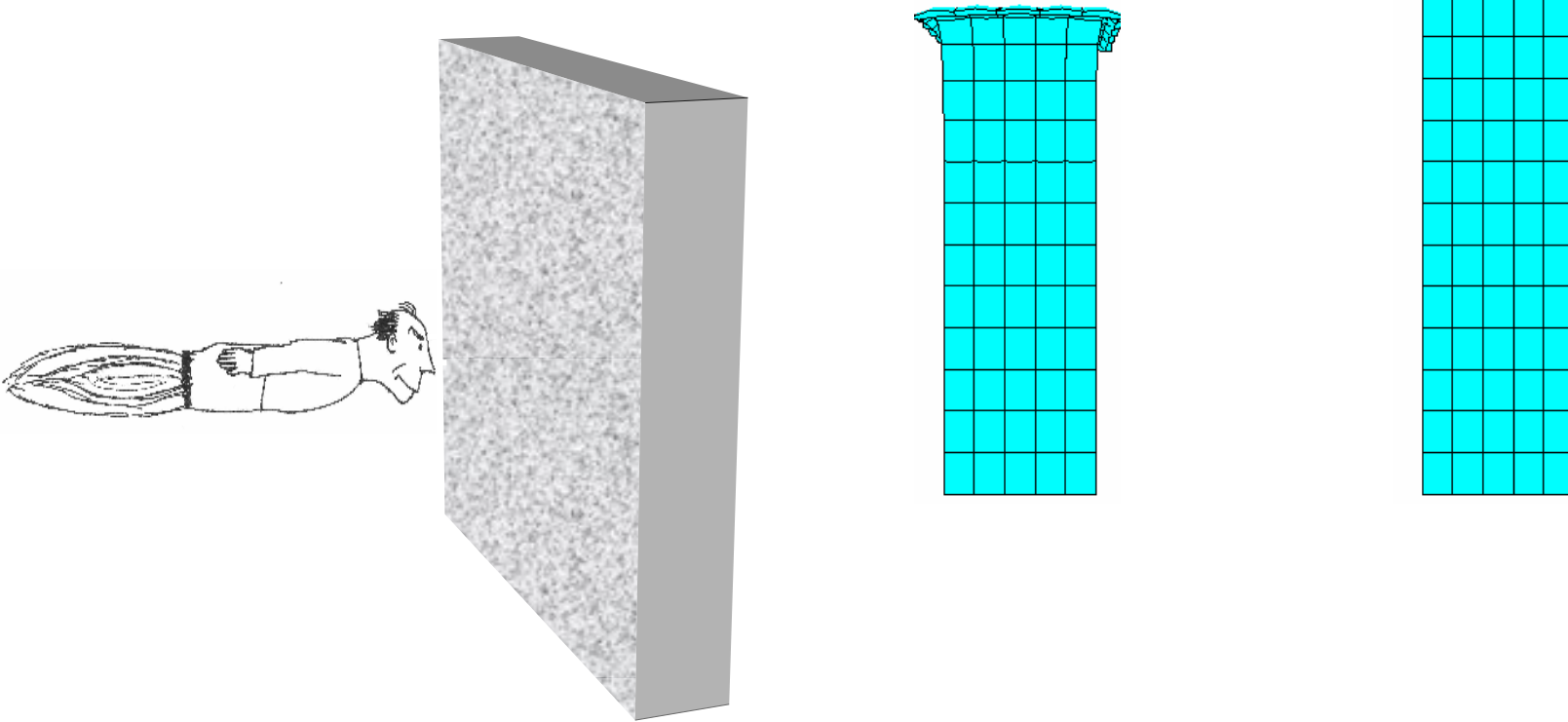
- Wave dissipation techniques
 - rigid boundaries



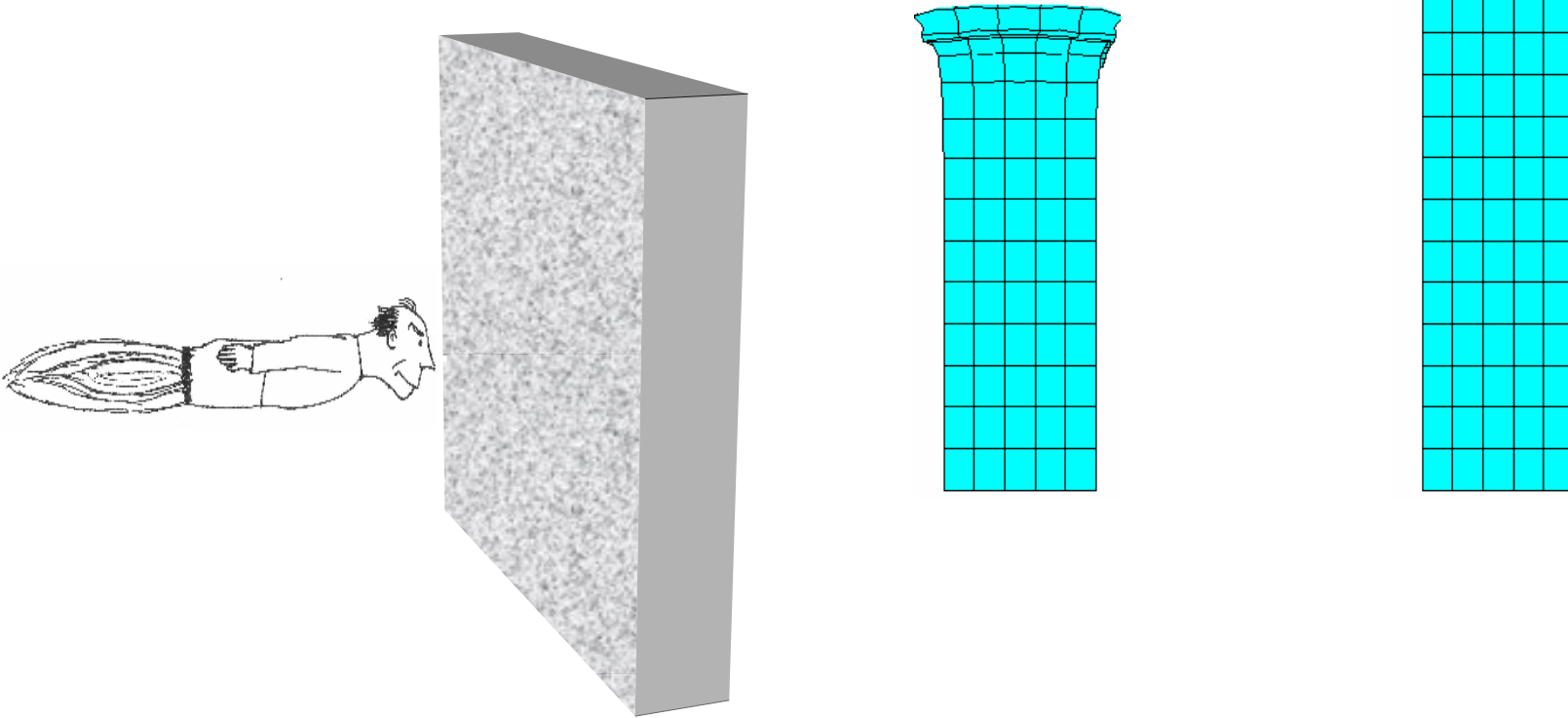
- Wave dissipation techniques
 - rigid boundaries



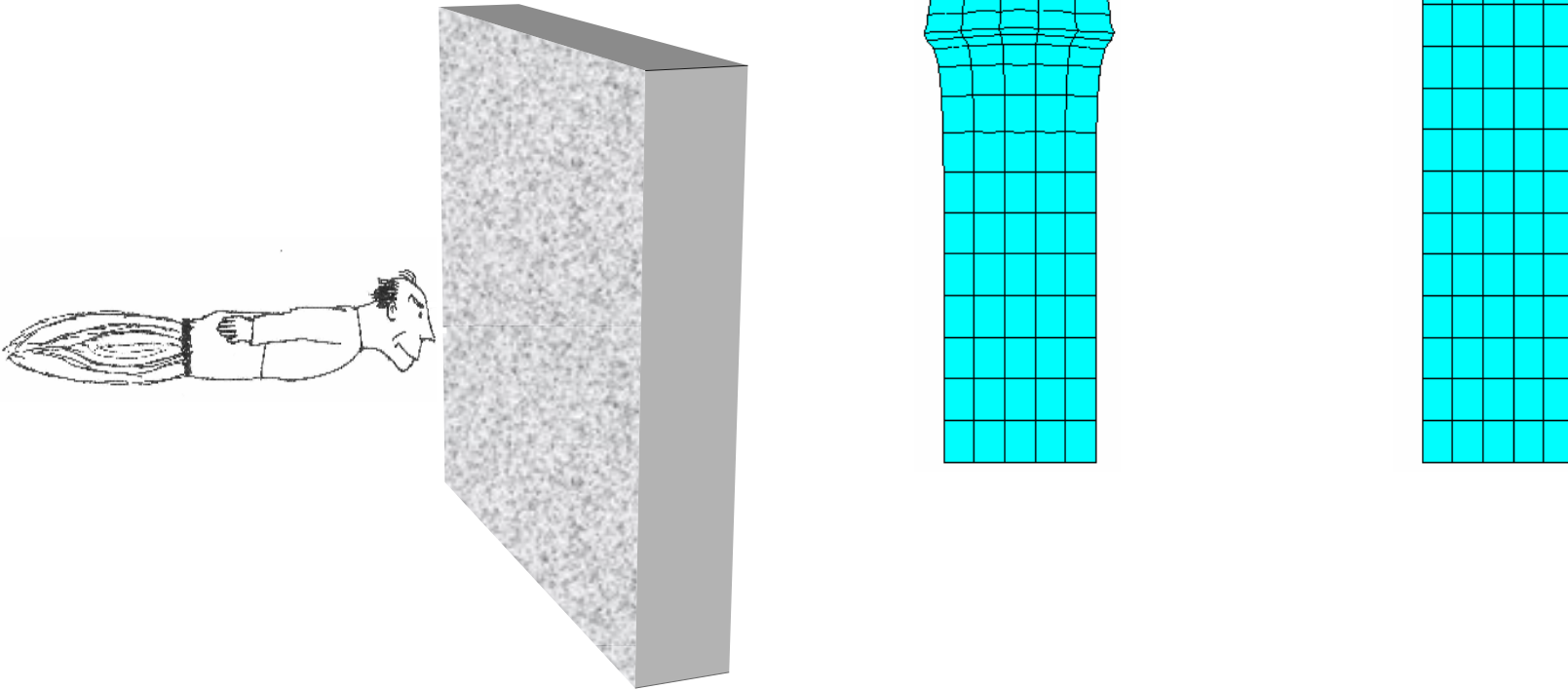
- Wave dissipation techniques
 - rigid boundaries



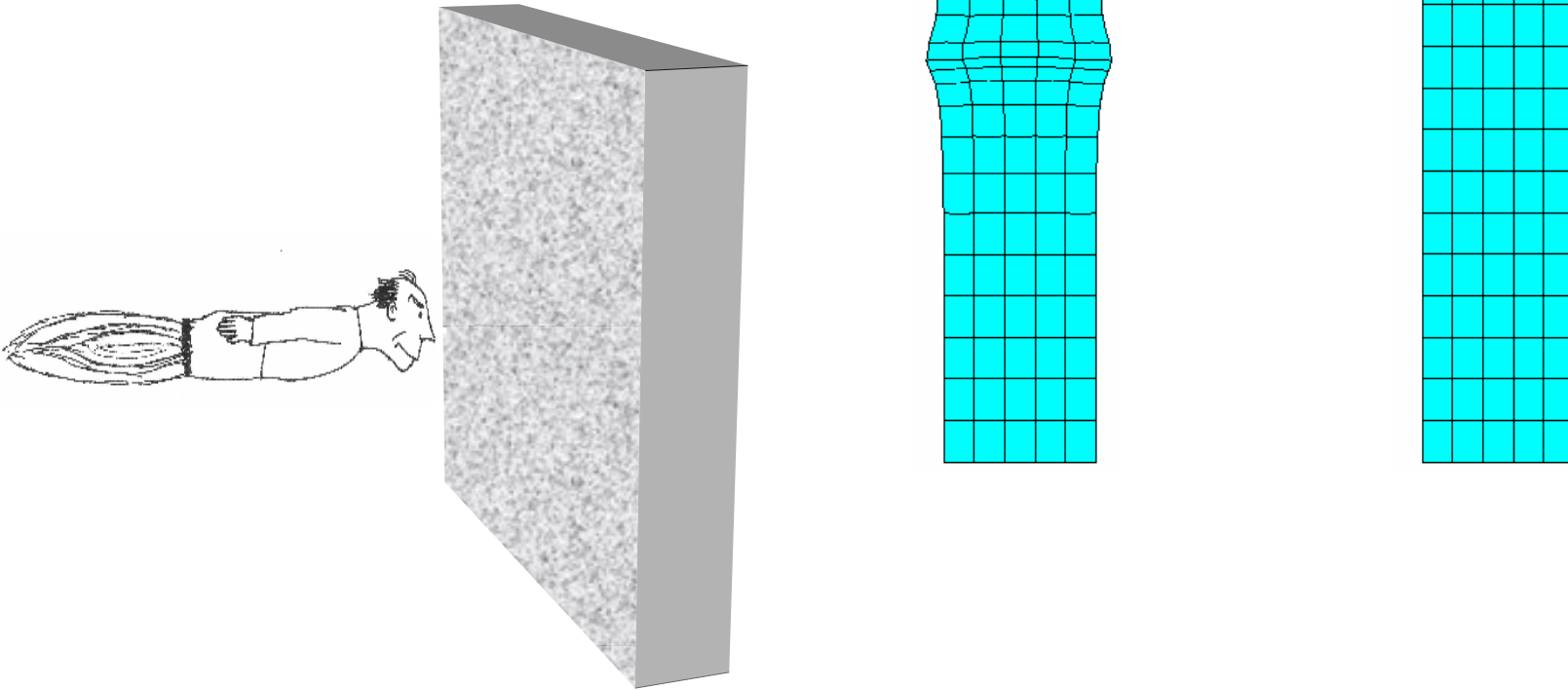
- Wave dissipation techniques
 - rigid boundaries



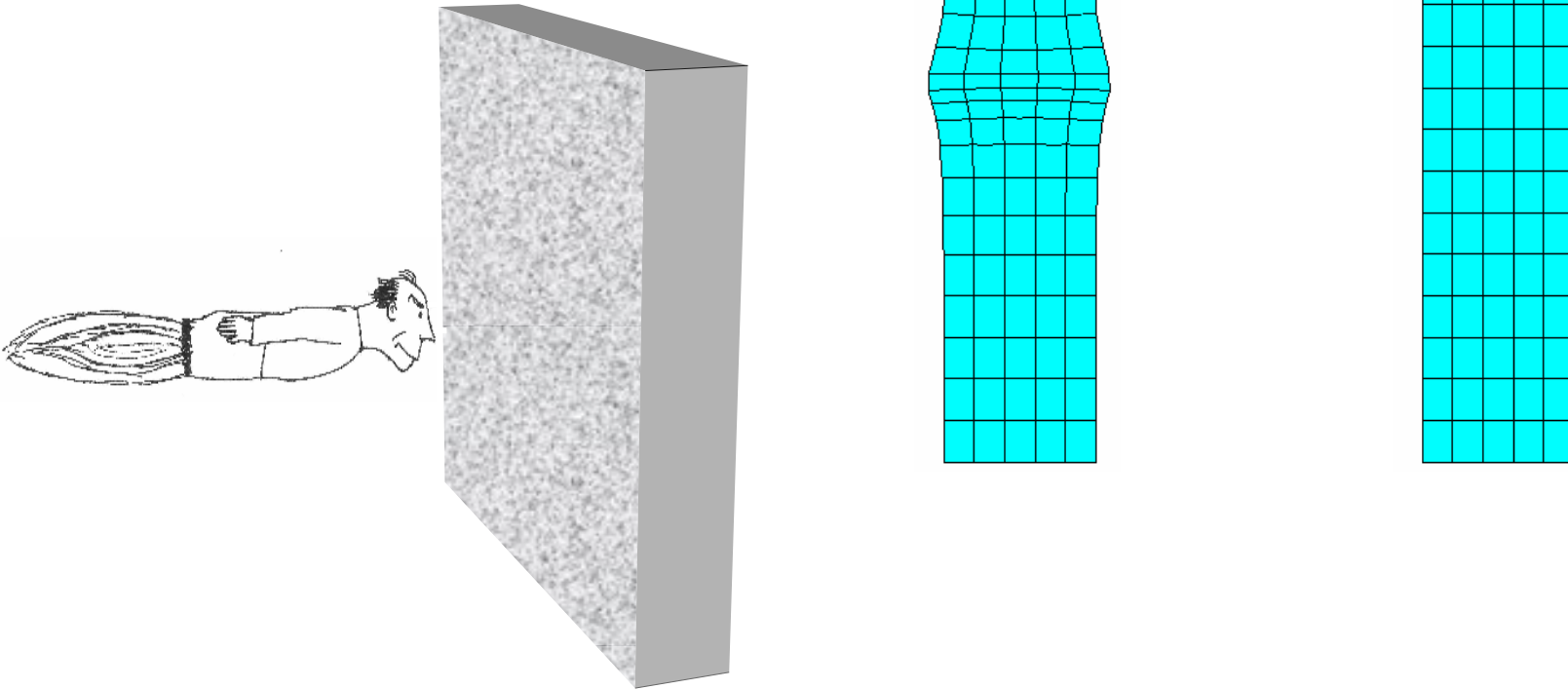
- Wave dissipation techniques
 - rigid boundaries



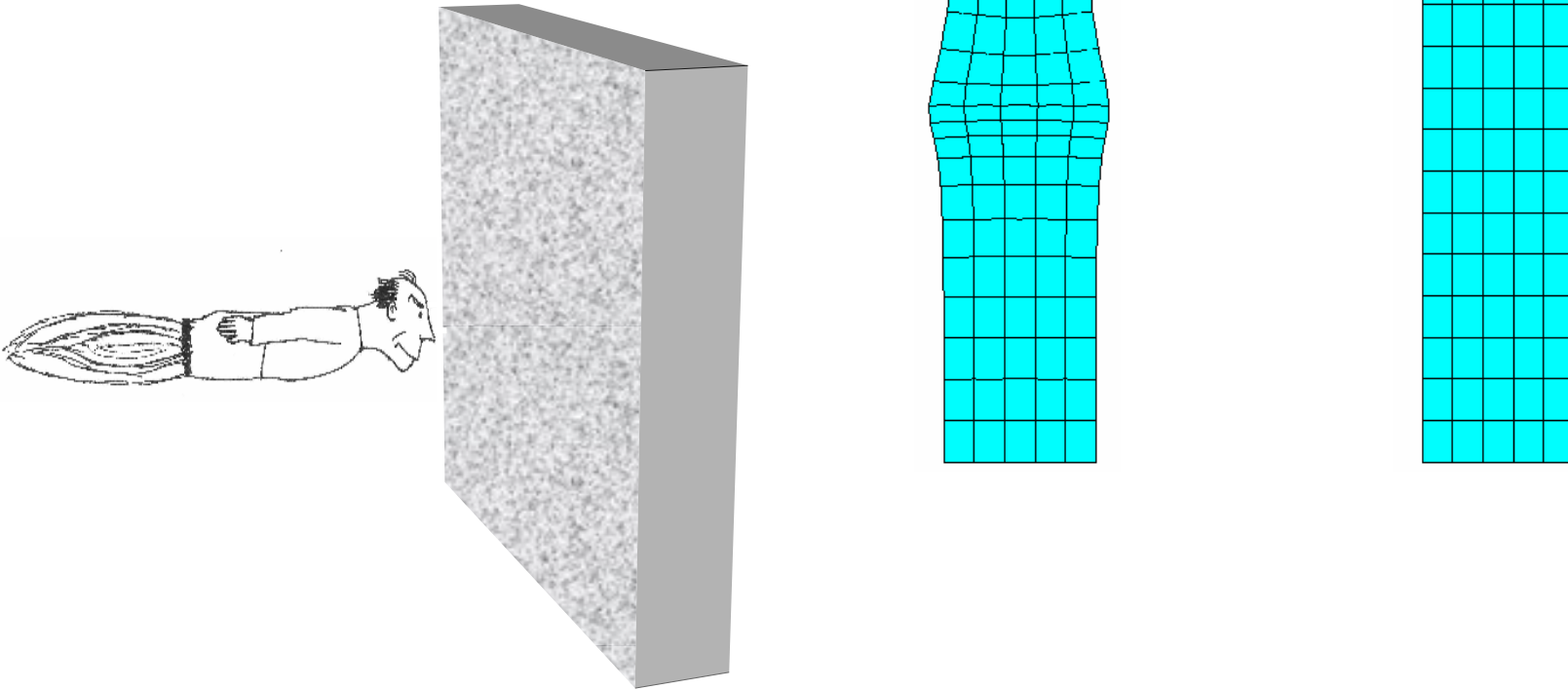
- Wave dissipation techniques
 - rigid boundaries



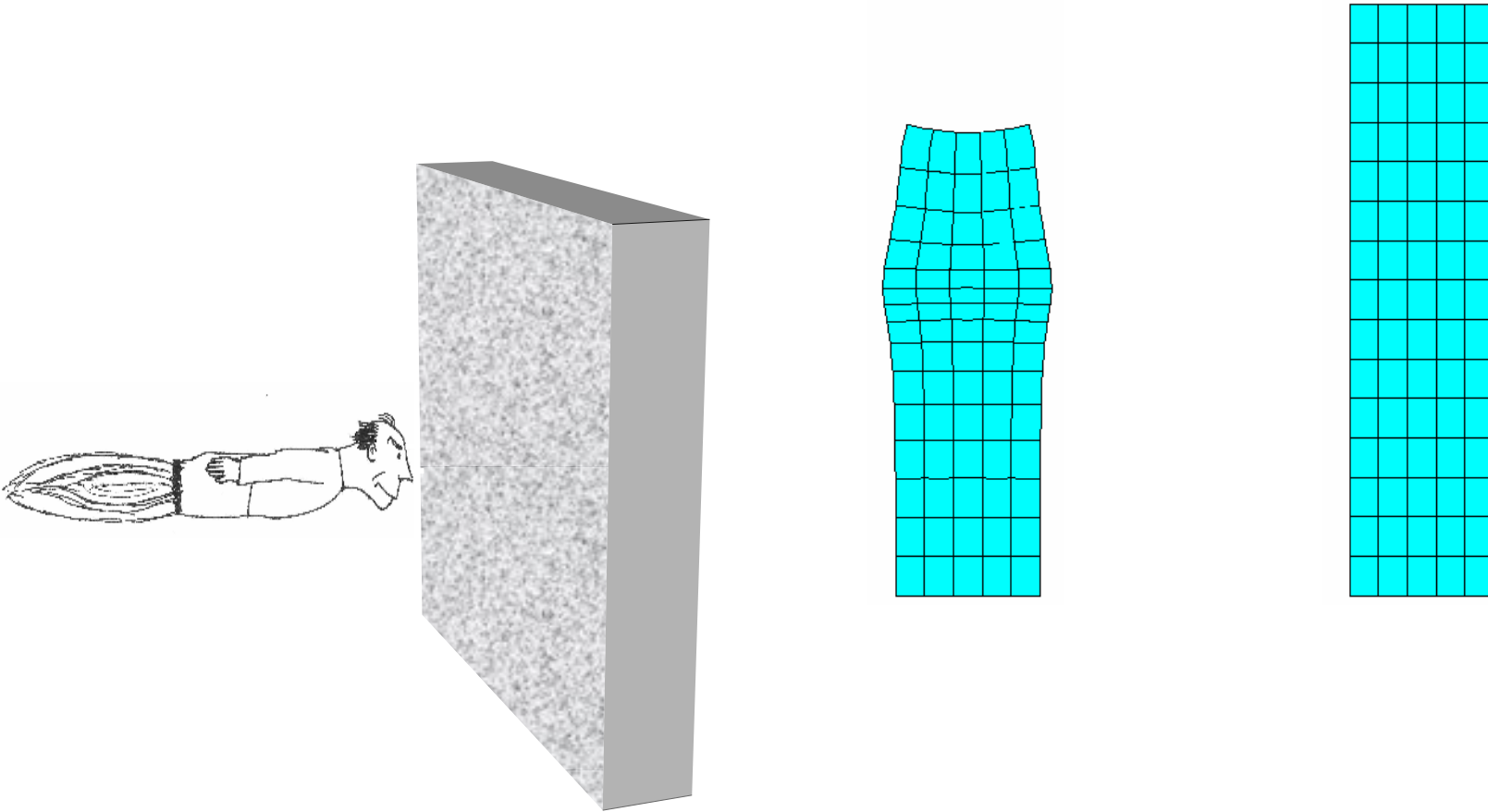
- Wave dissipation techniques
 - rigid boundaries



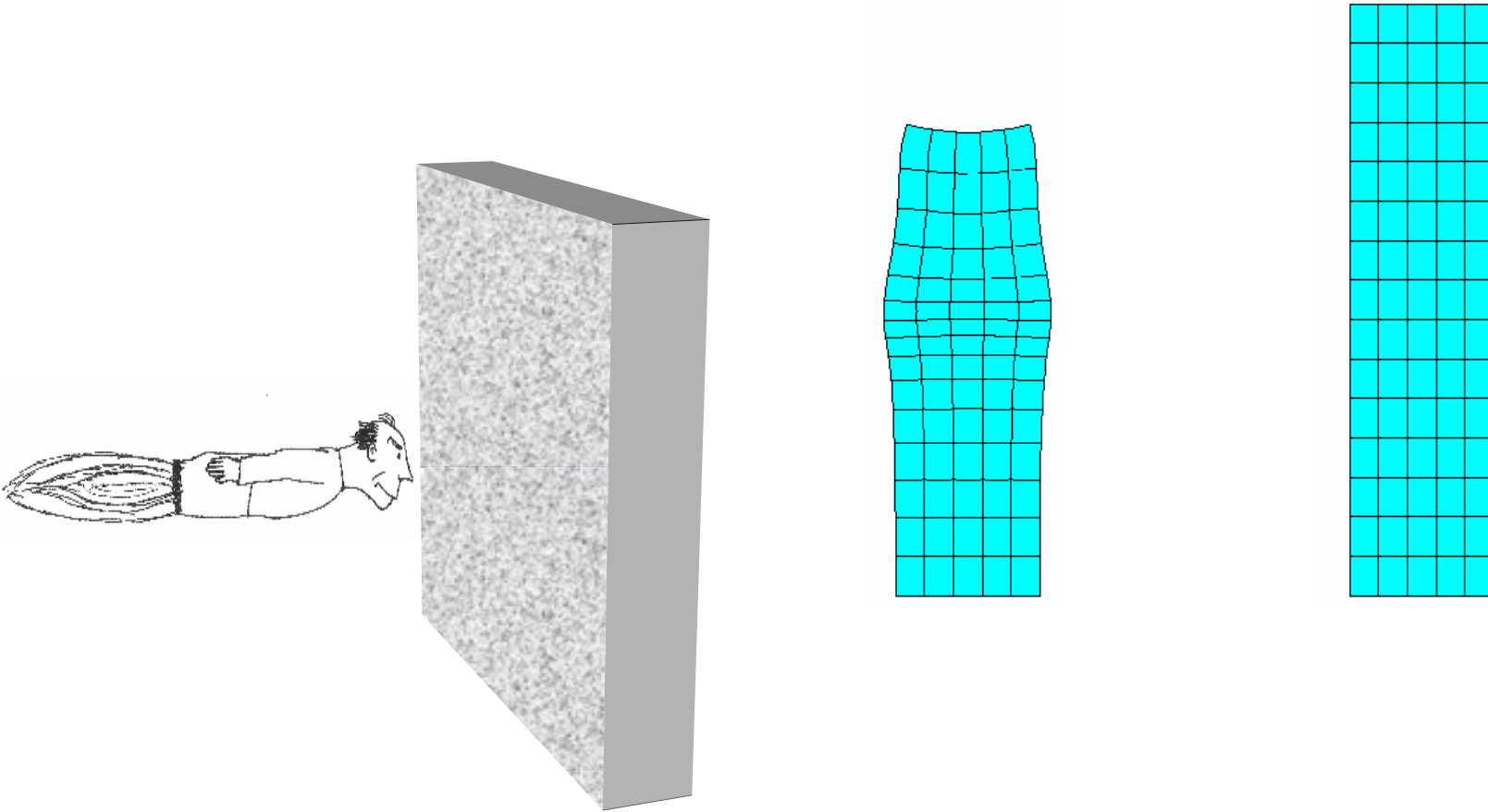
- Wave dissipation techniques
 - rigid boundaries



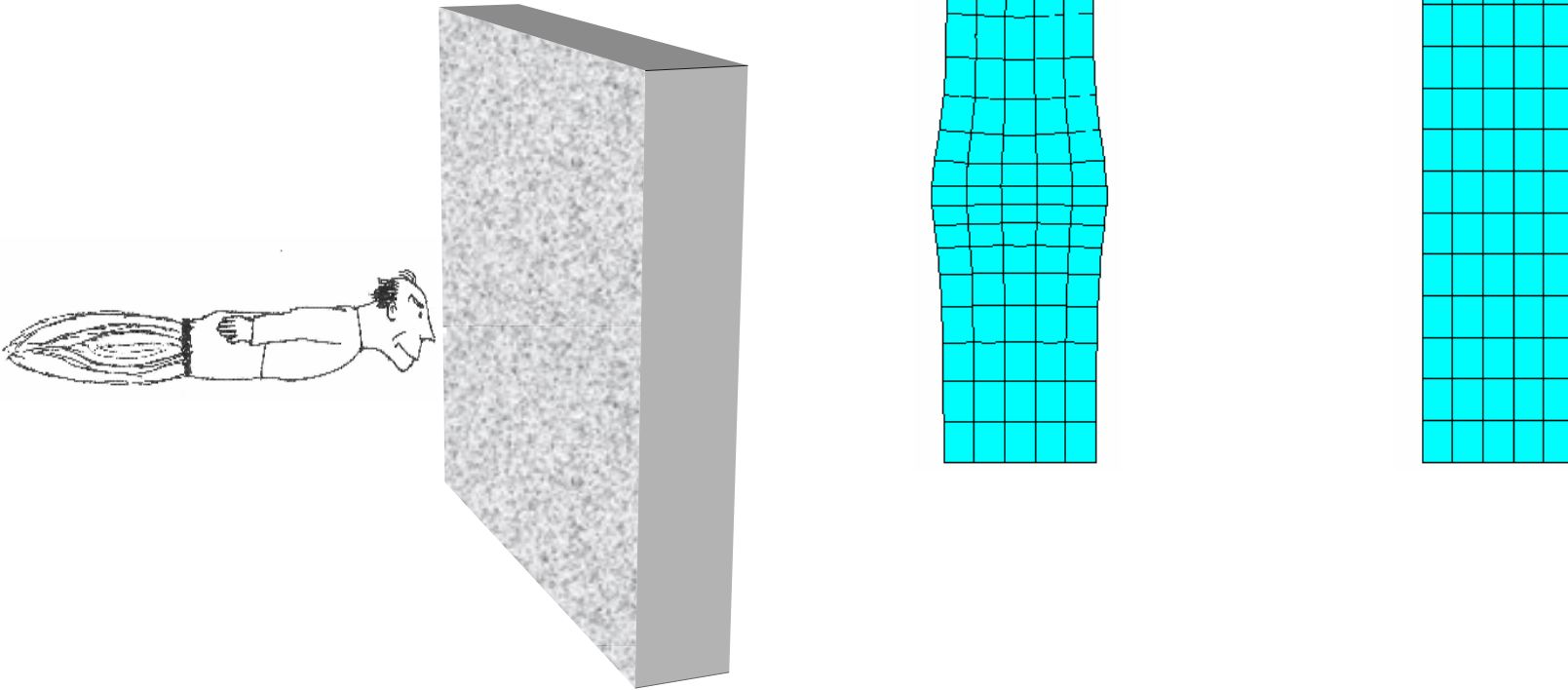
- Wave dissipation techniques
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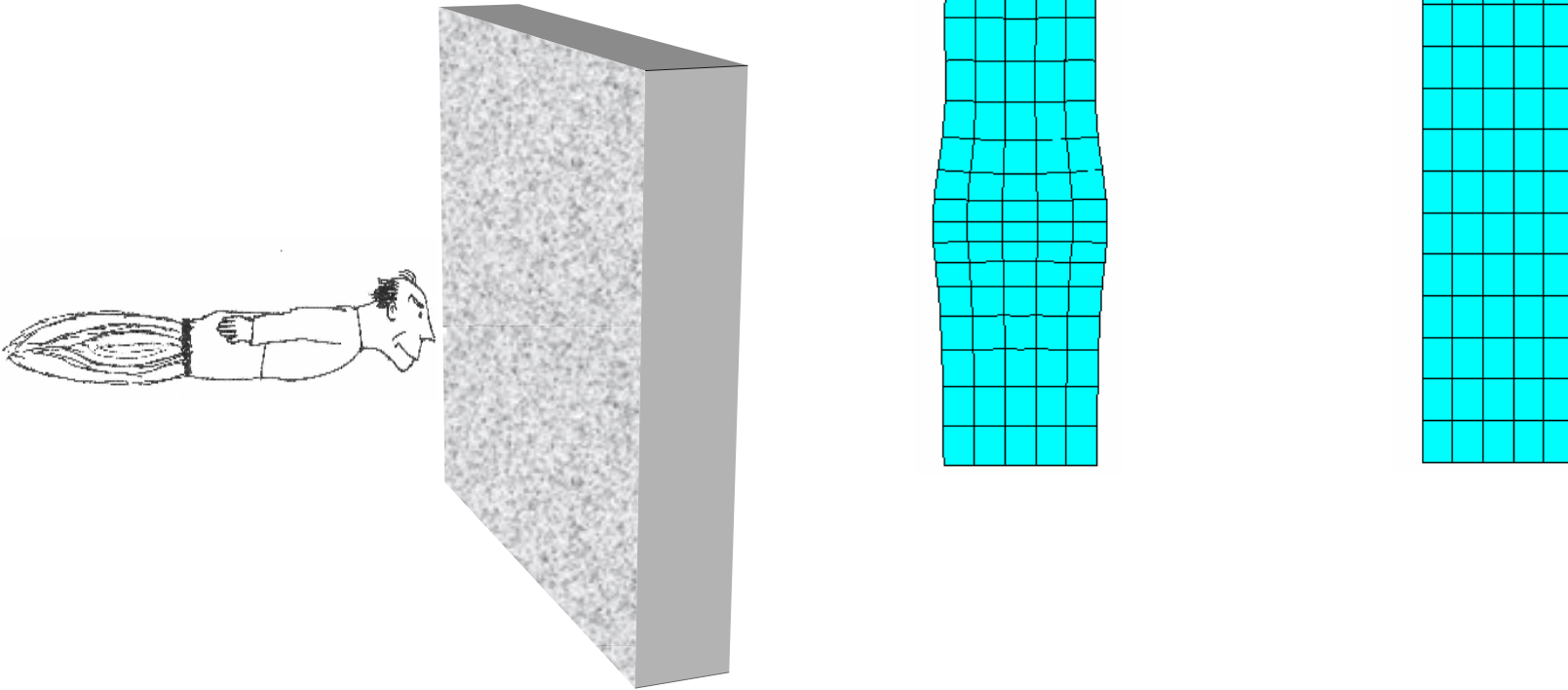
- Wave dissipation techniques
 - rigid boundaries



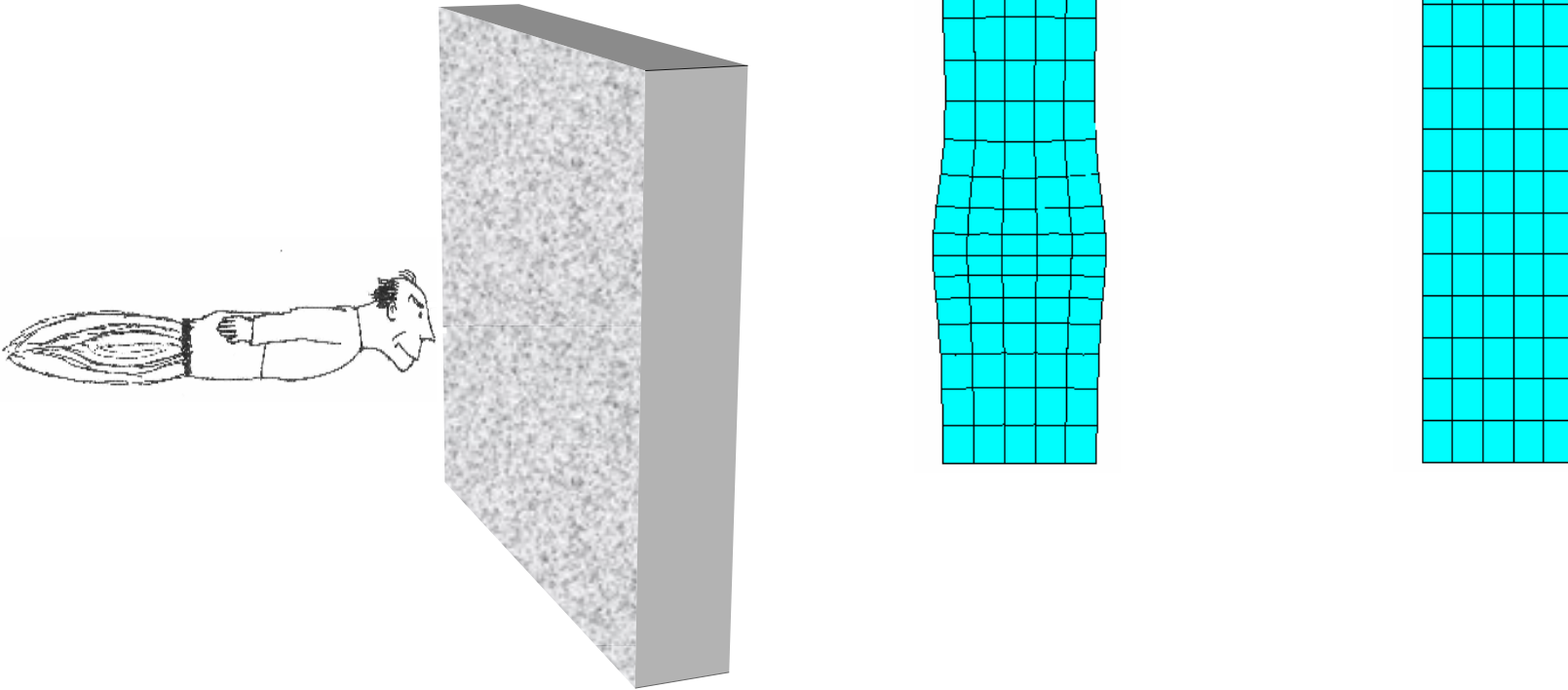
- Wave dissipation techniques
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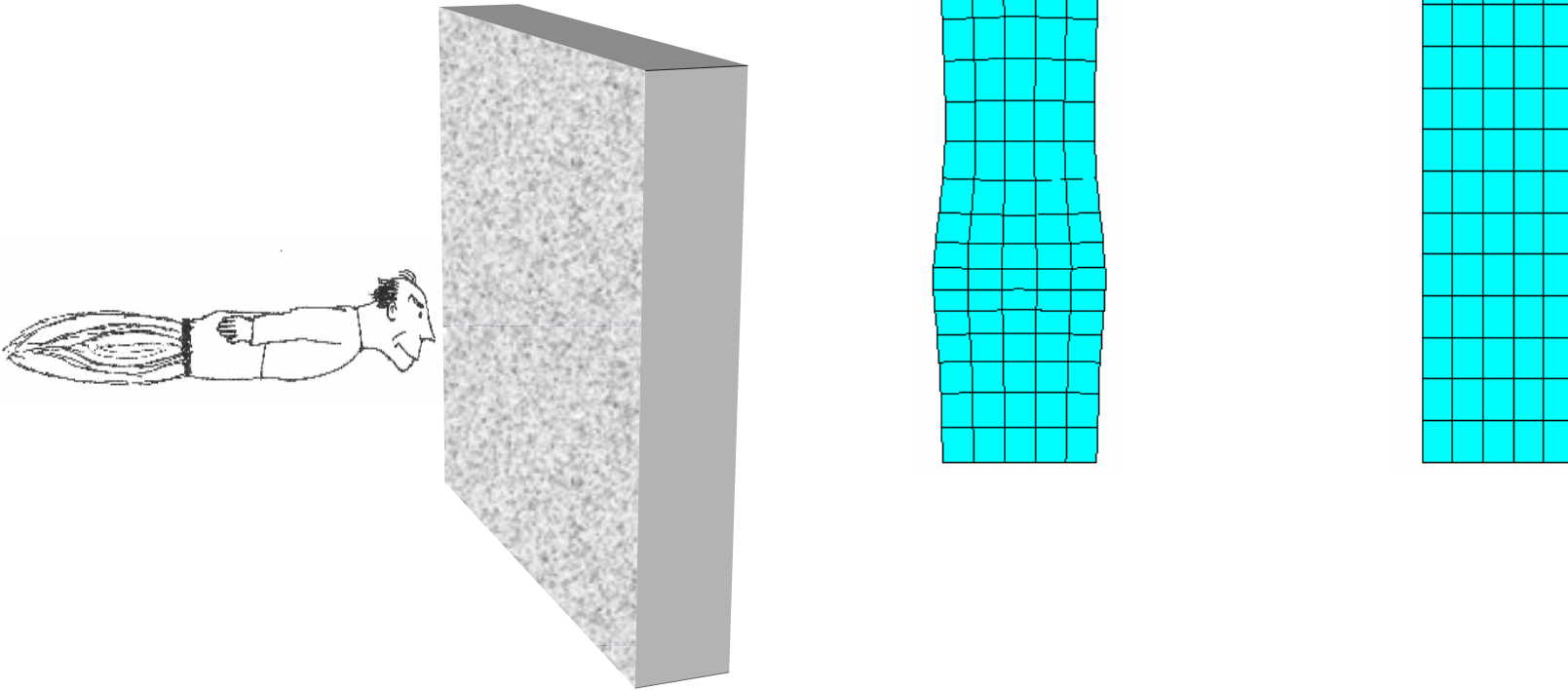
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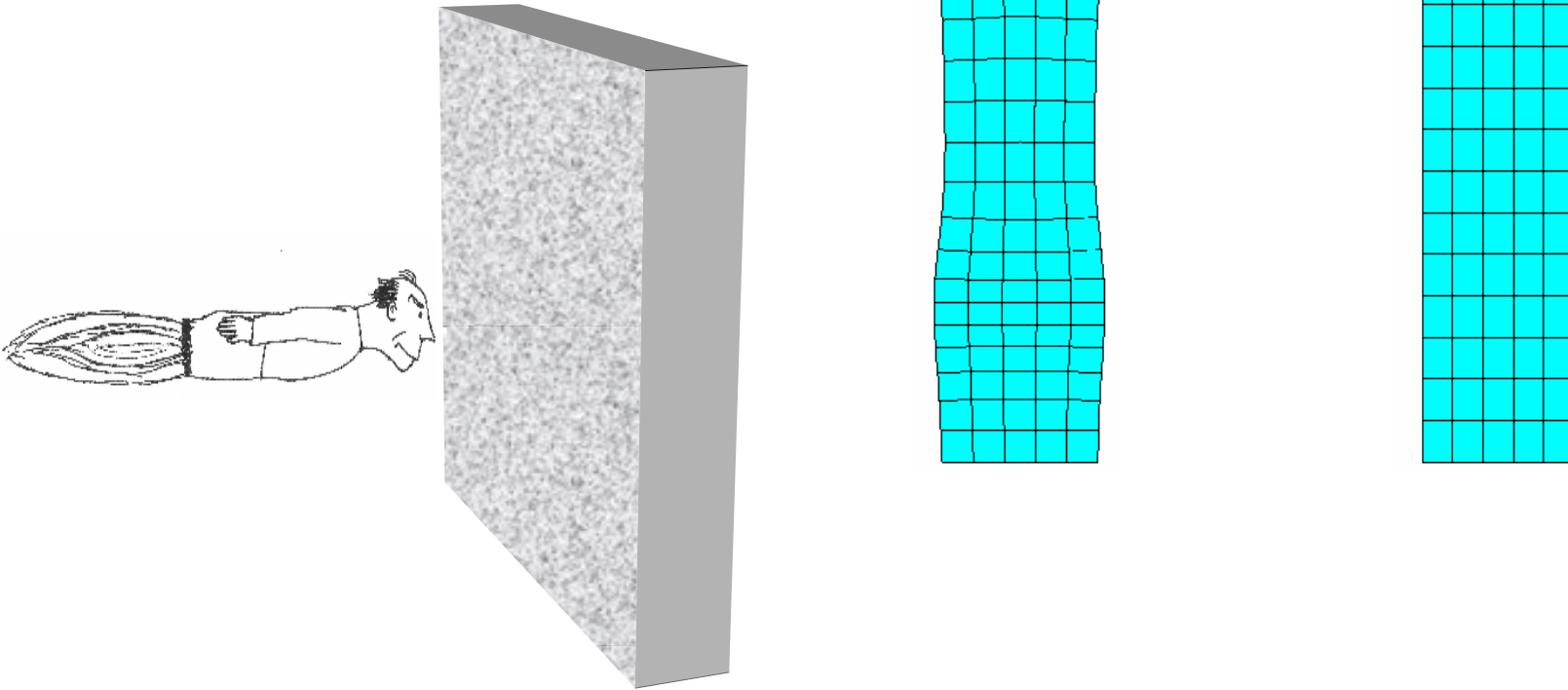
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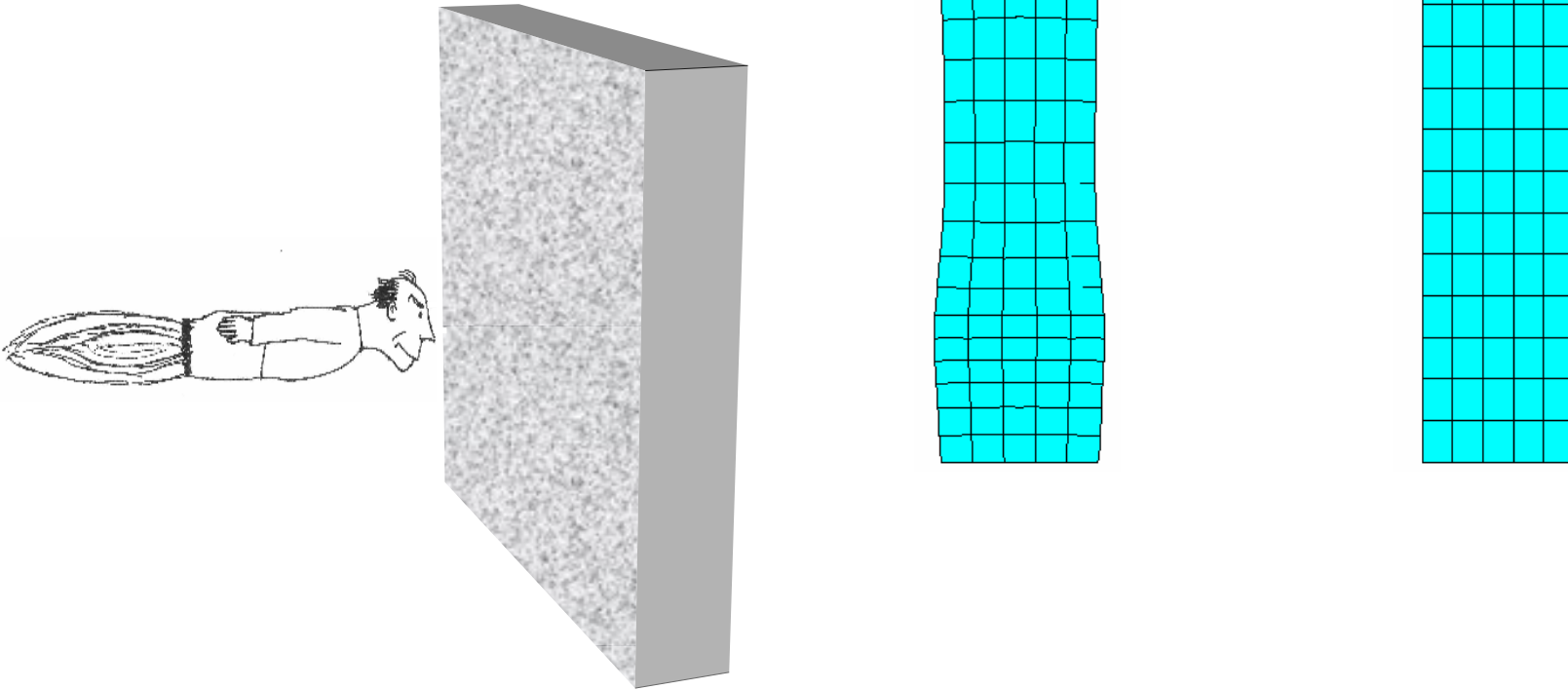
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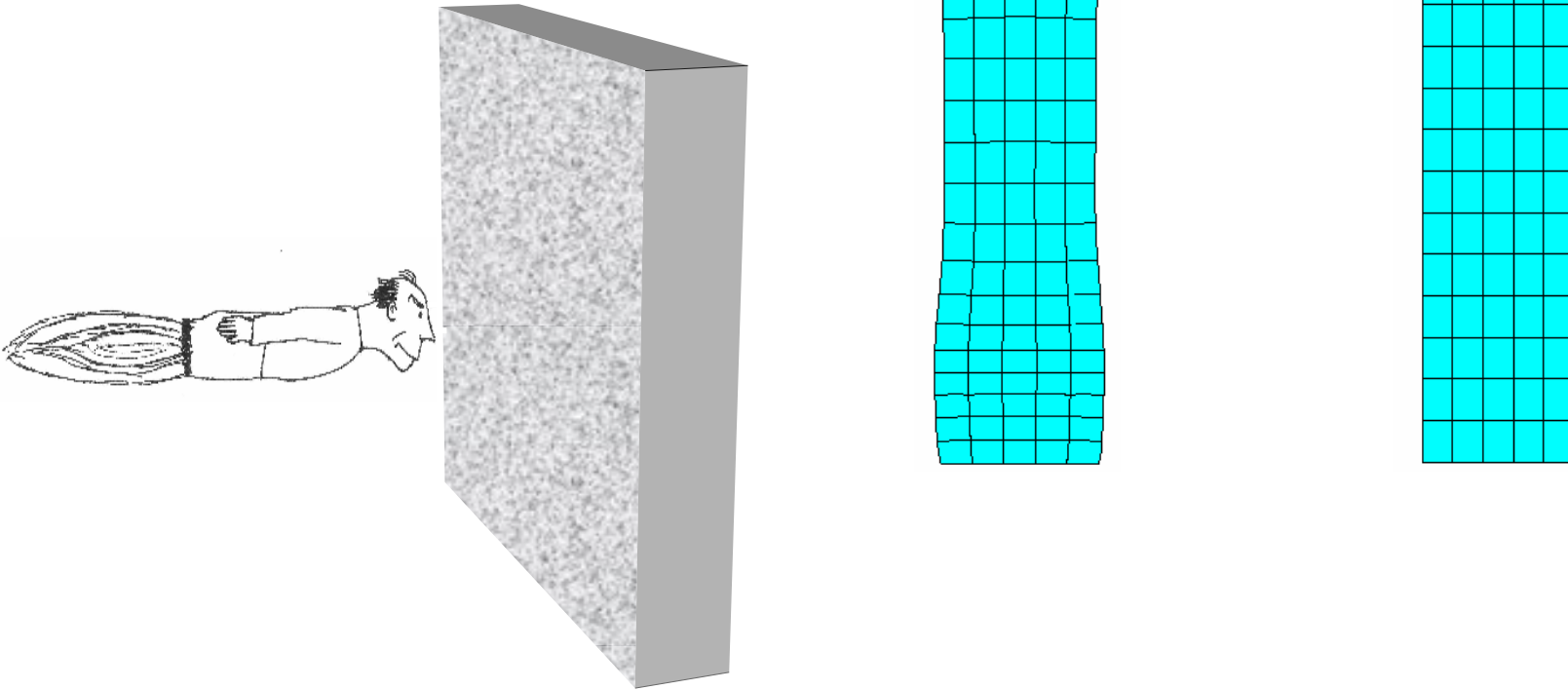
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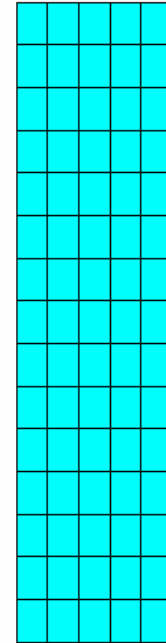
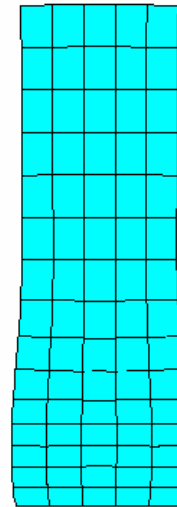
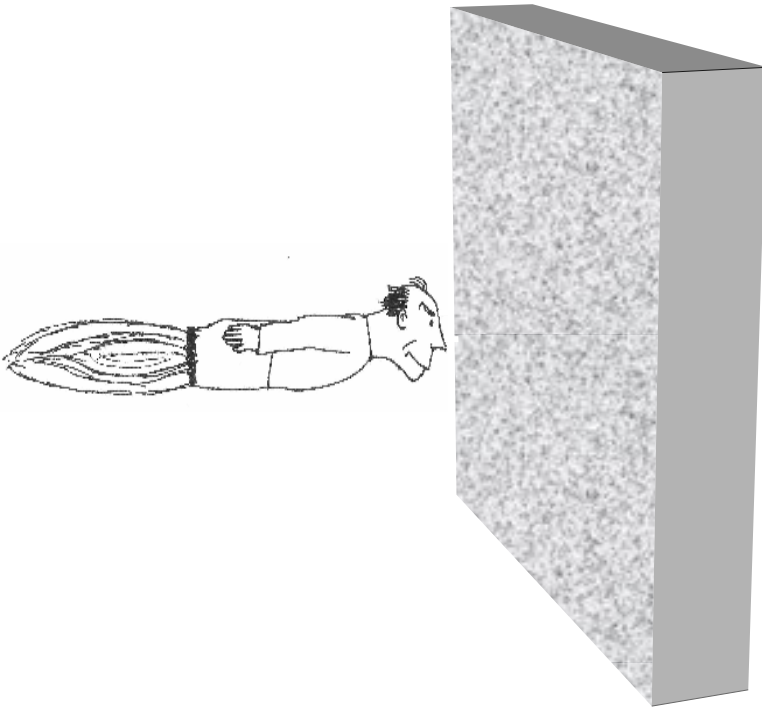
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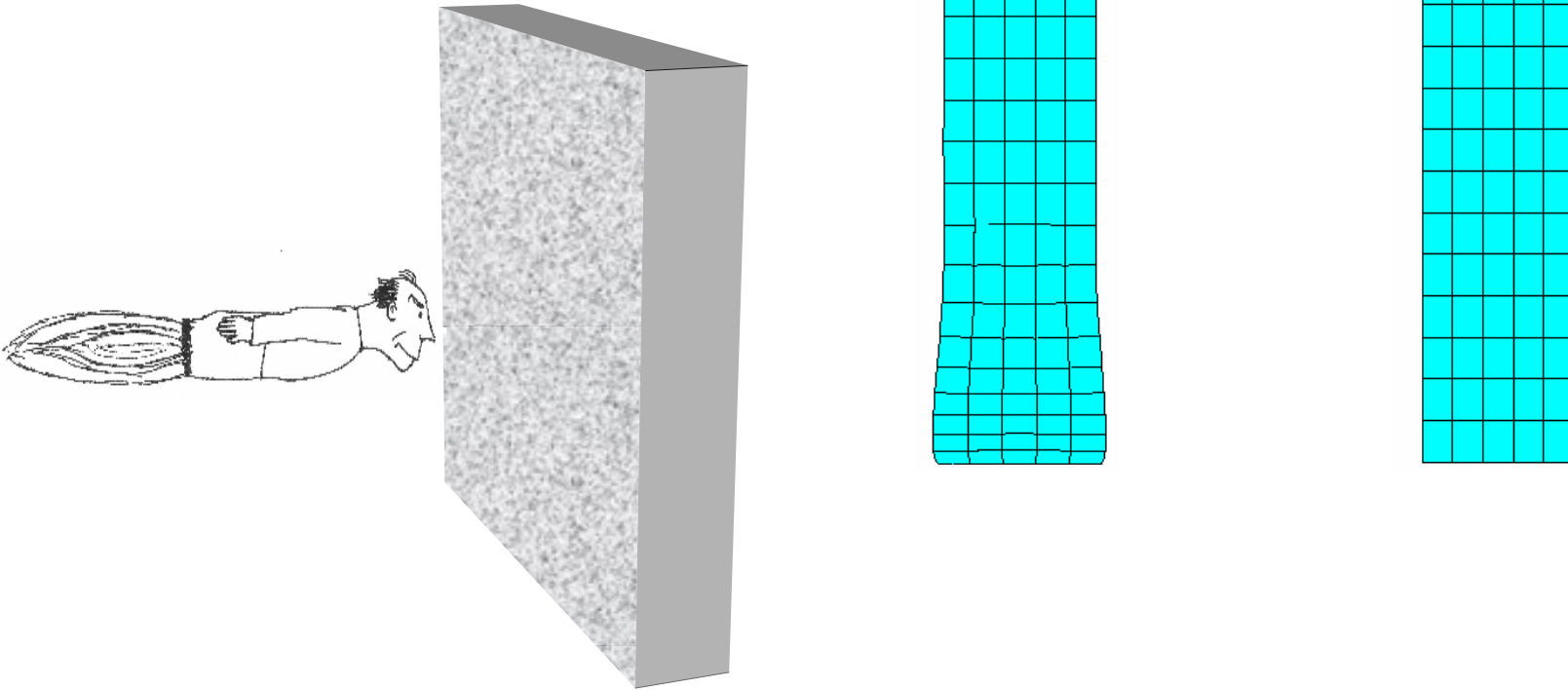
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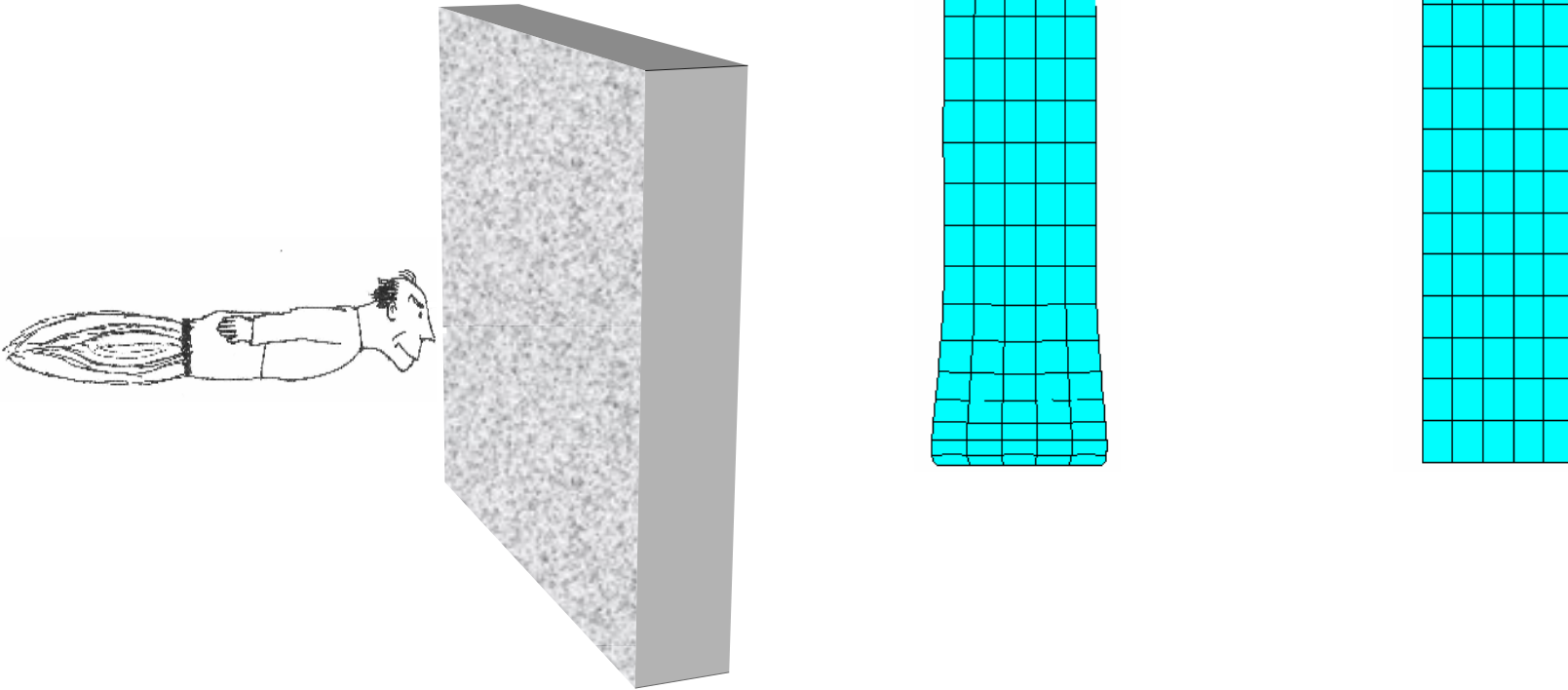
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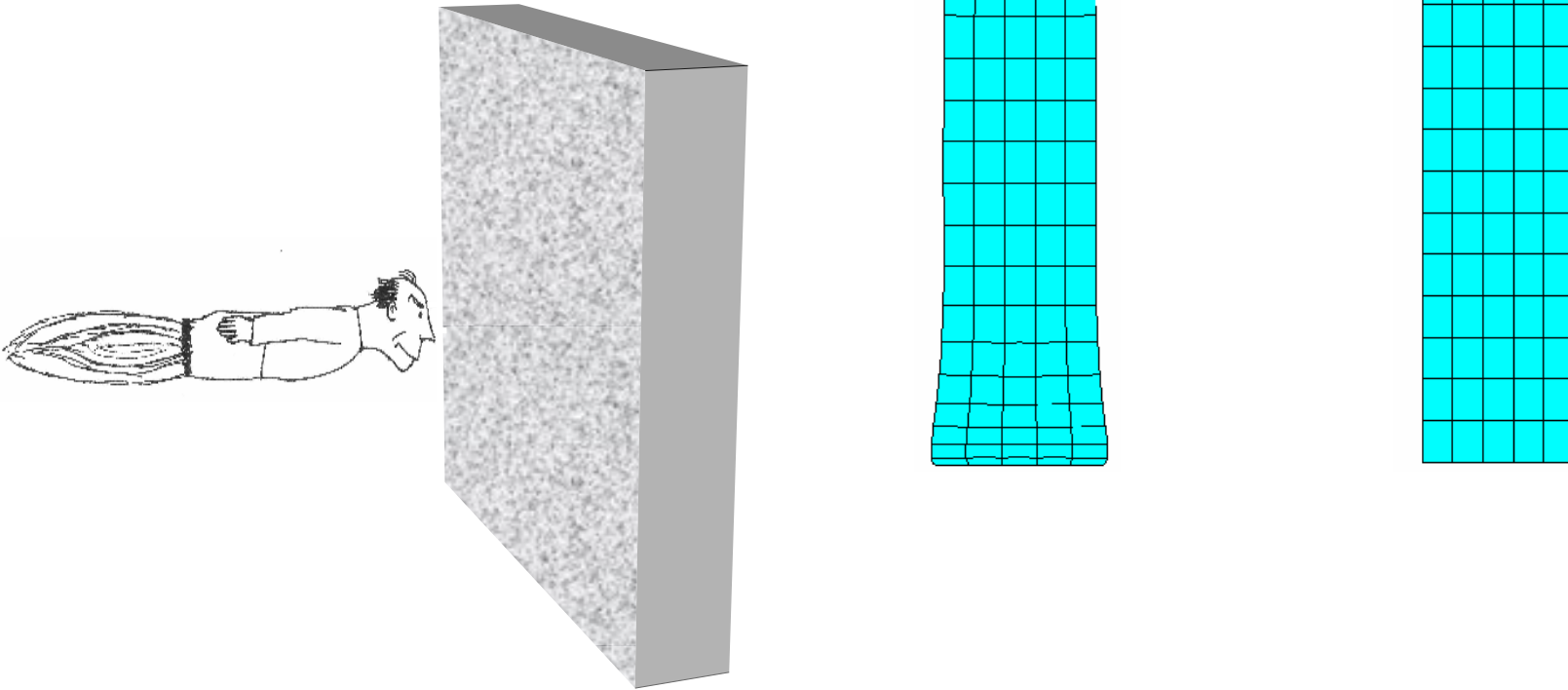
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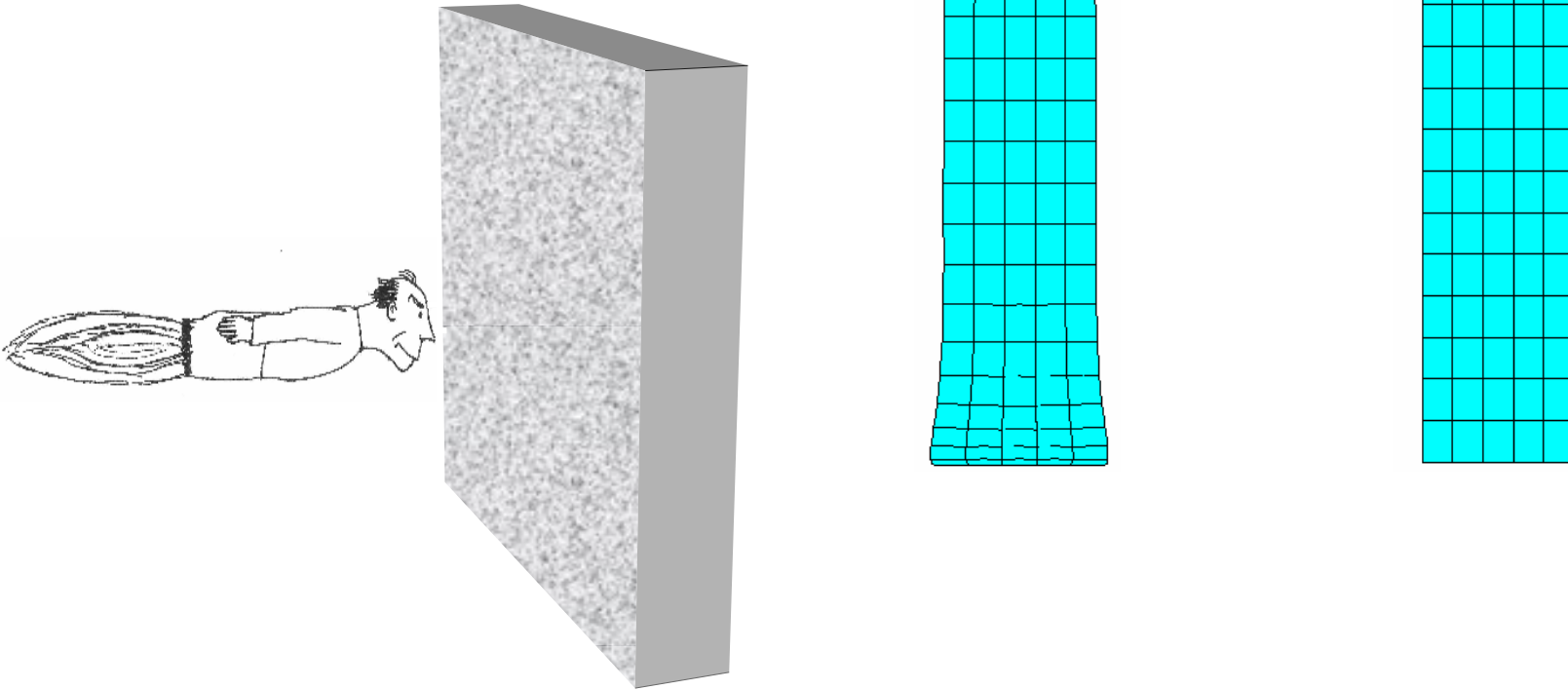
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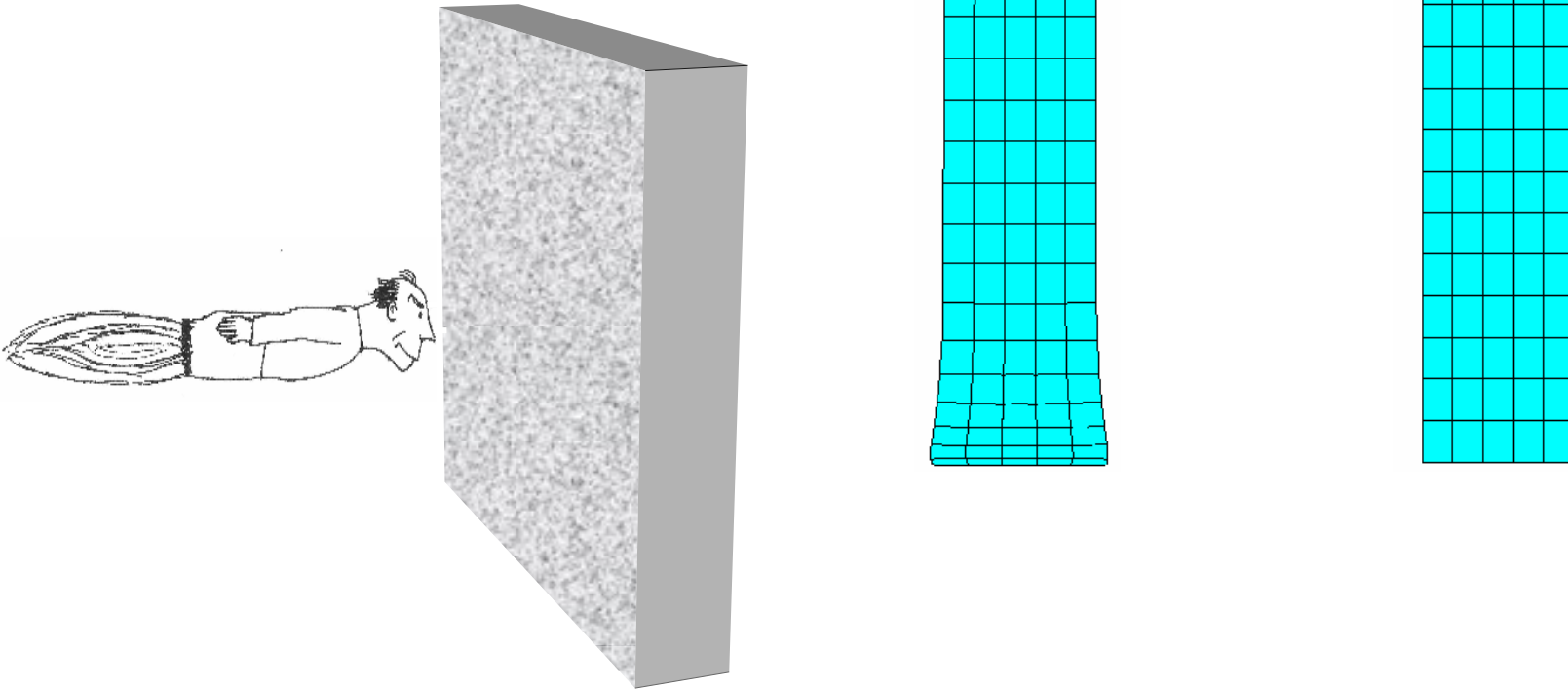
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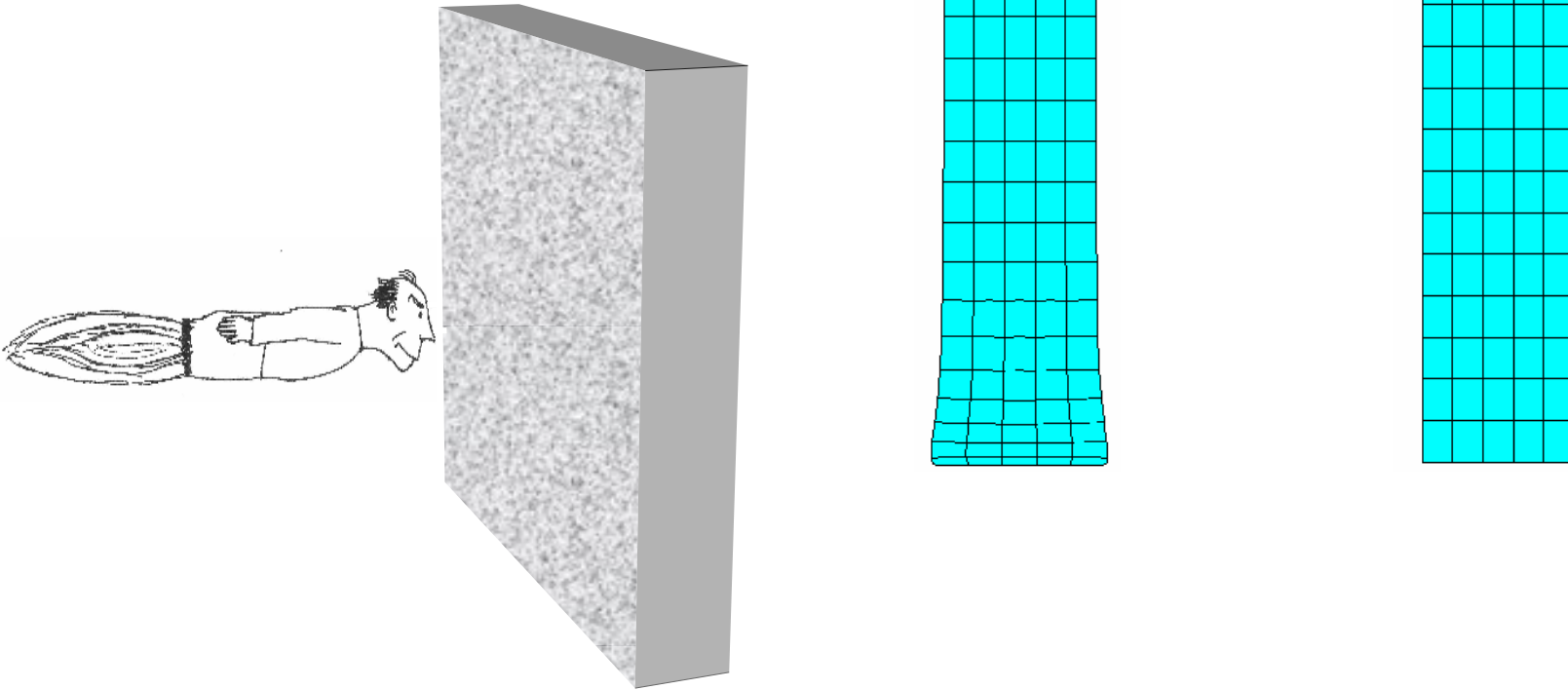
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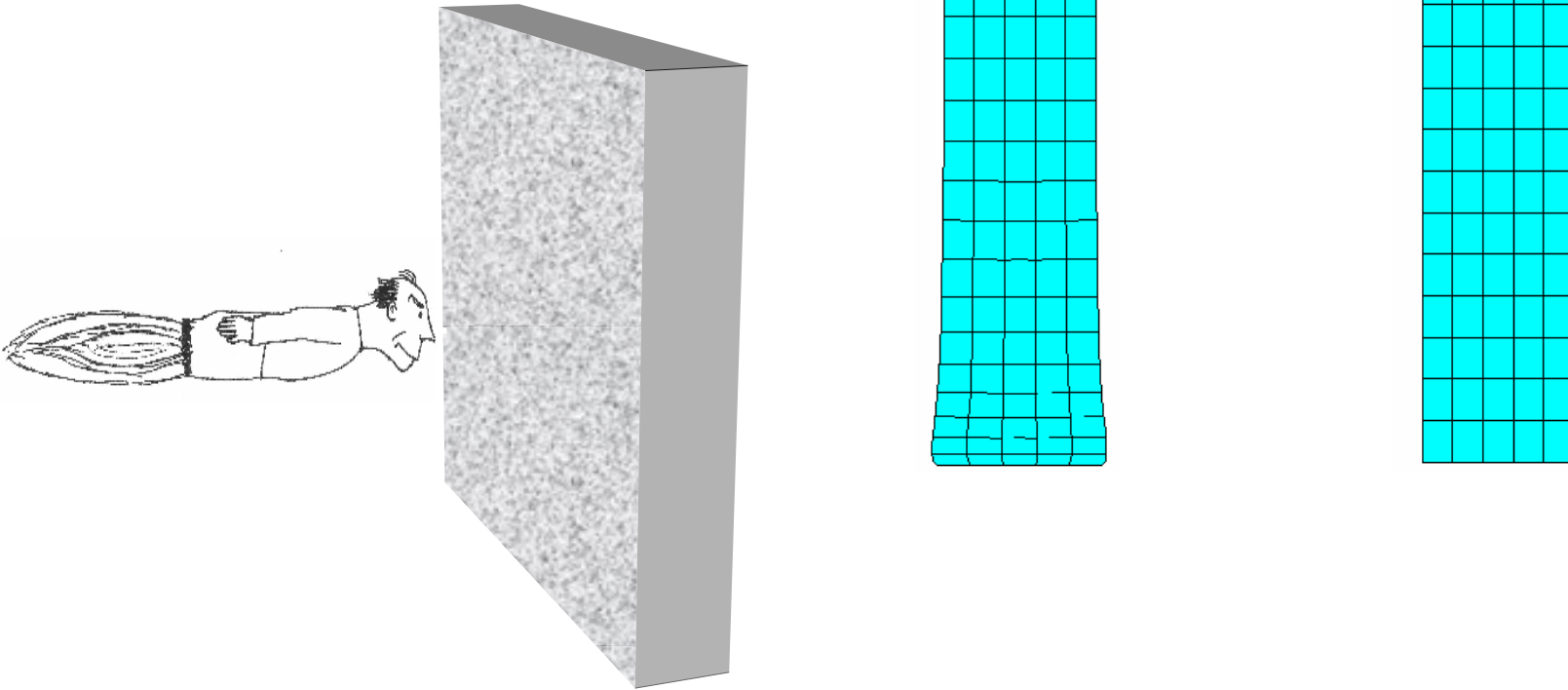
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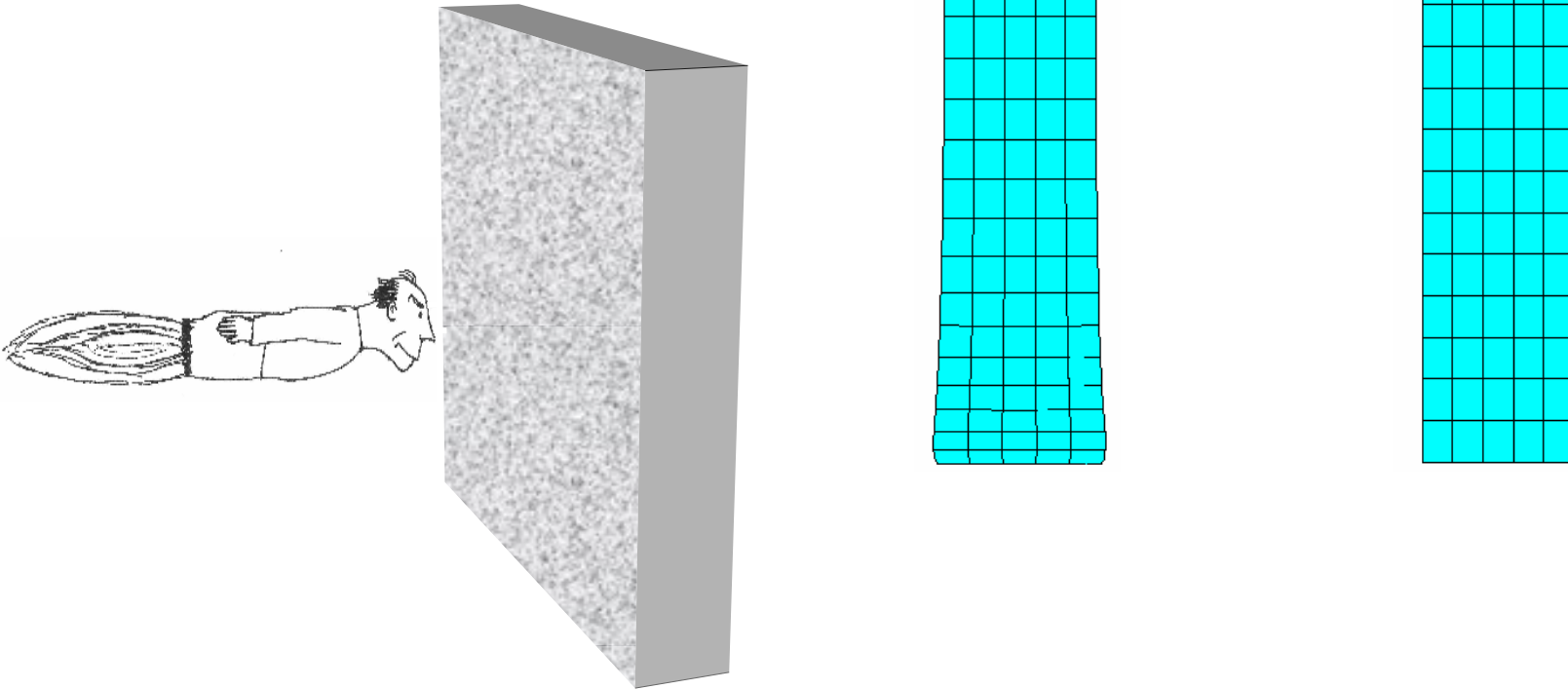
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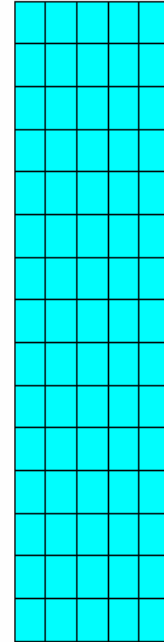
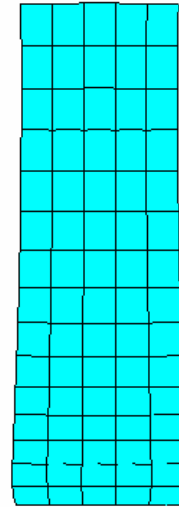
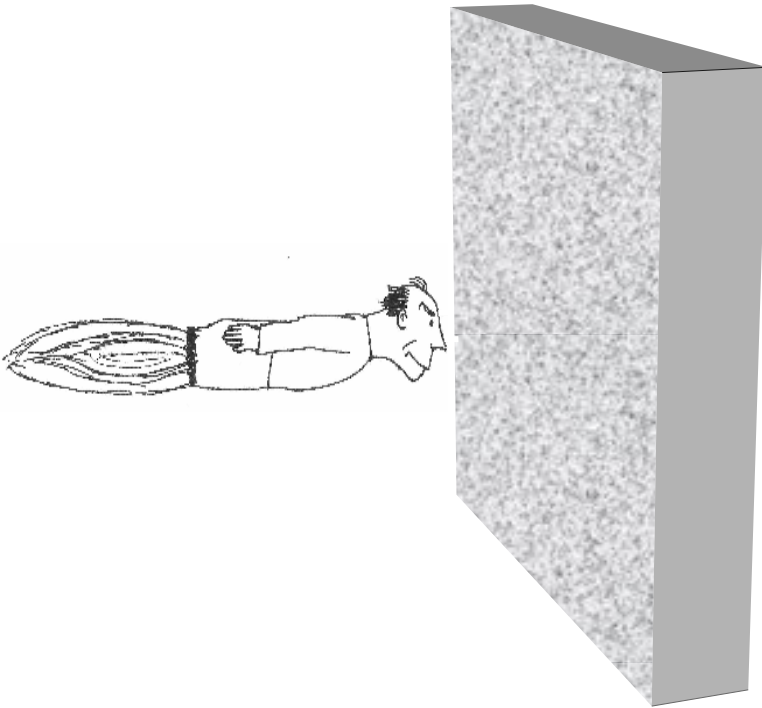
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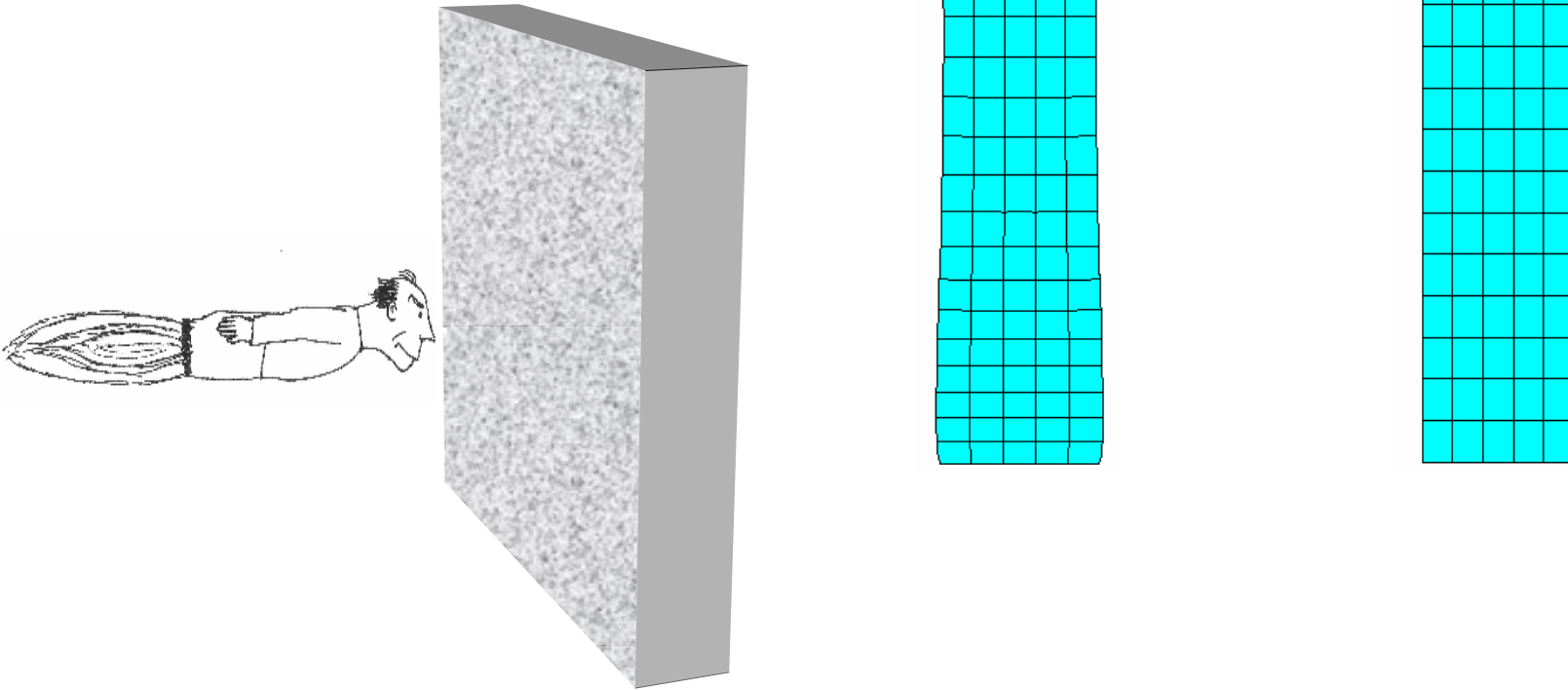
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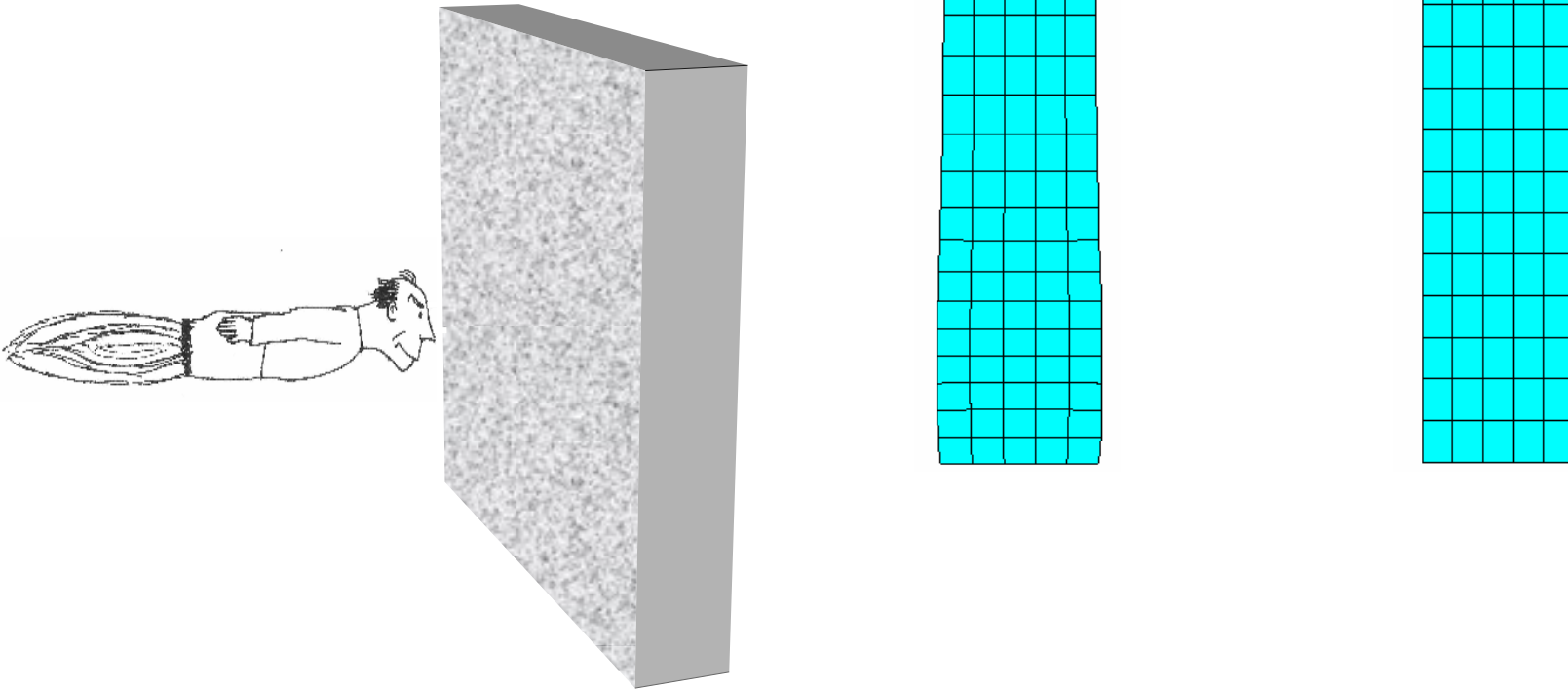
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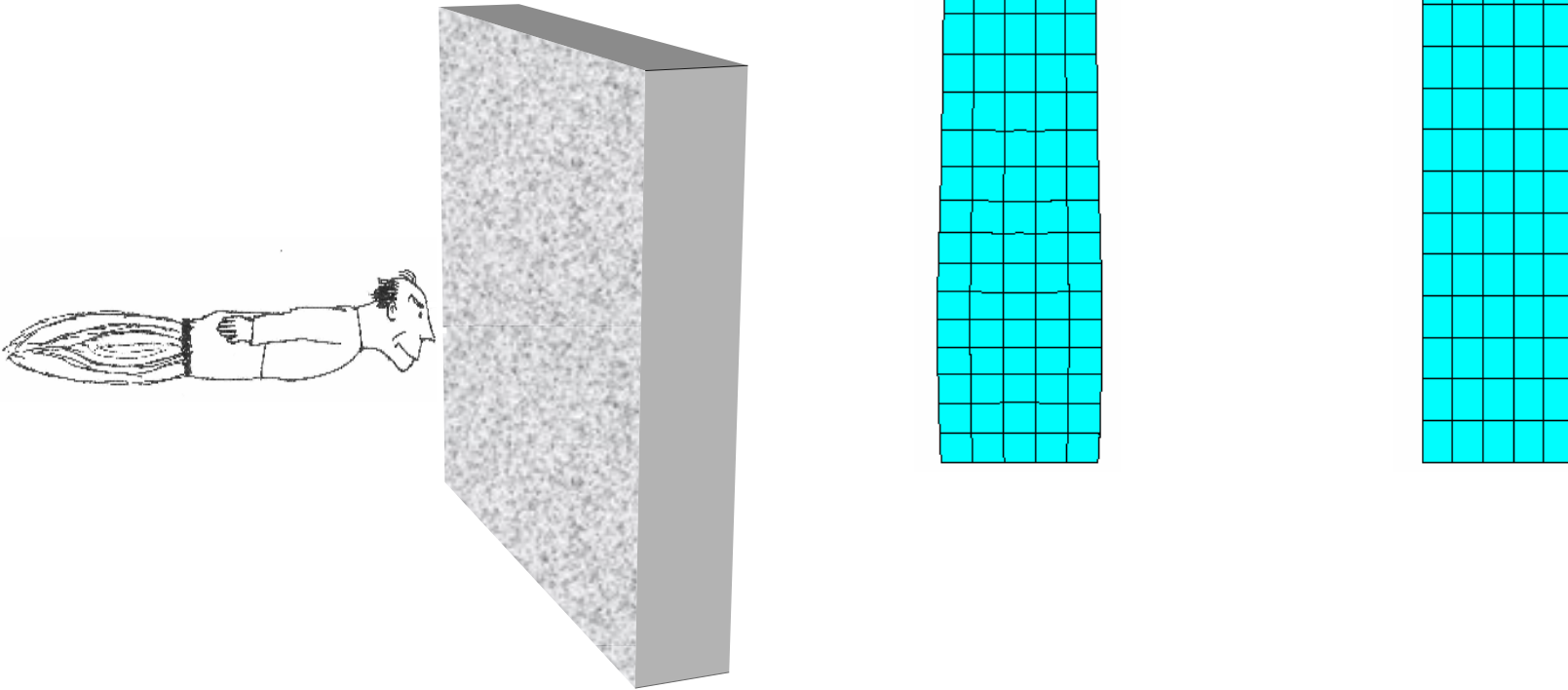
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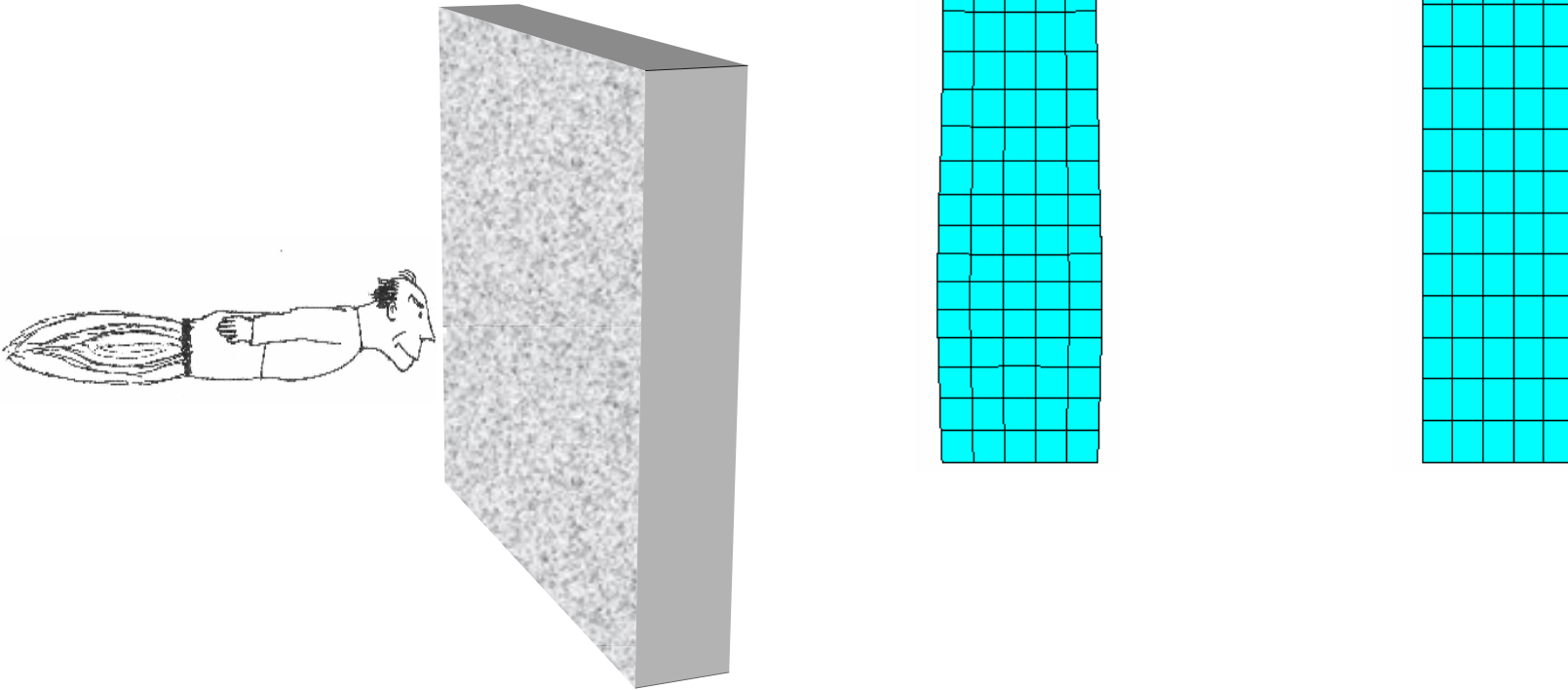
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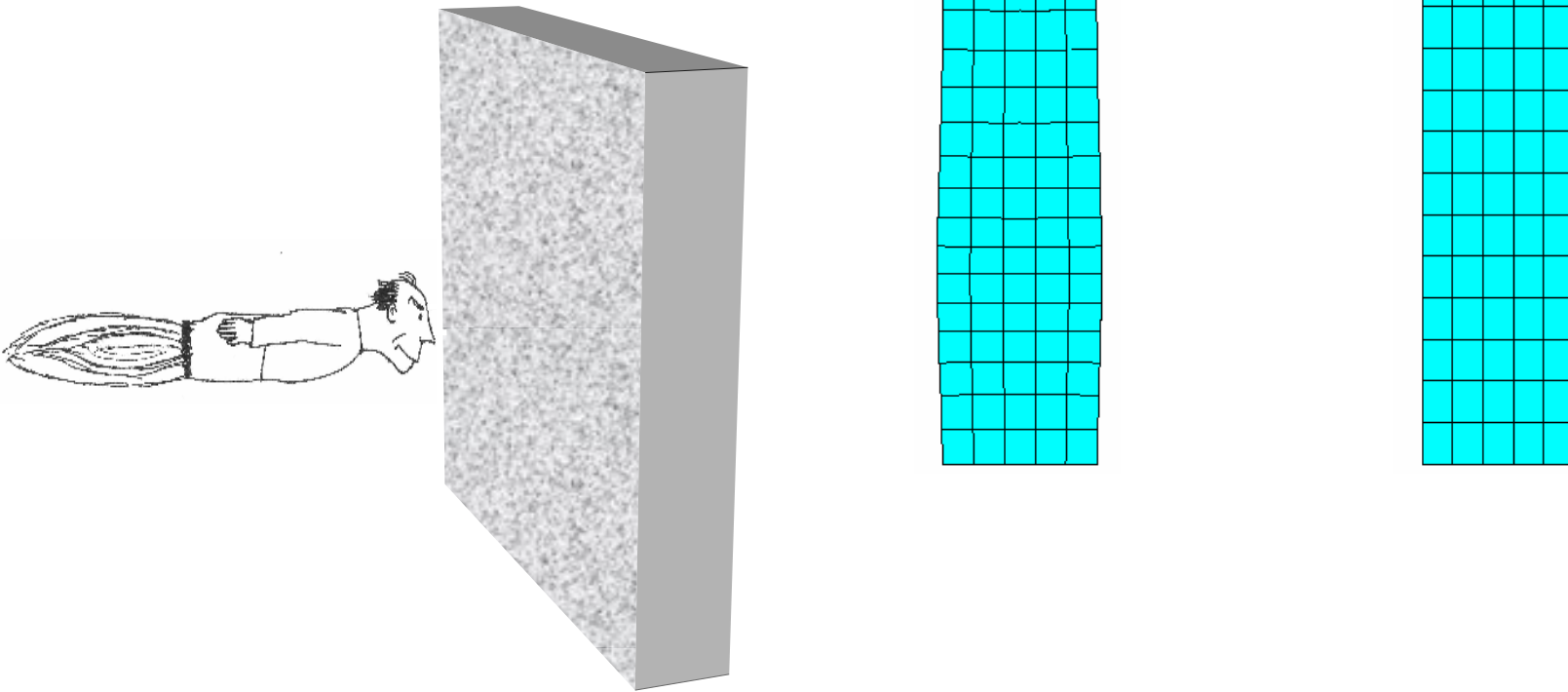
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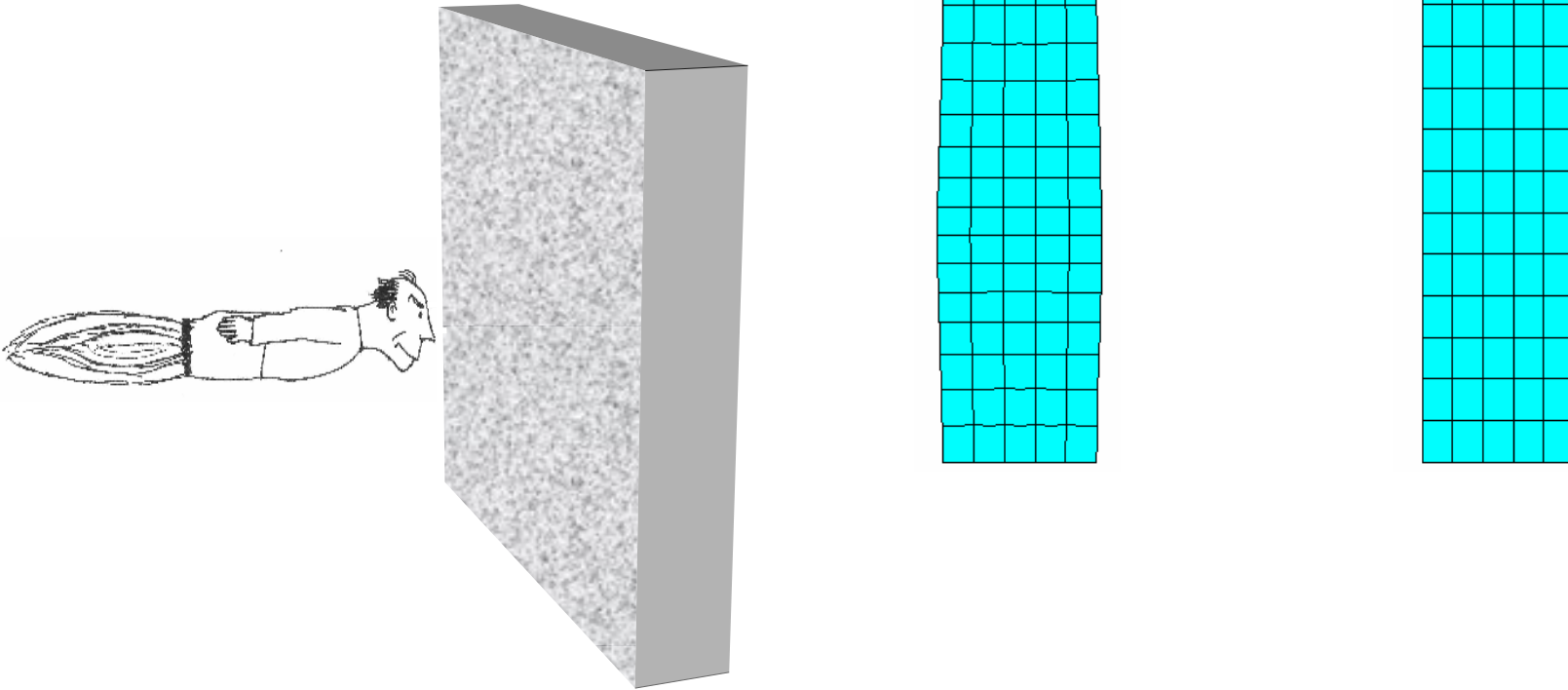
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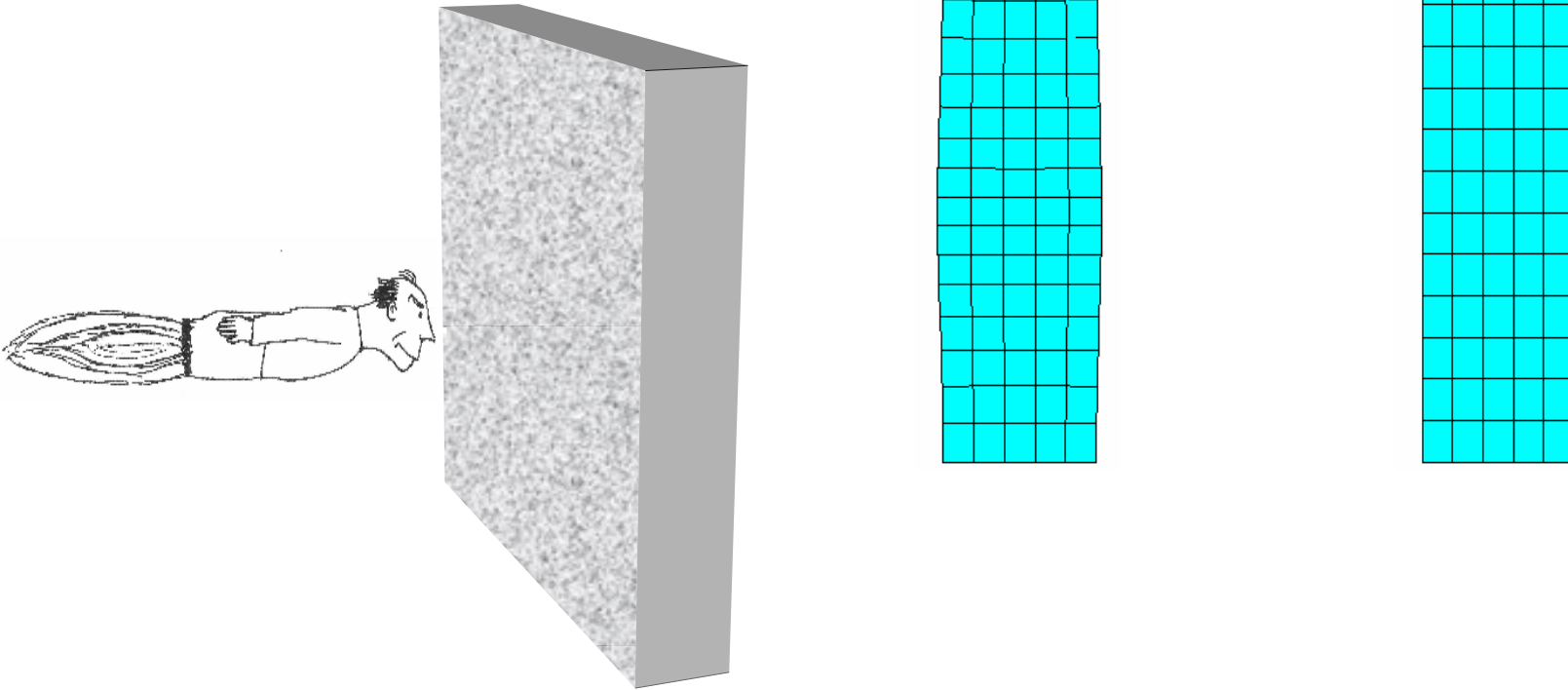
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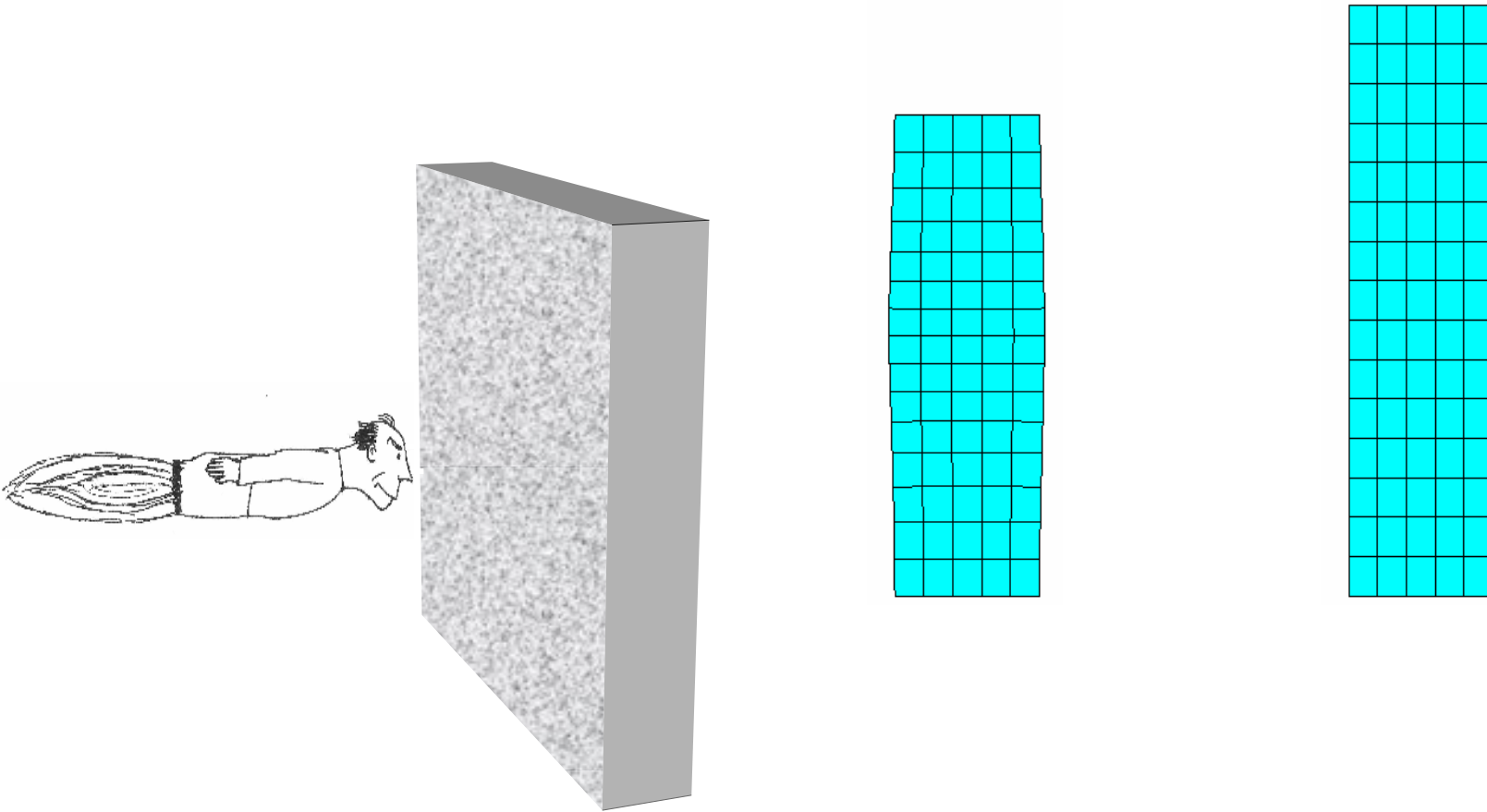
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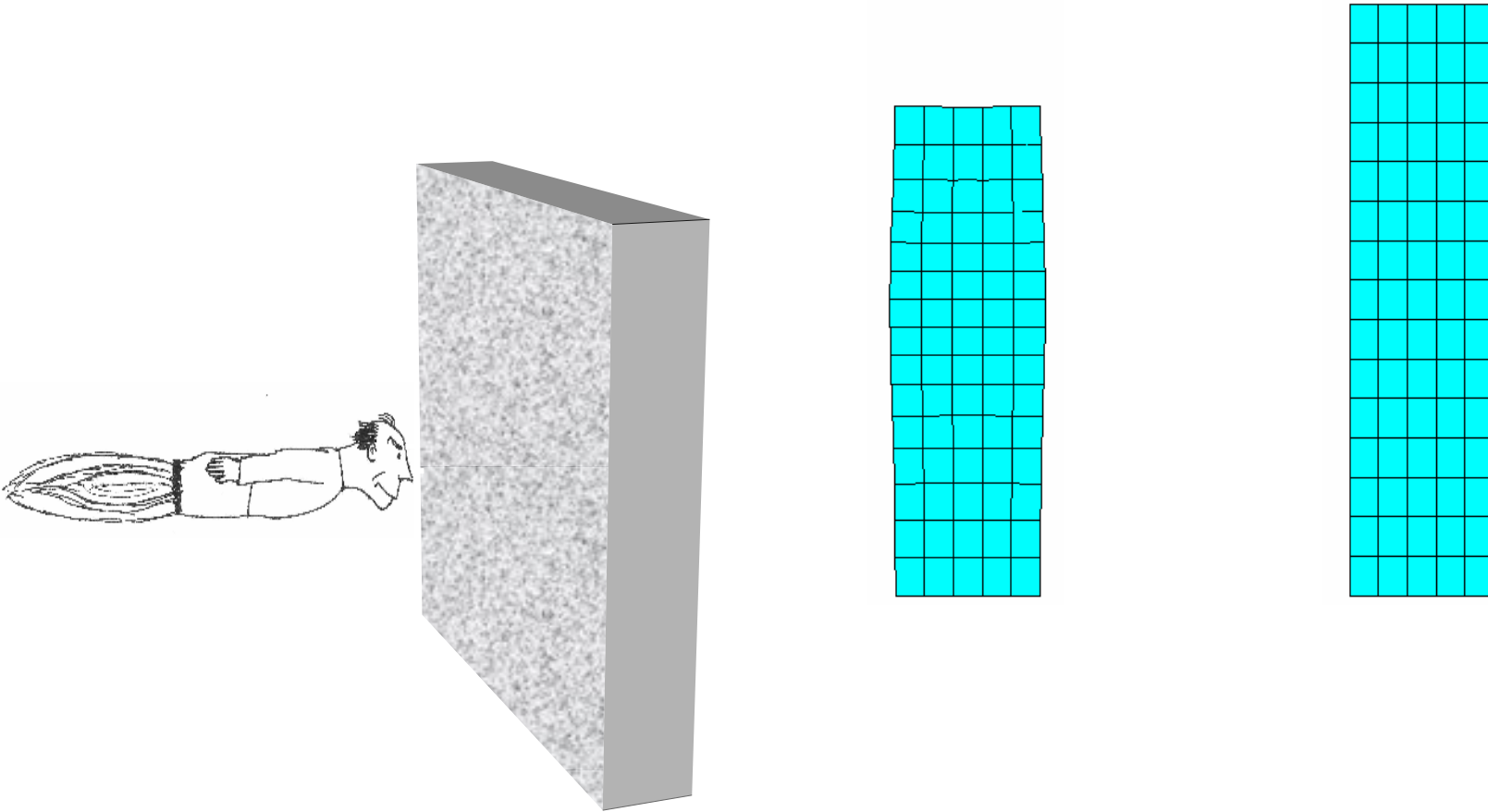
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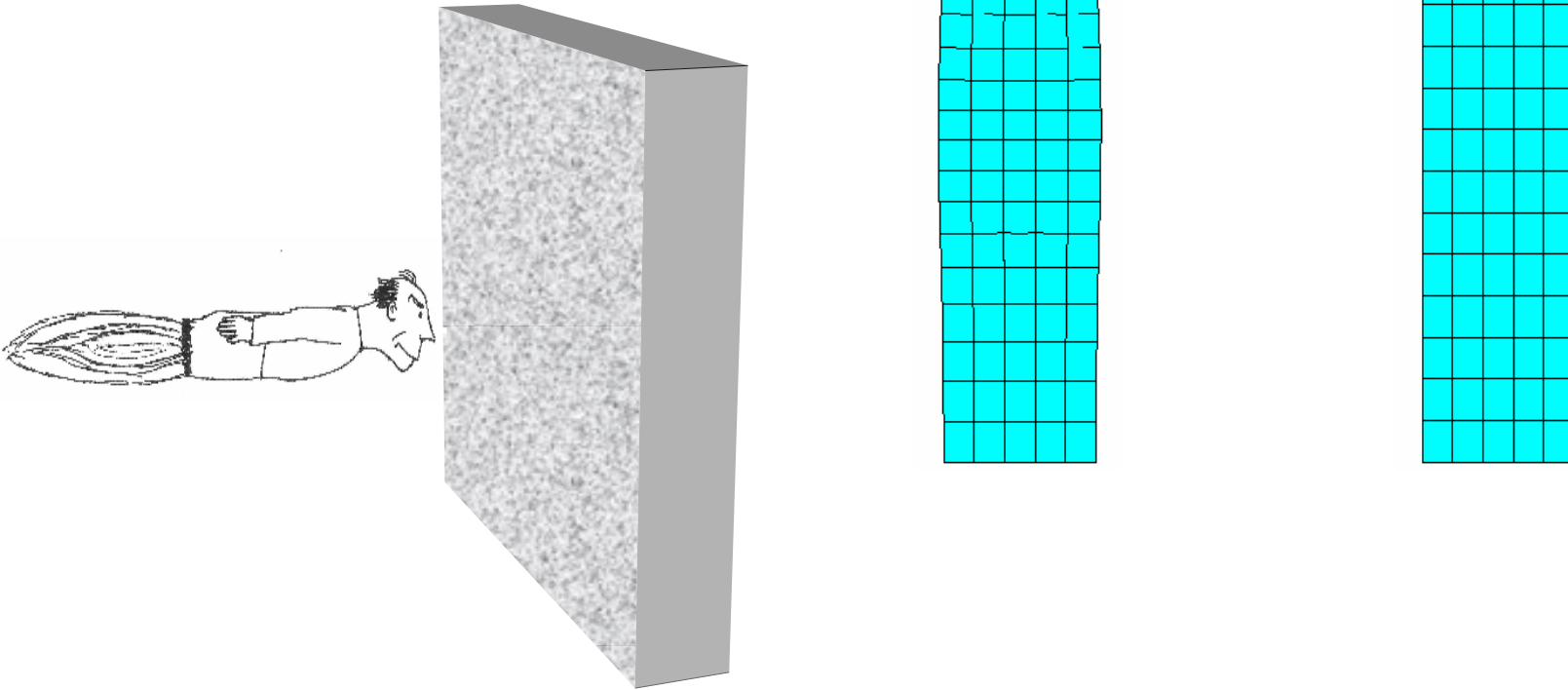
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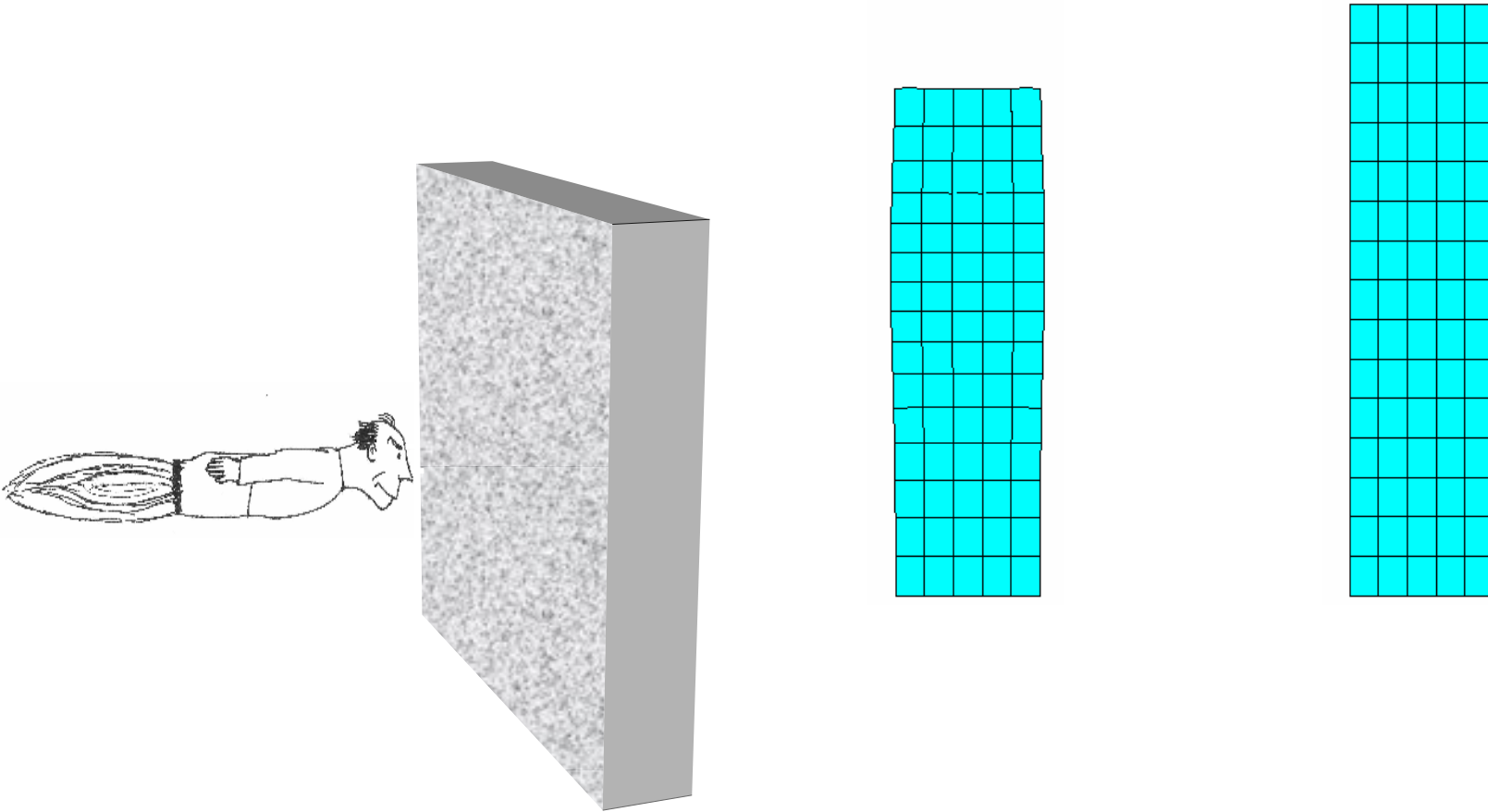
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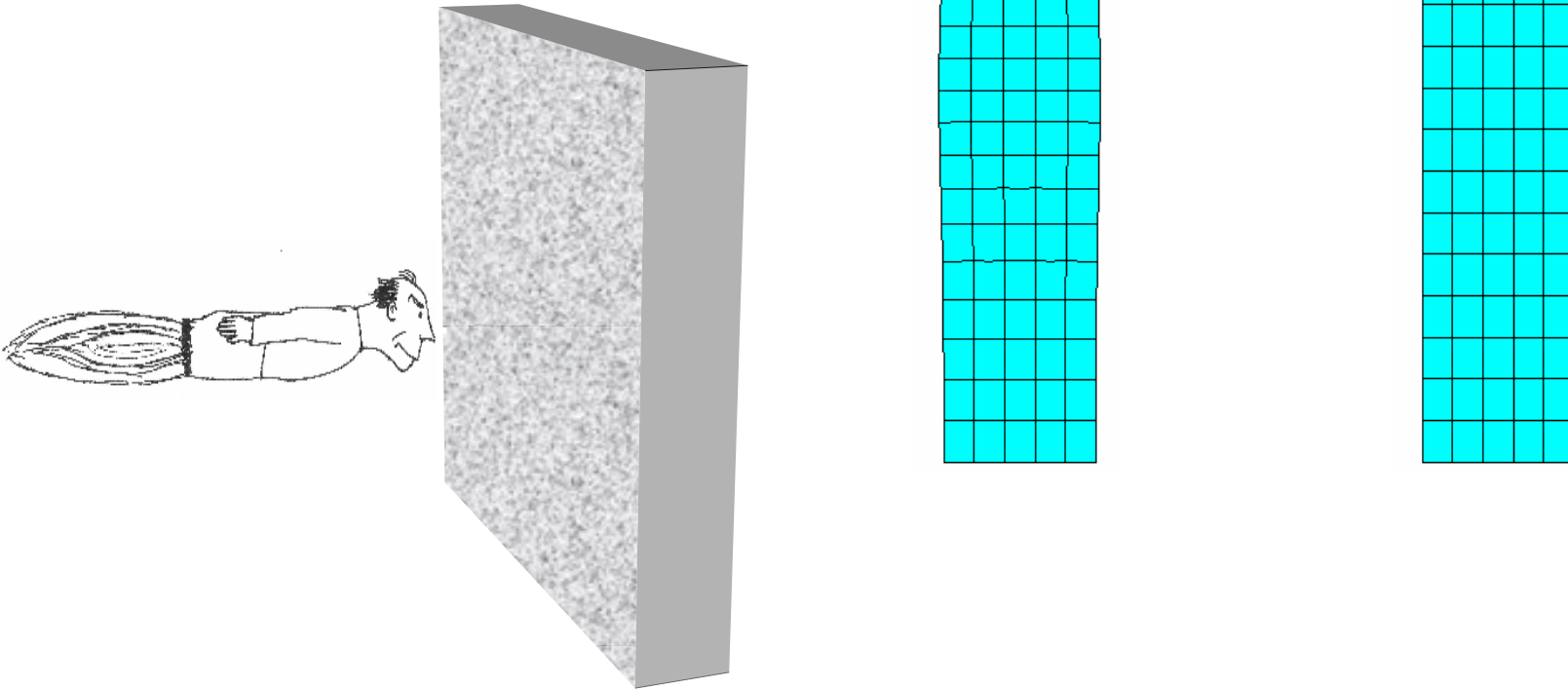
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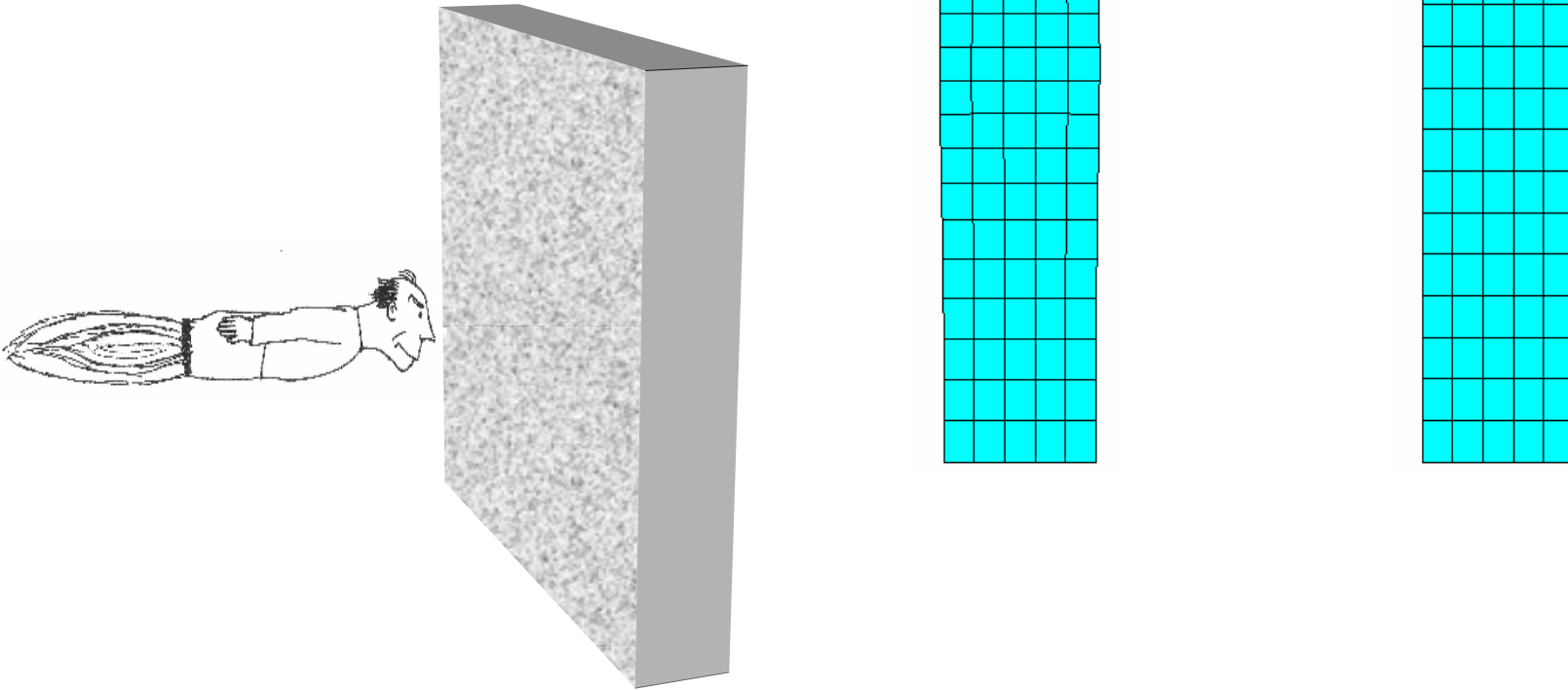
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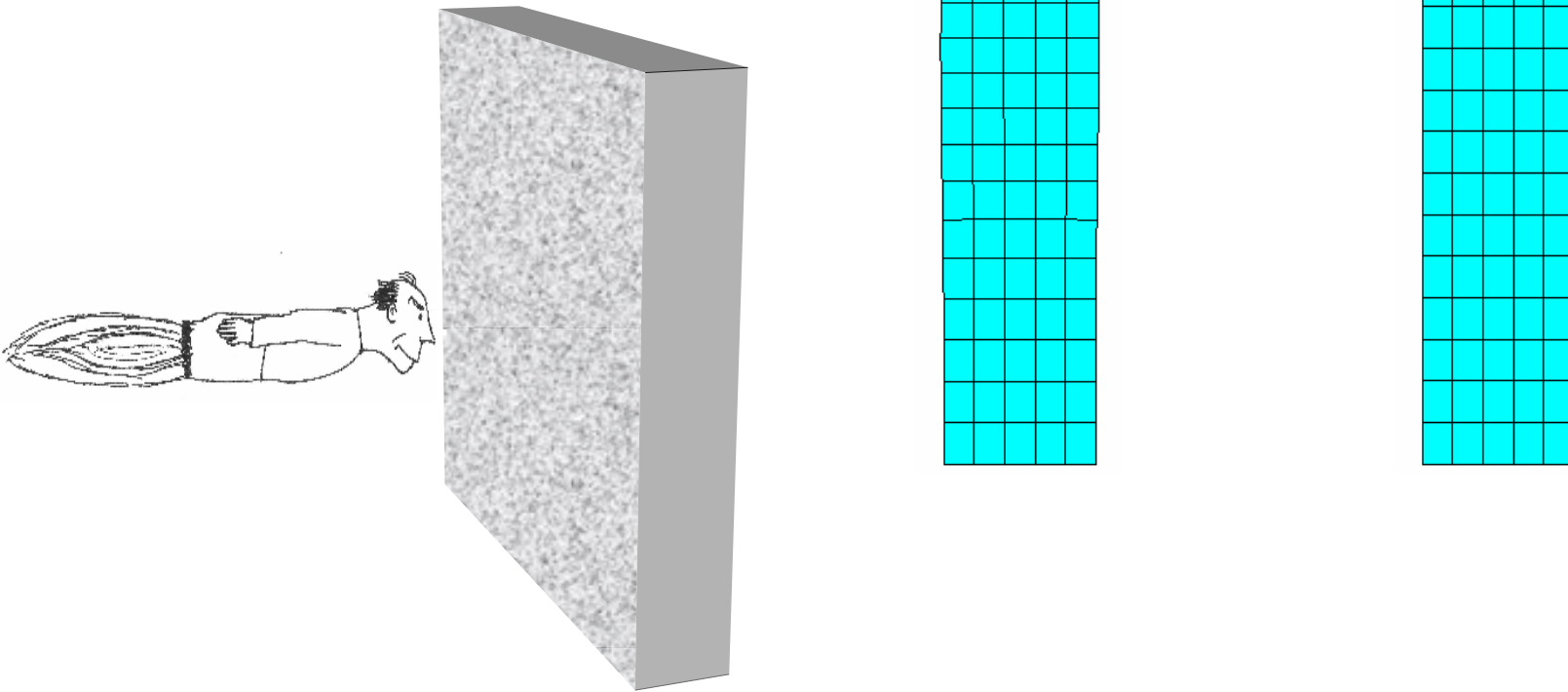
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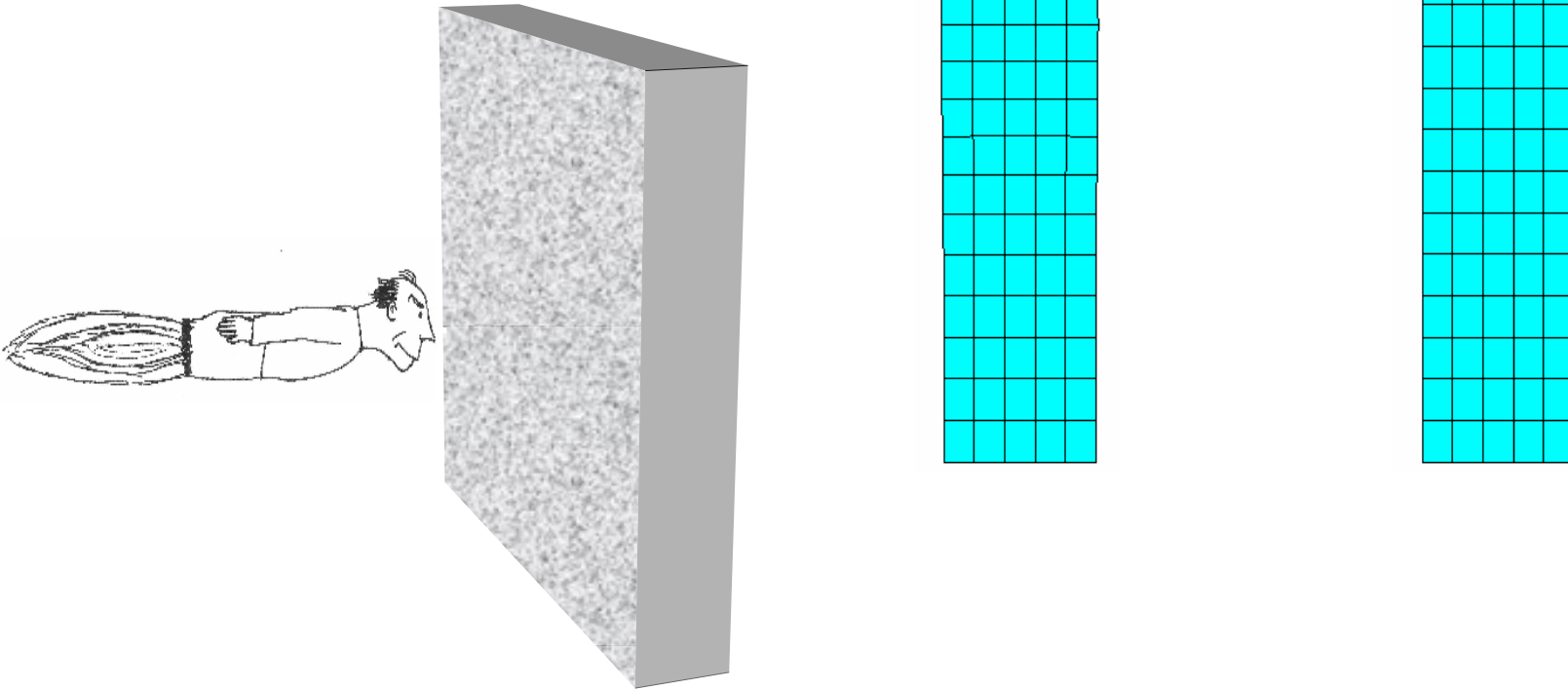
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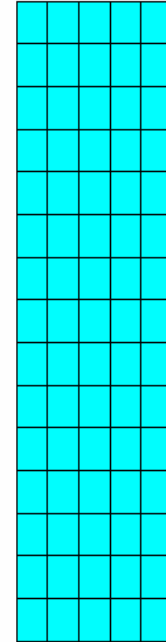
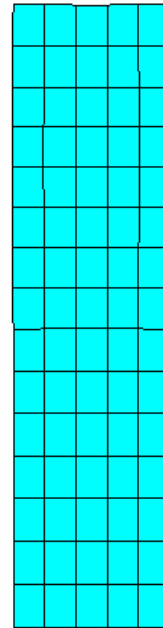
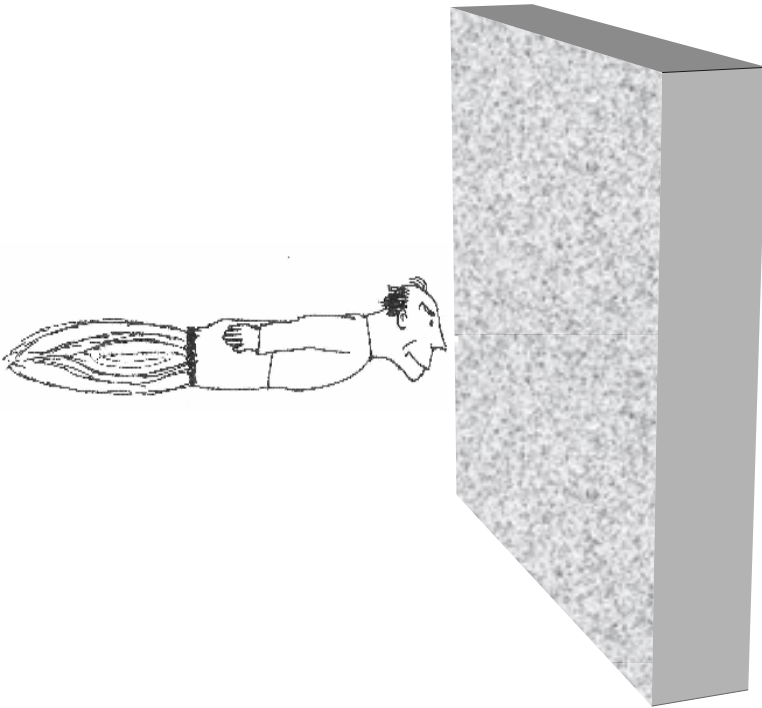
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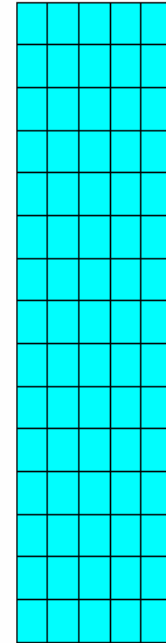
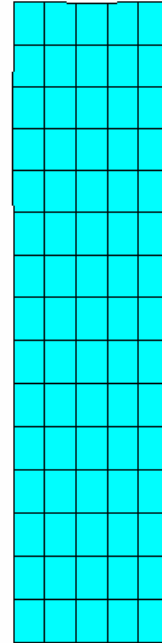
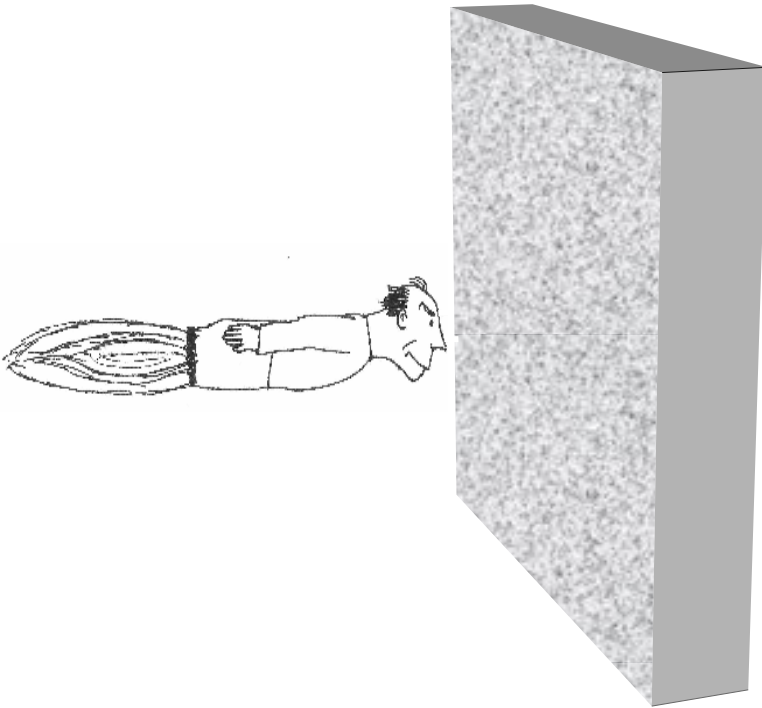
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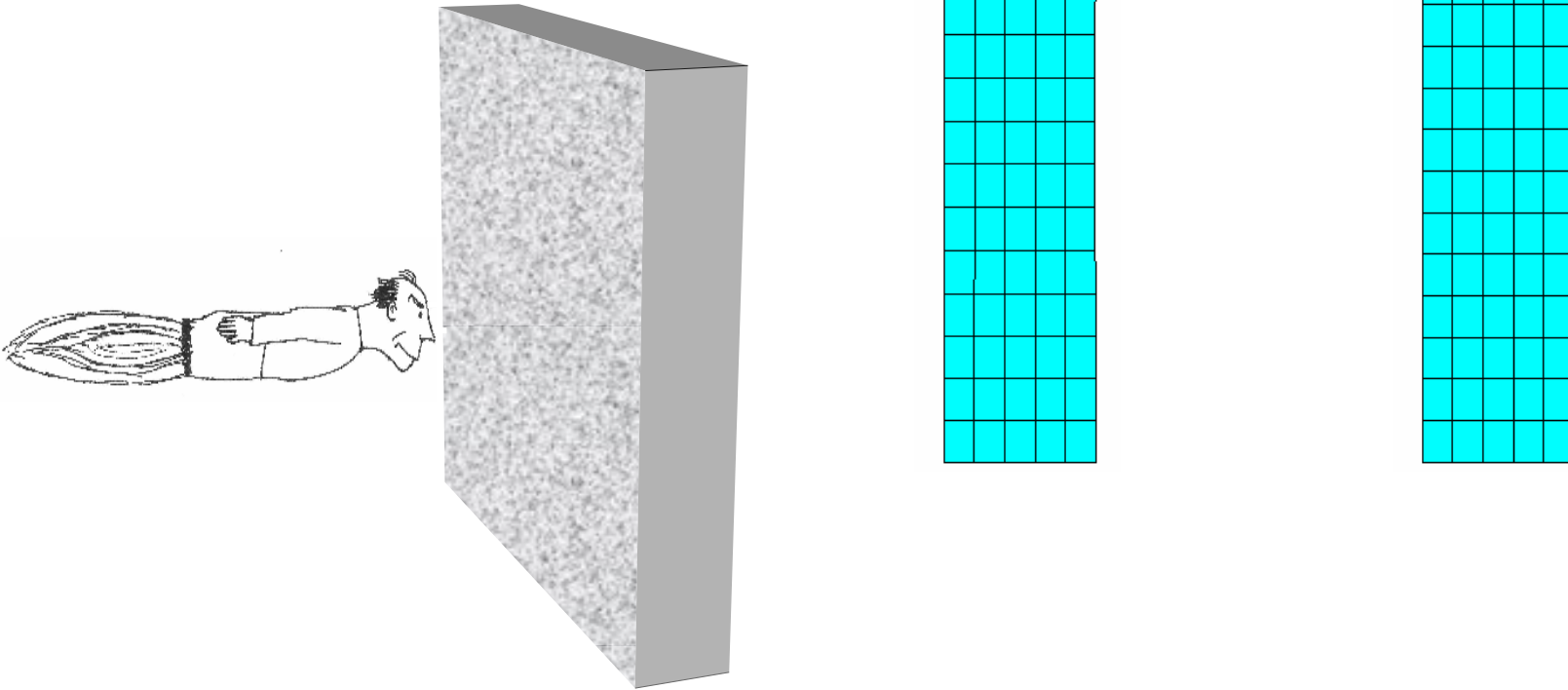
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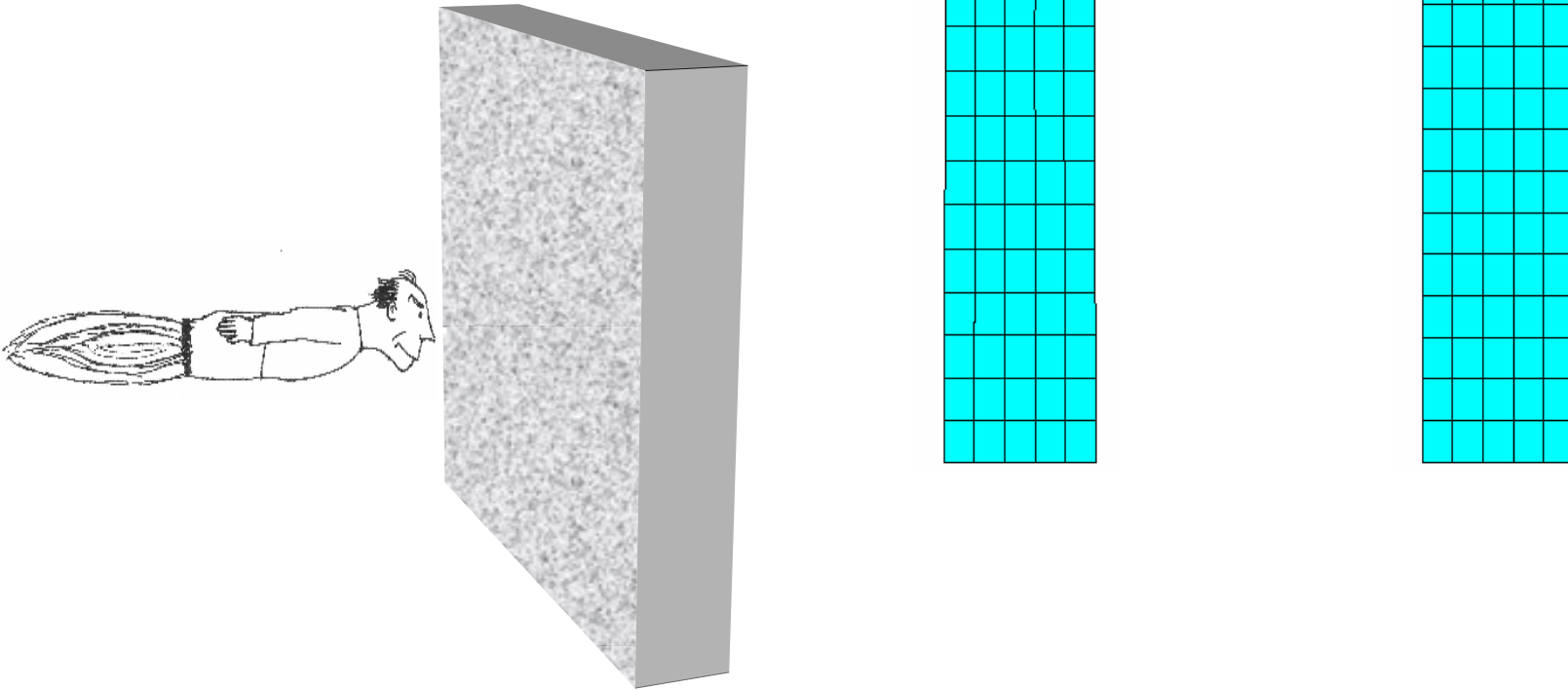
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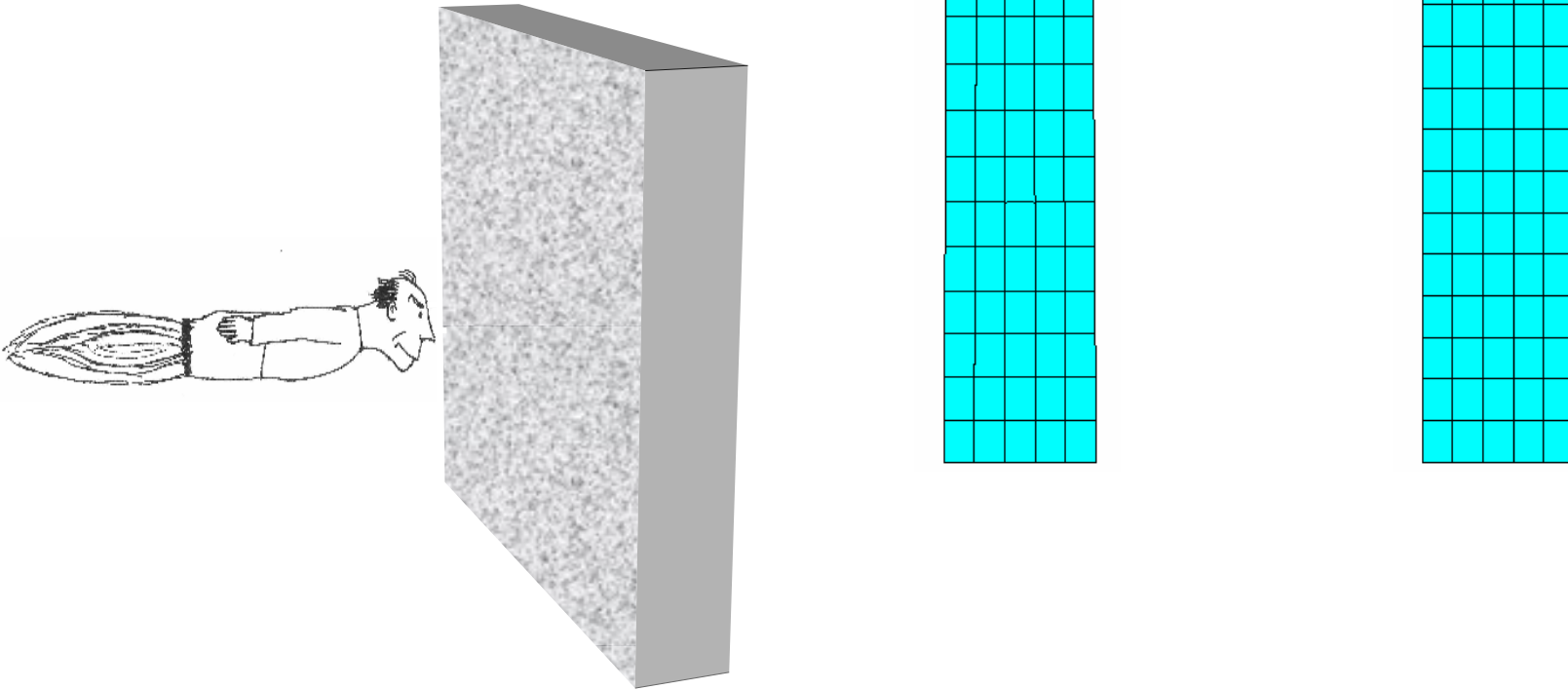
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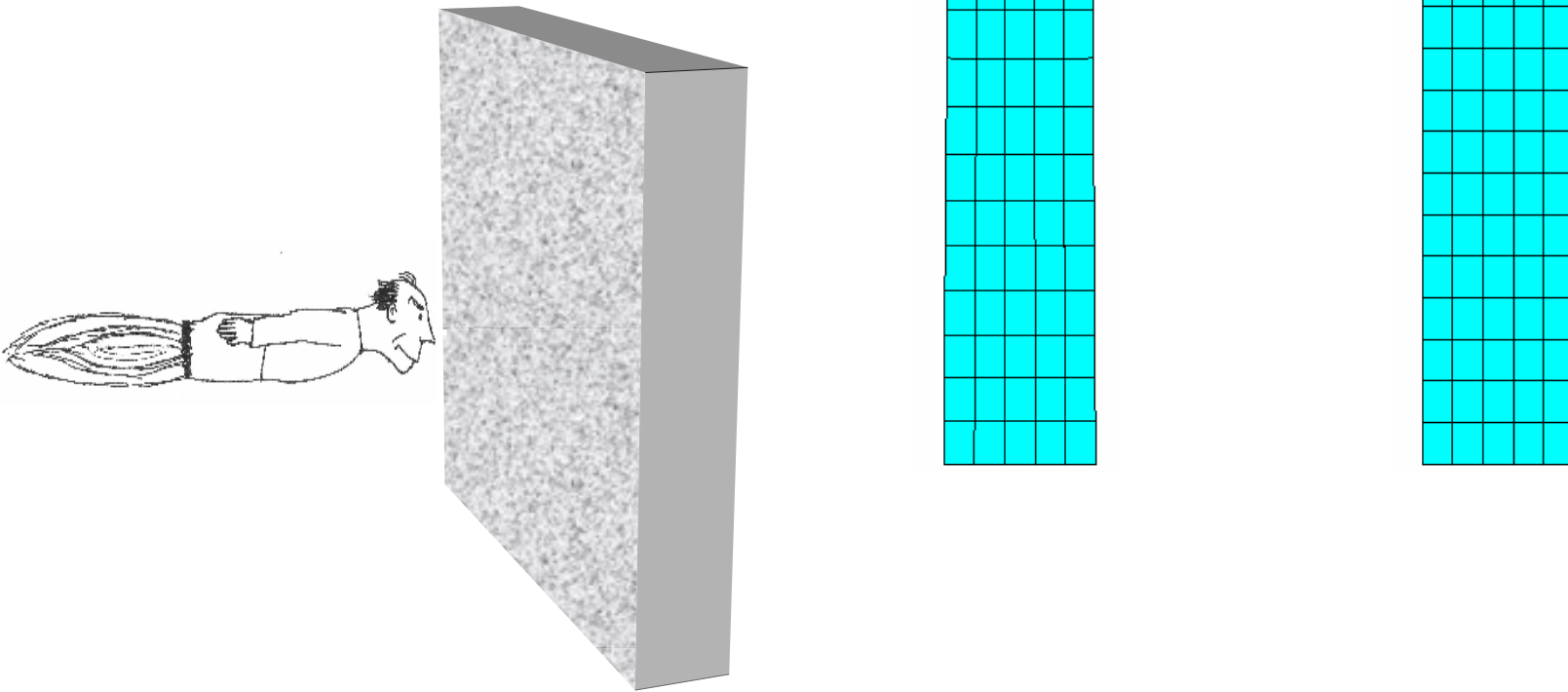
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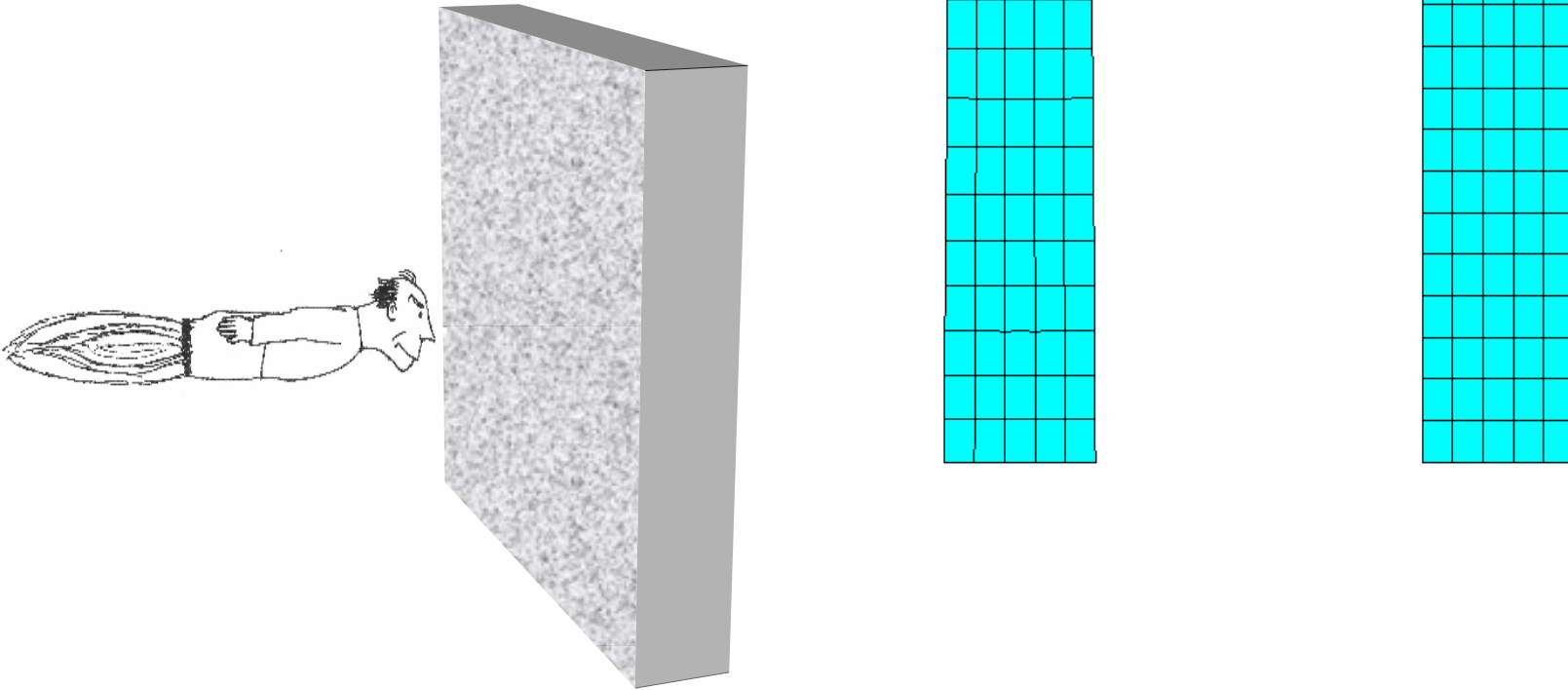
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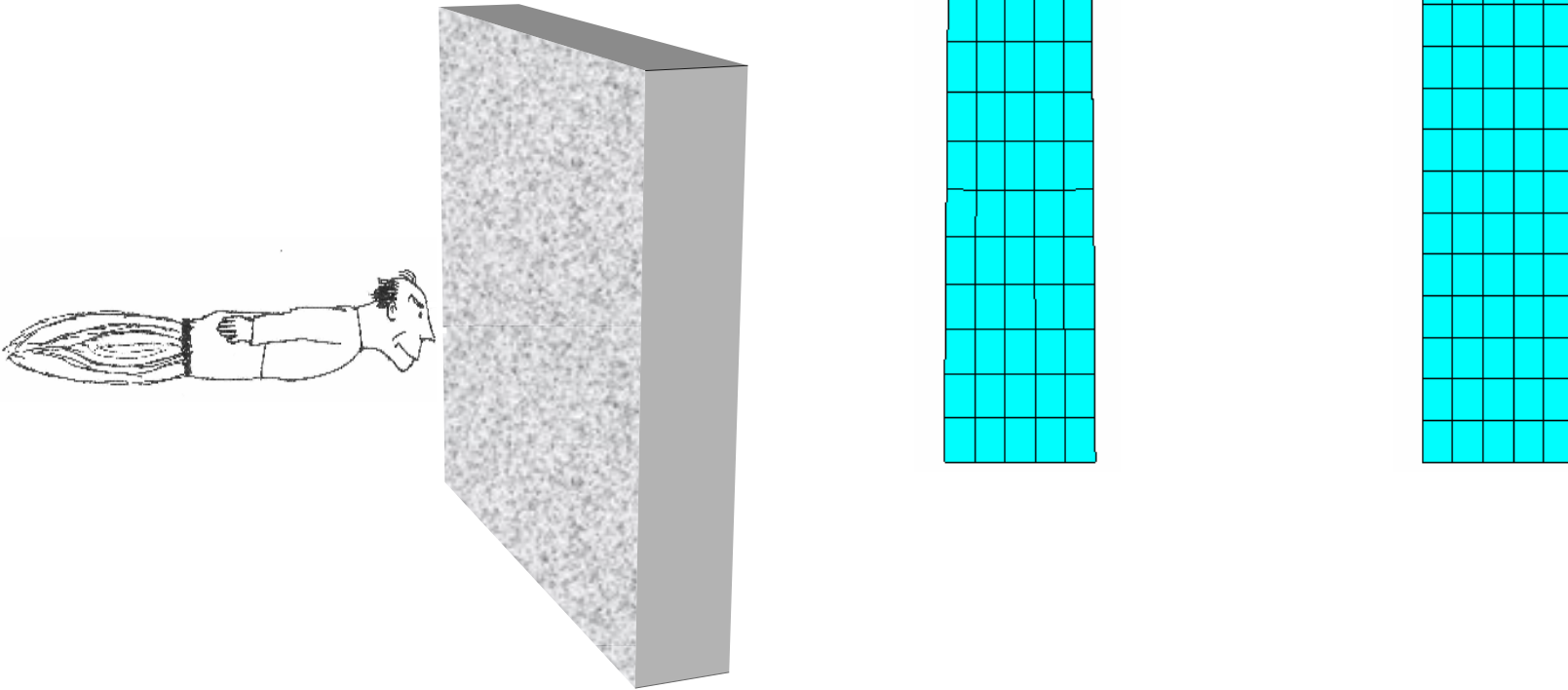
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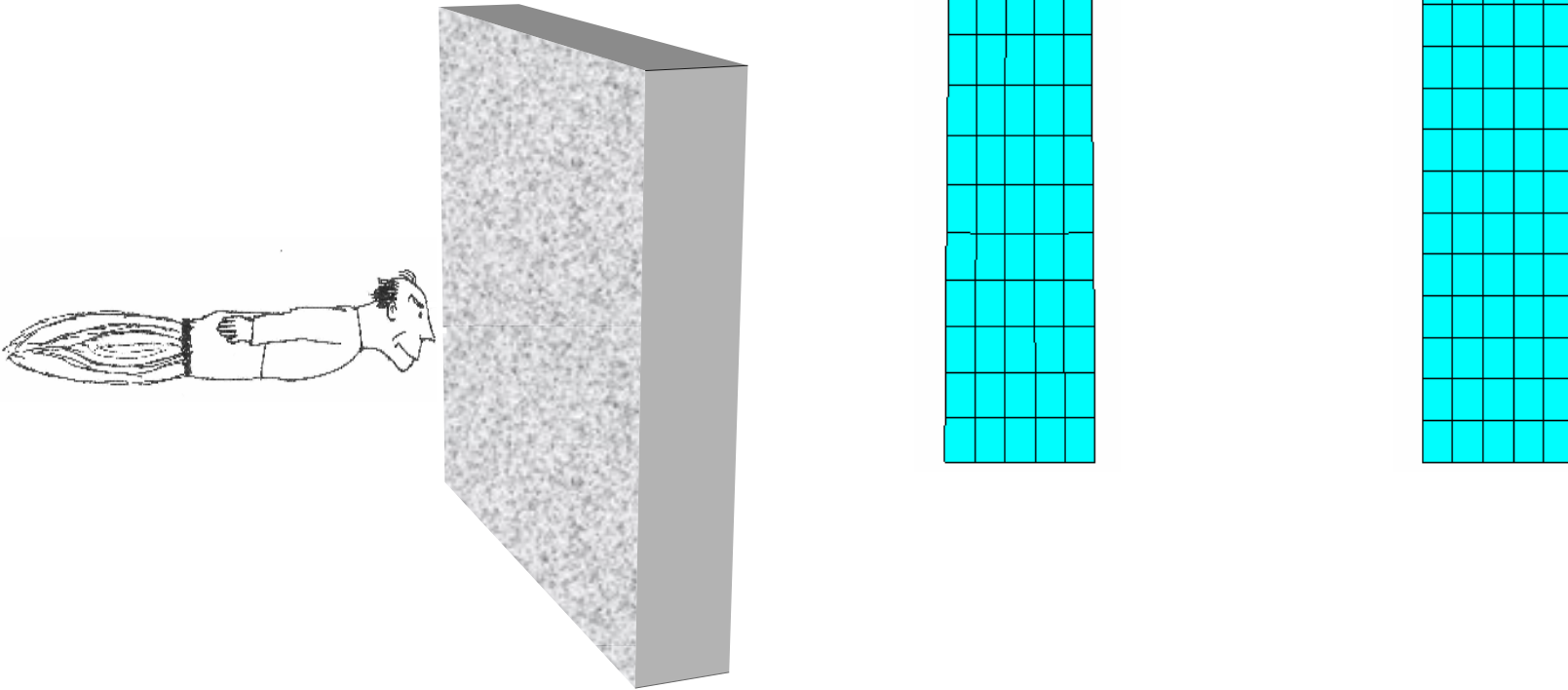
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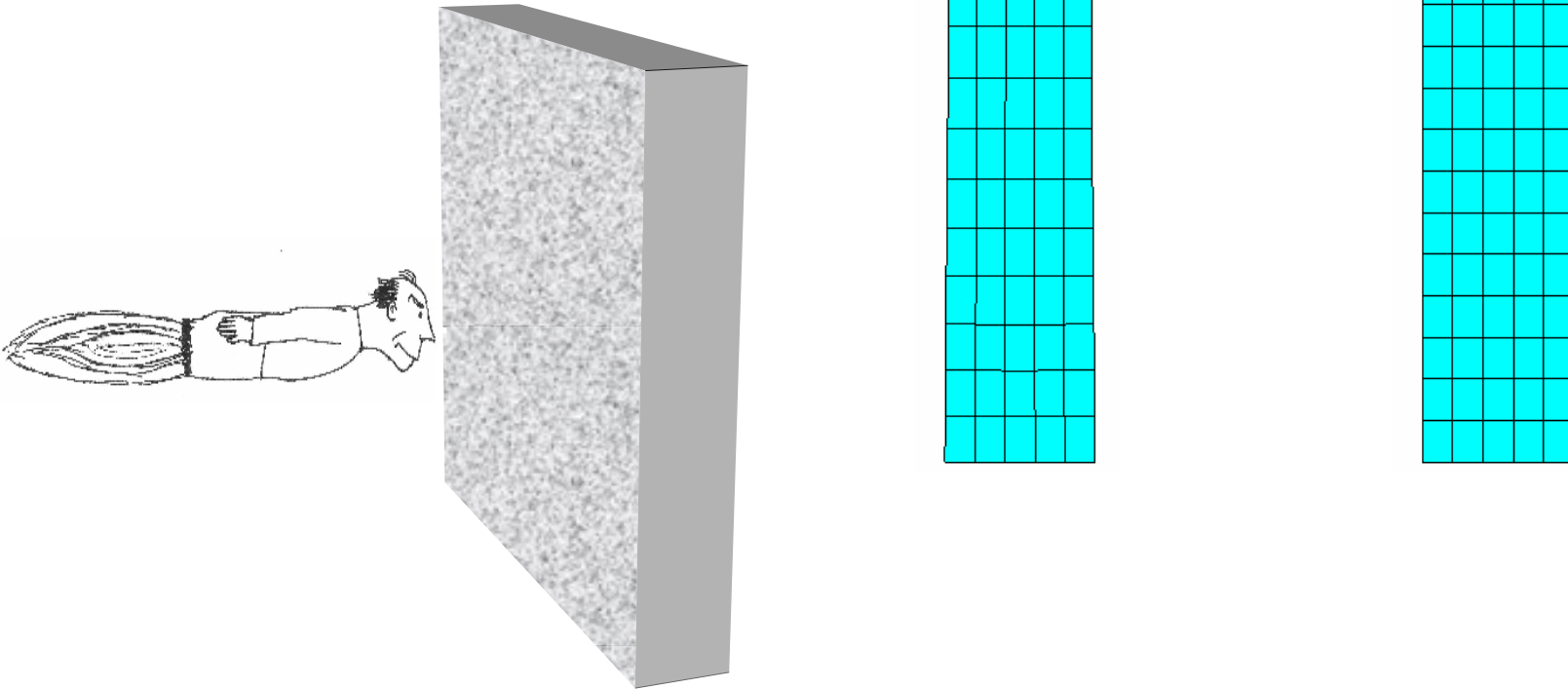
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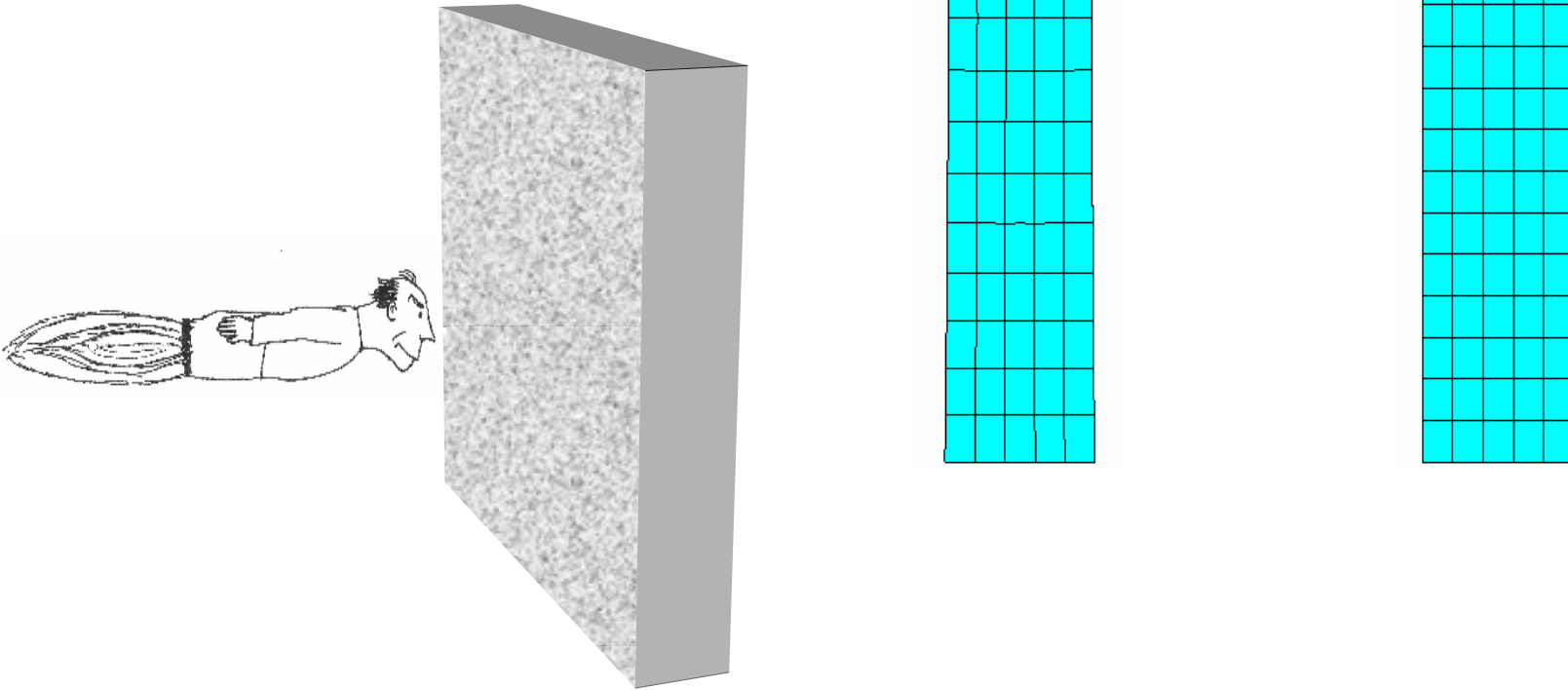
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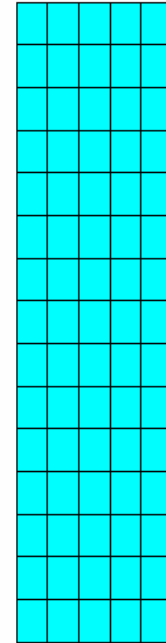
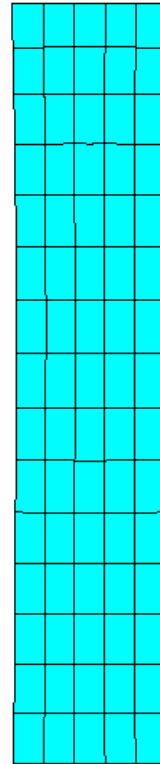
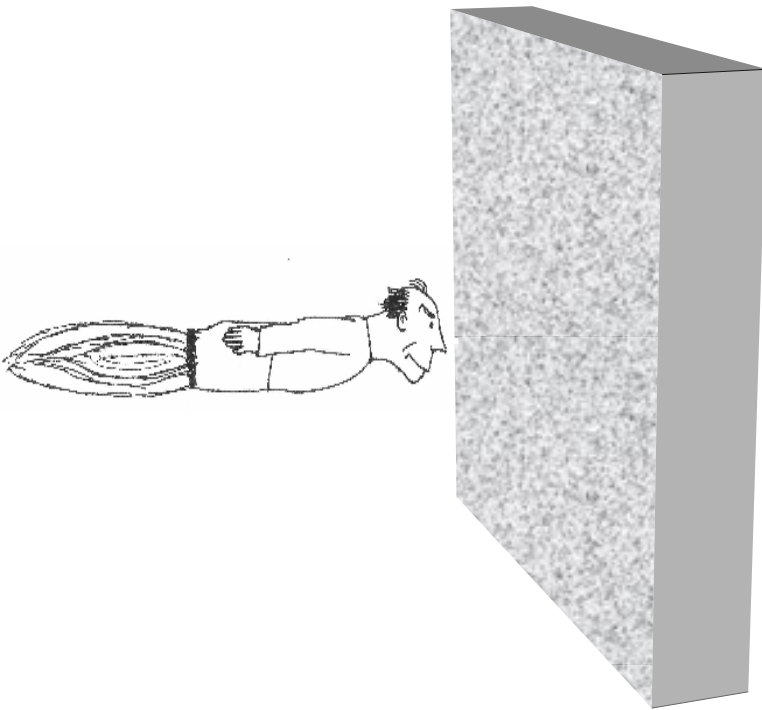
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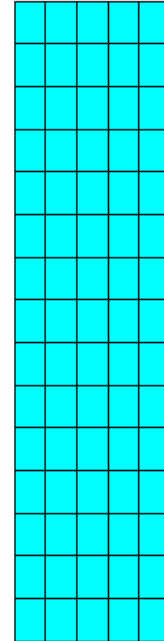
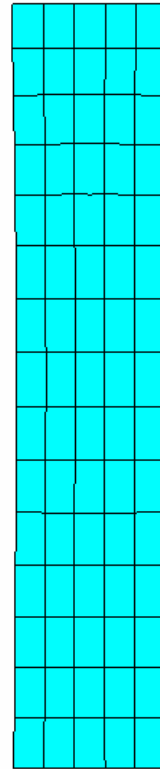
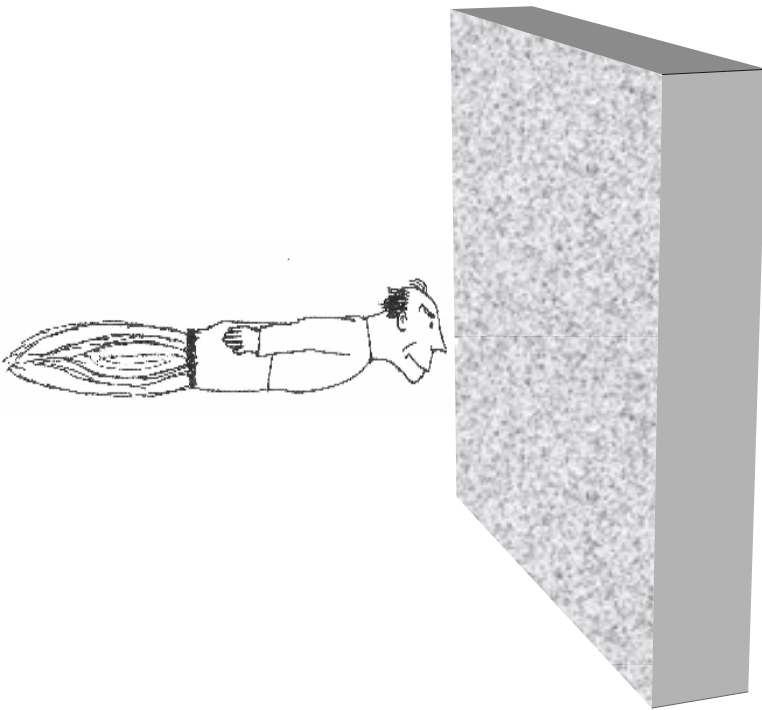
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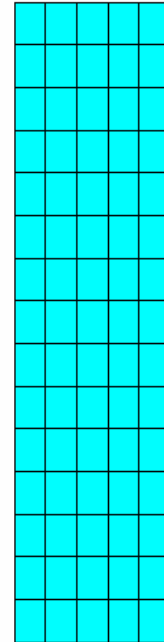
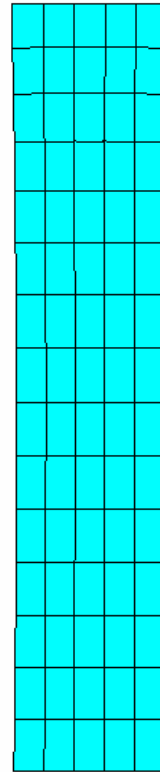
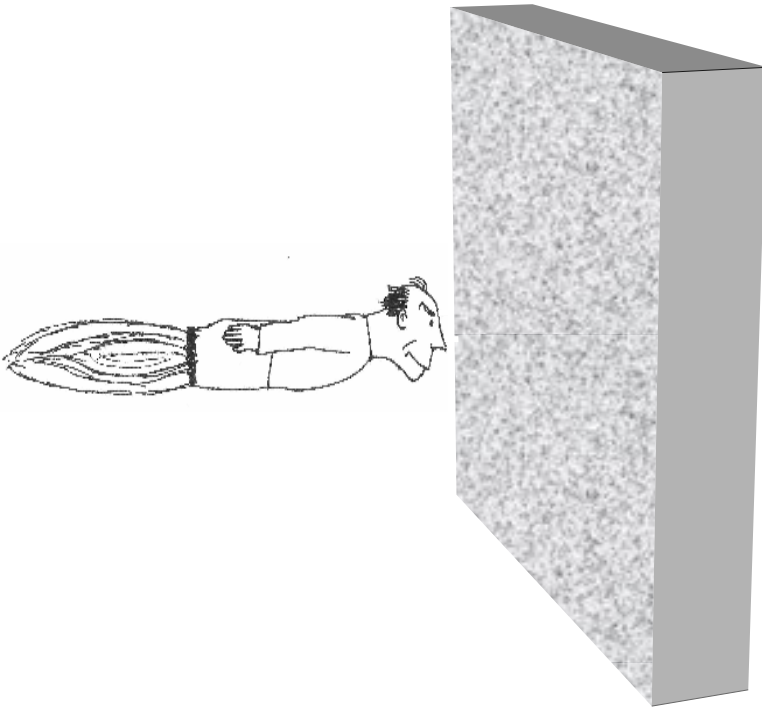
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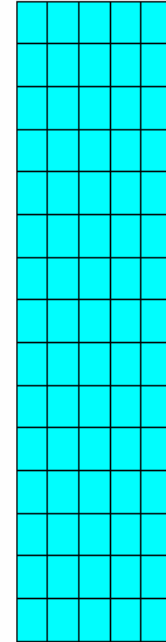
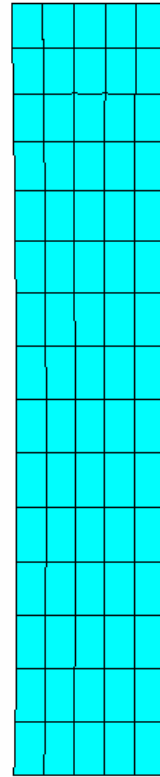
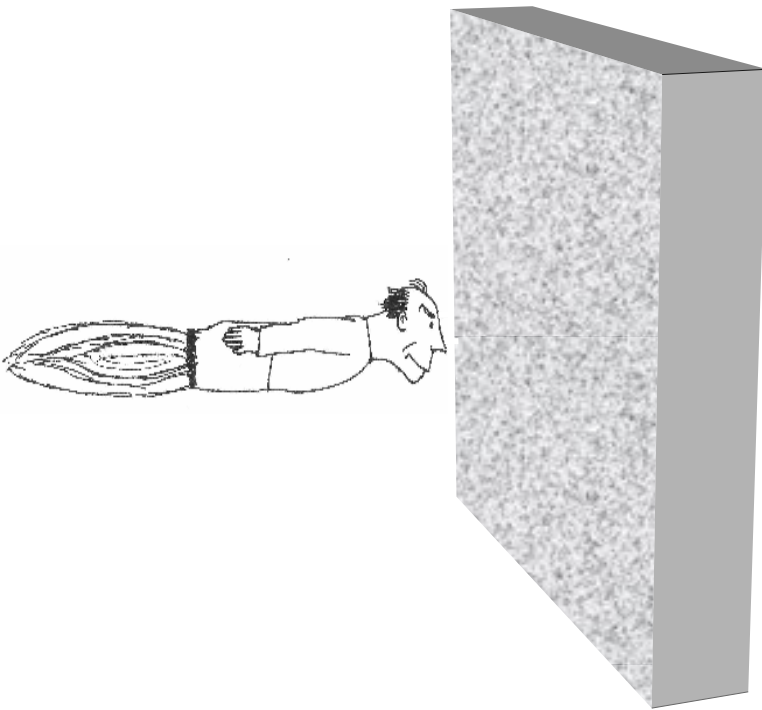
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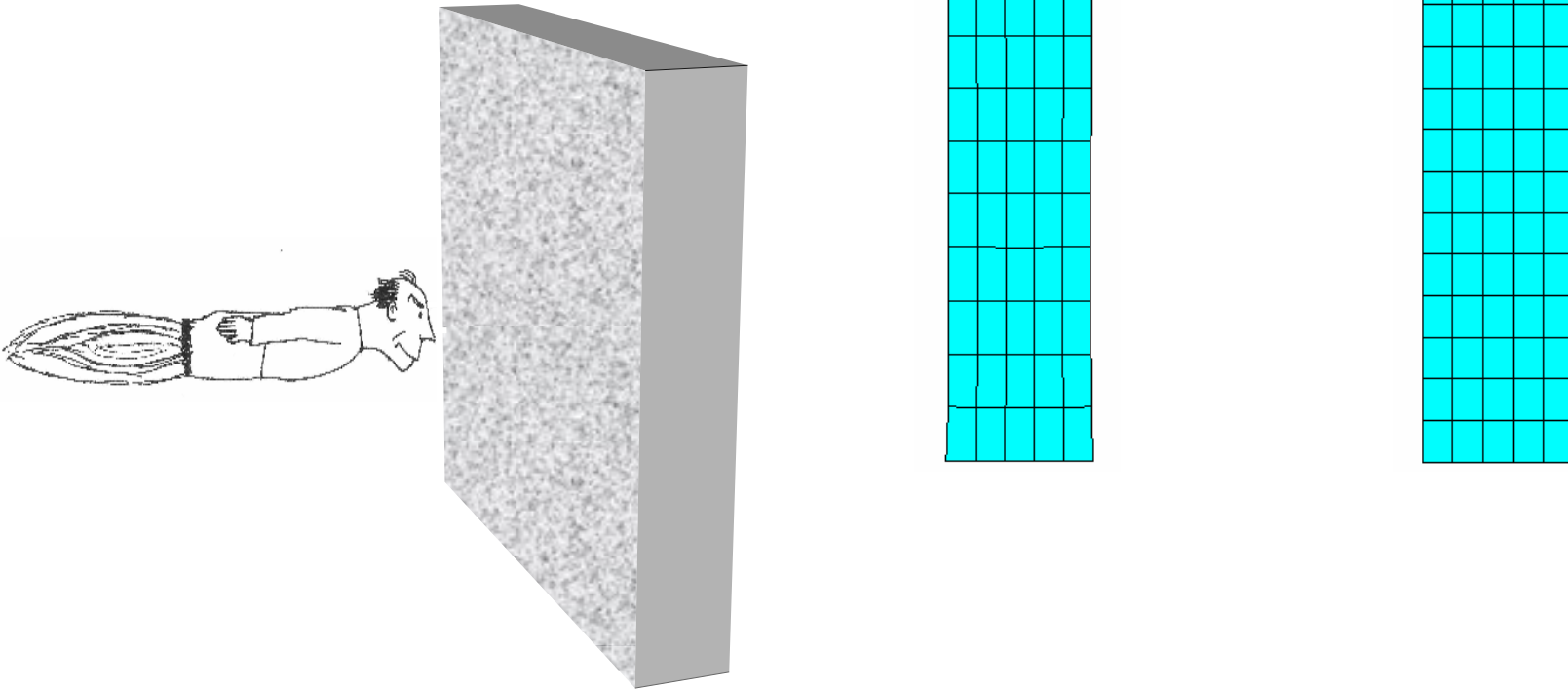
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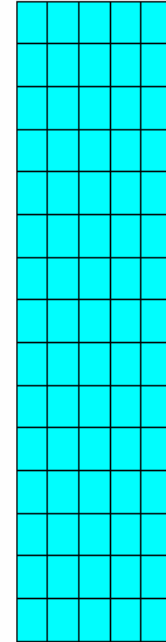
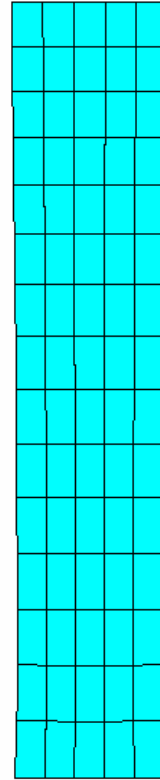
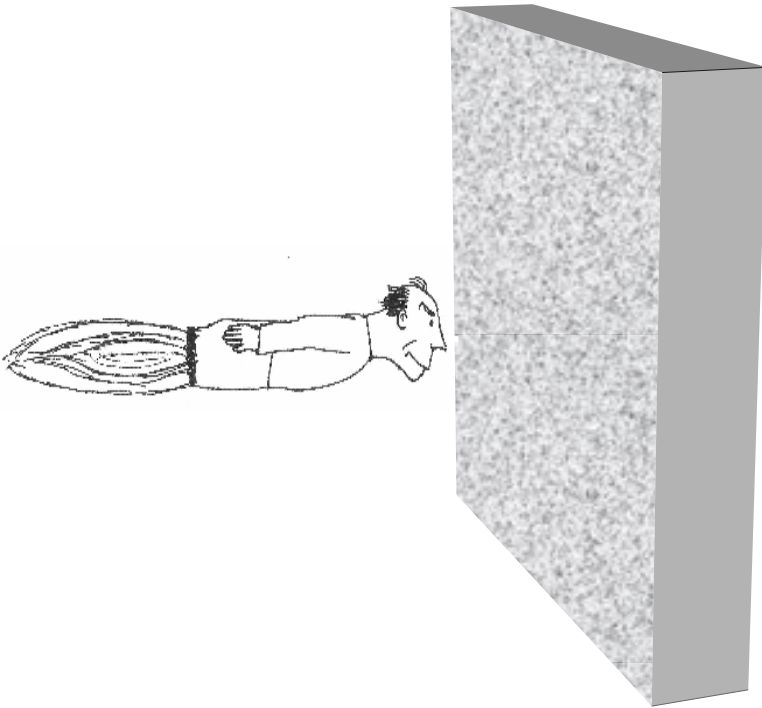
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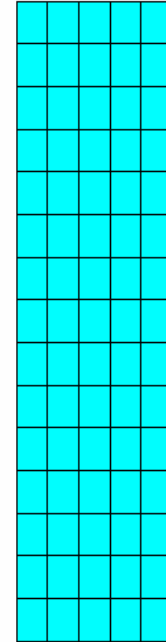
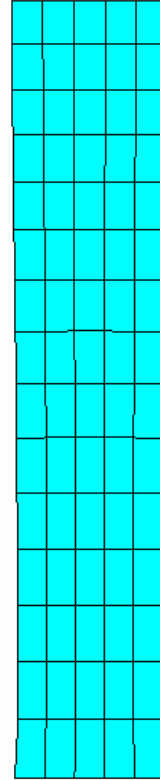
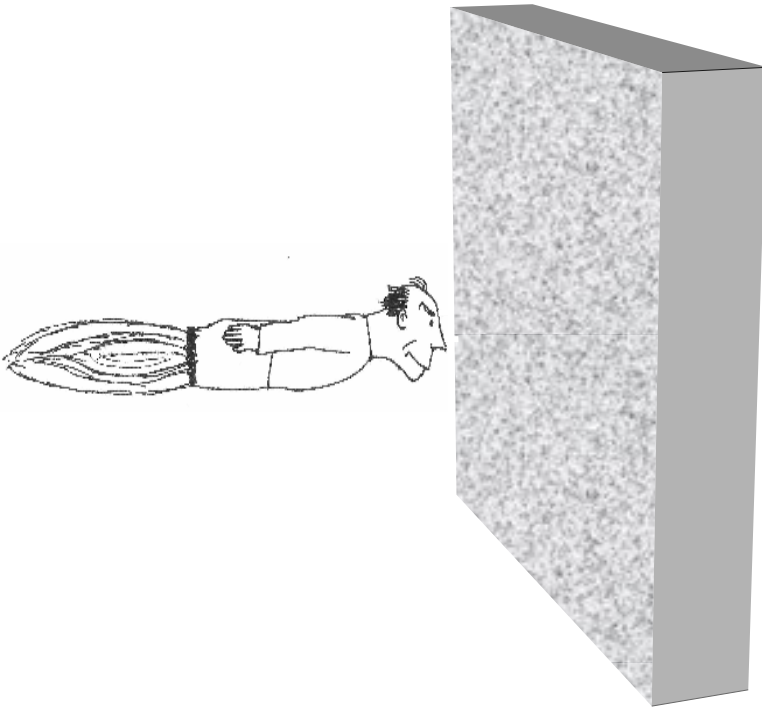
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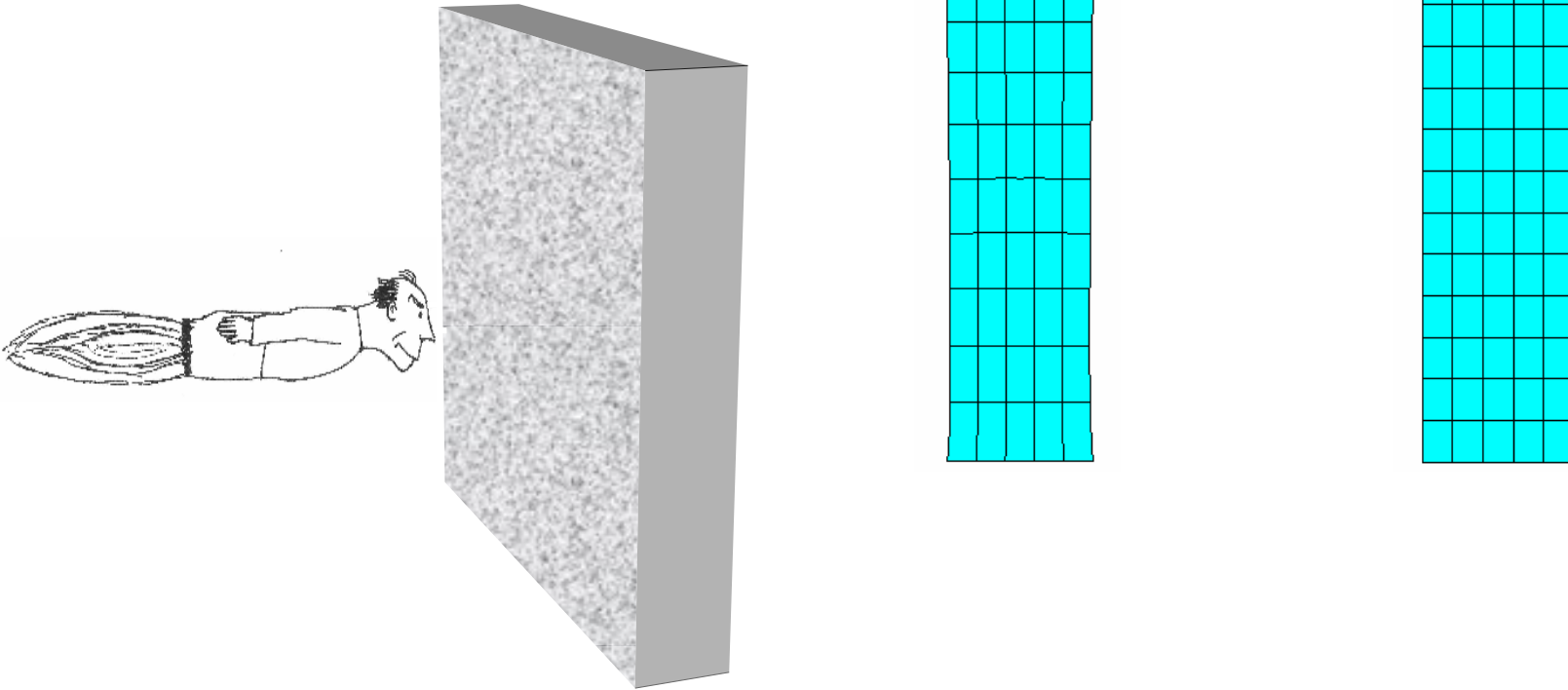
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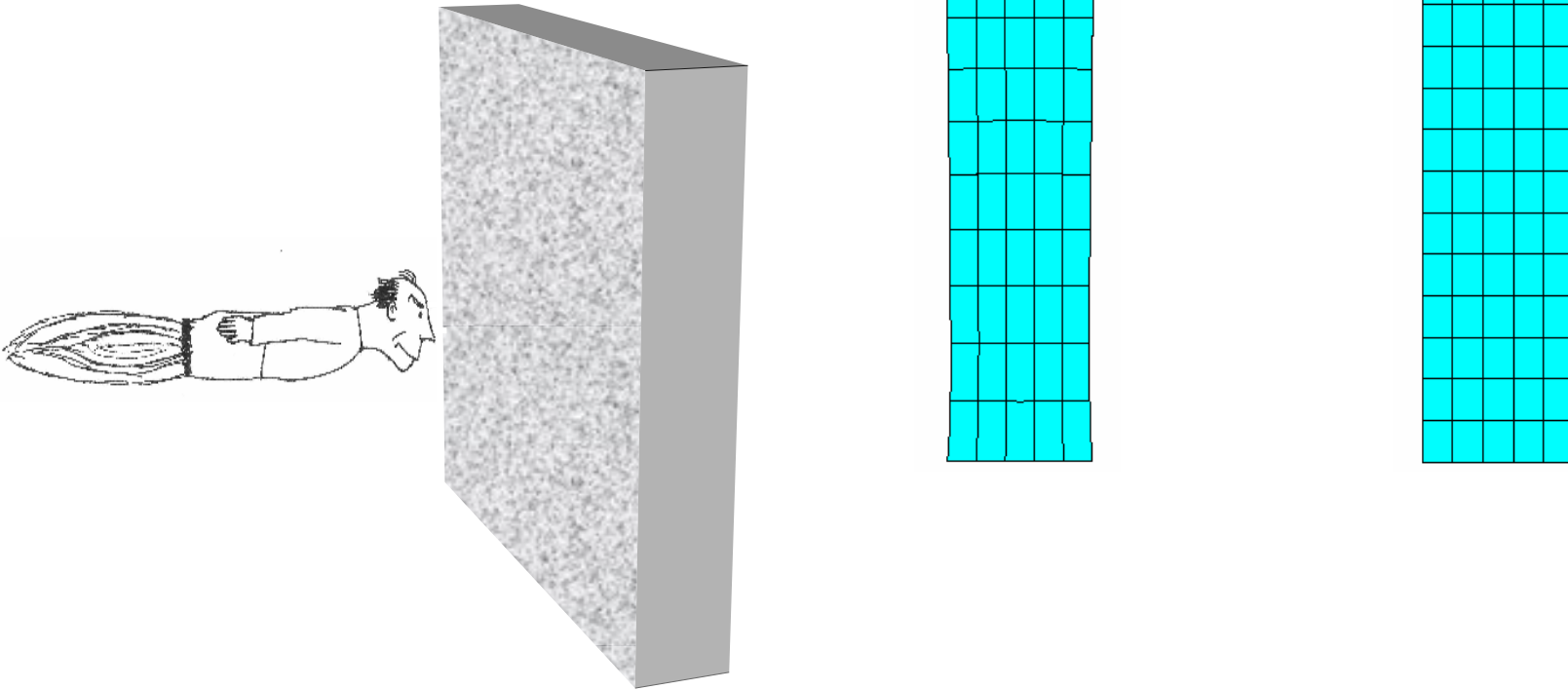
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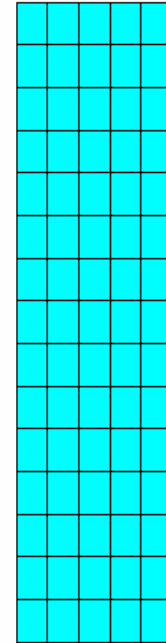
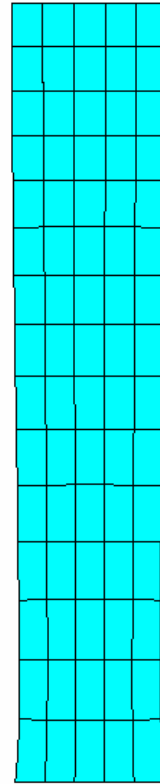
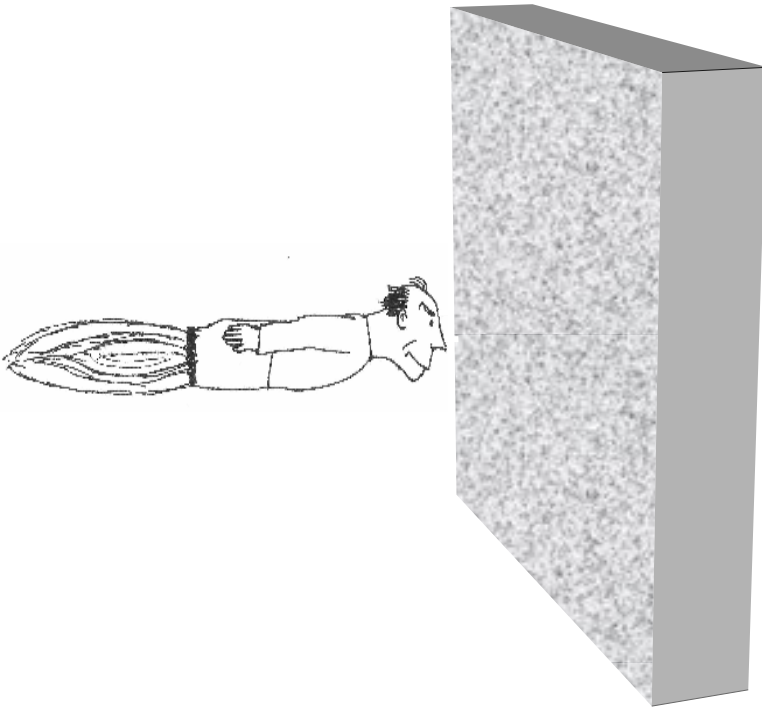
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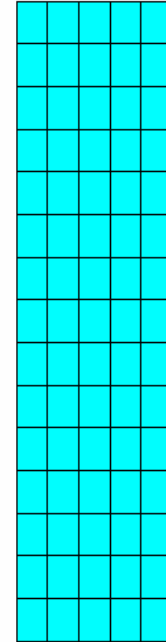
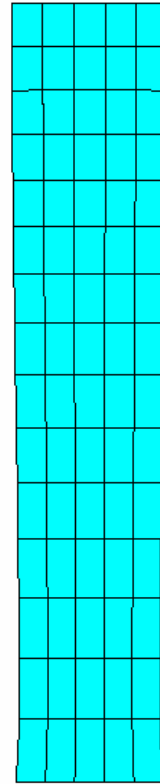
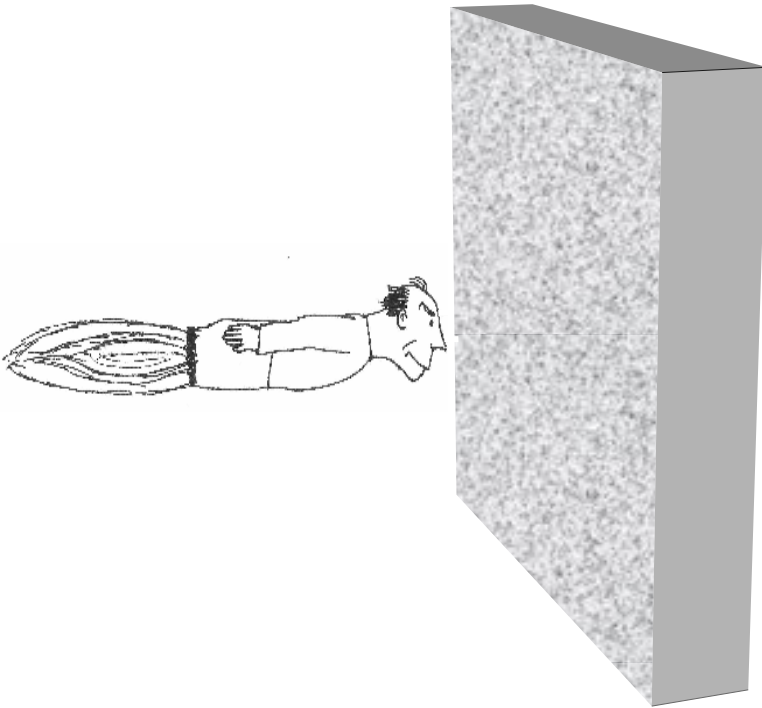
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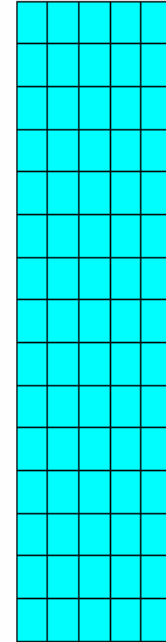
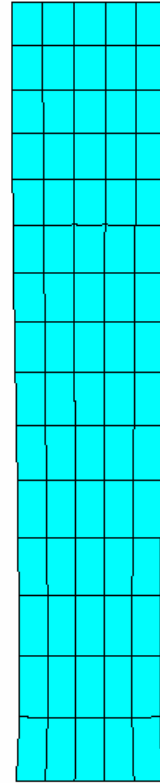
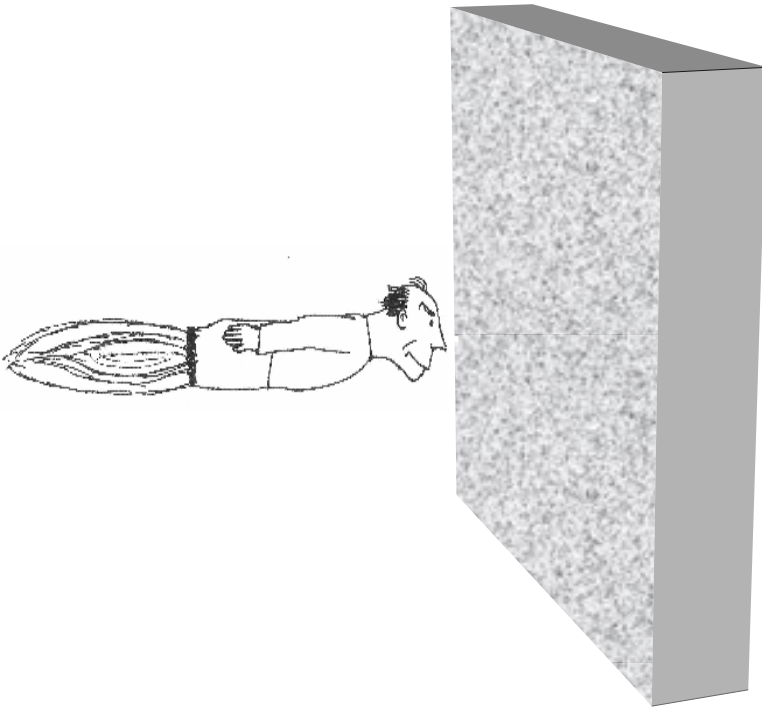
- Wave dissipation techniques
 - rigid boundaries



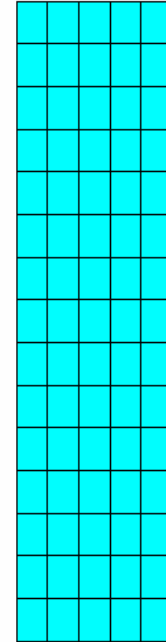
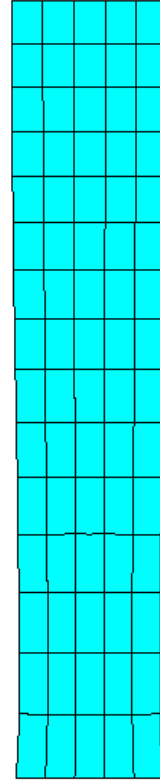
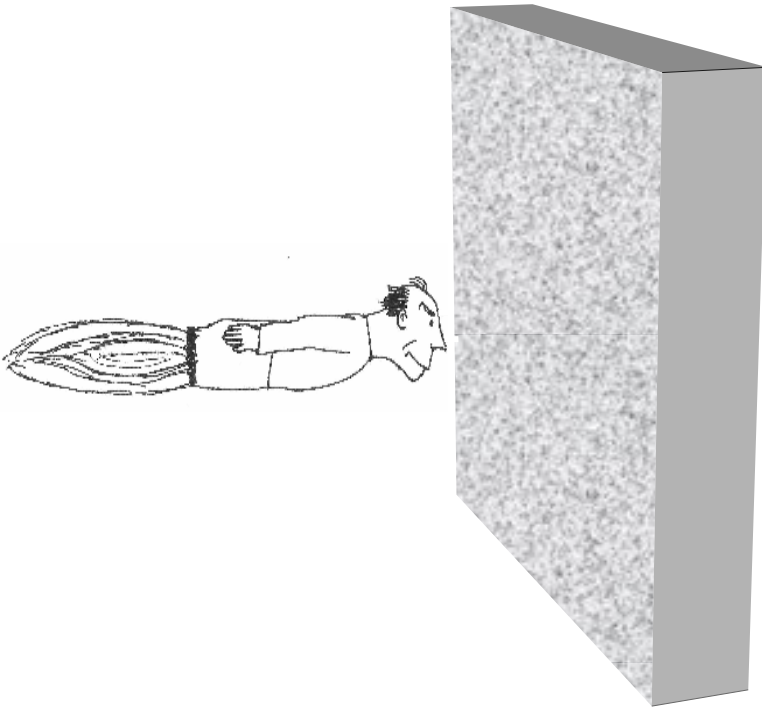
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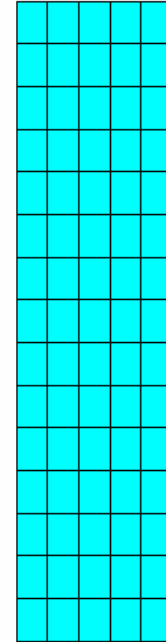
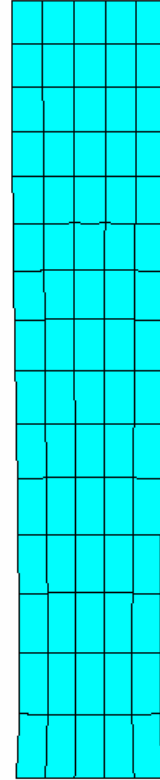
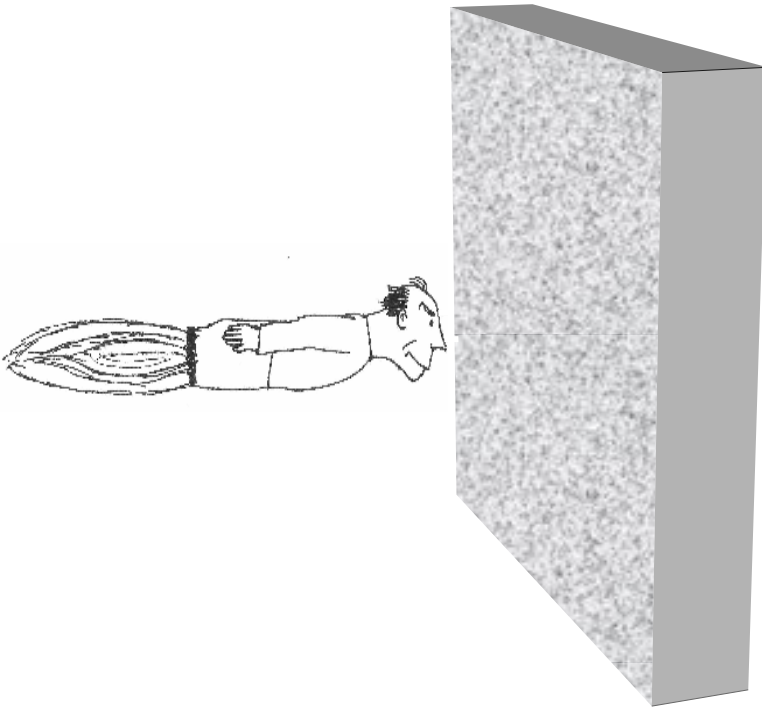
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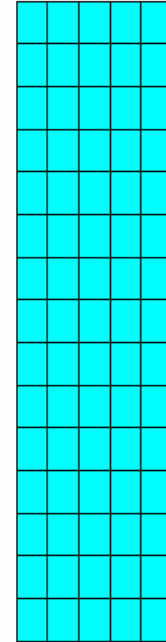
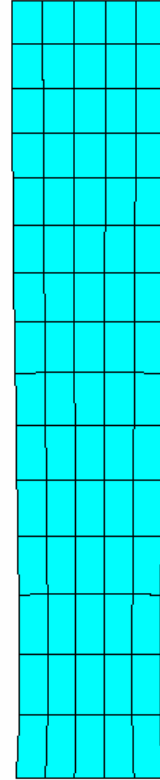
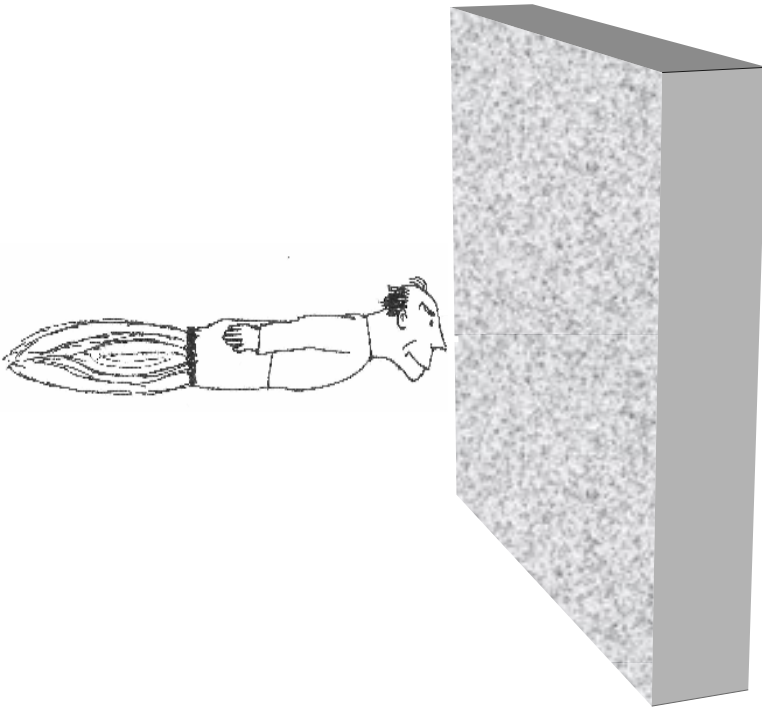
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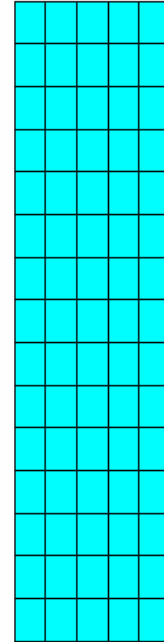
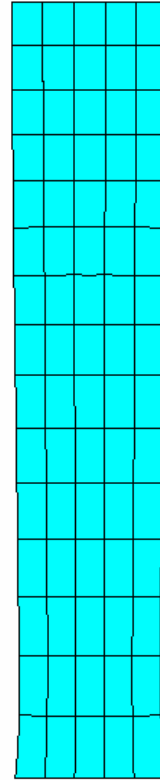
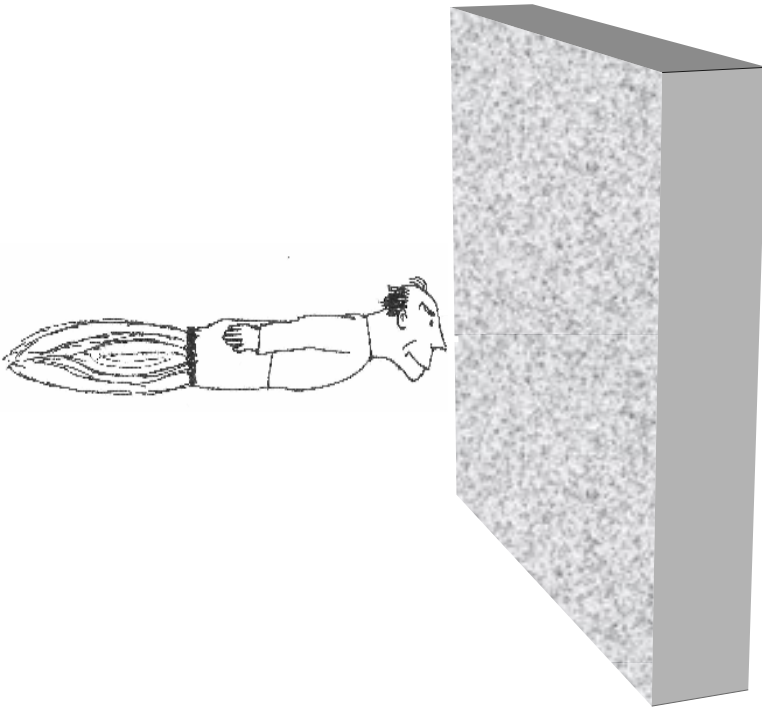
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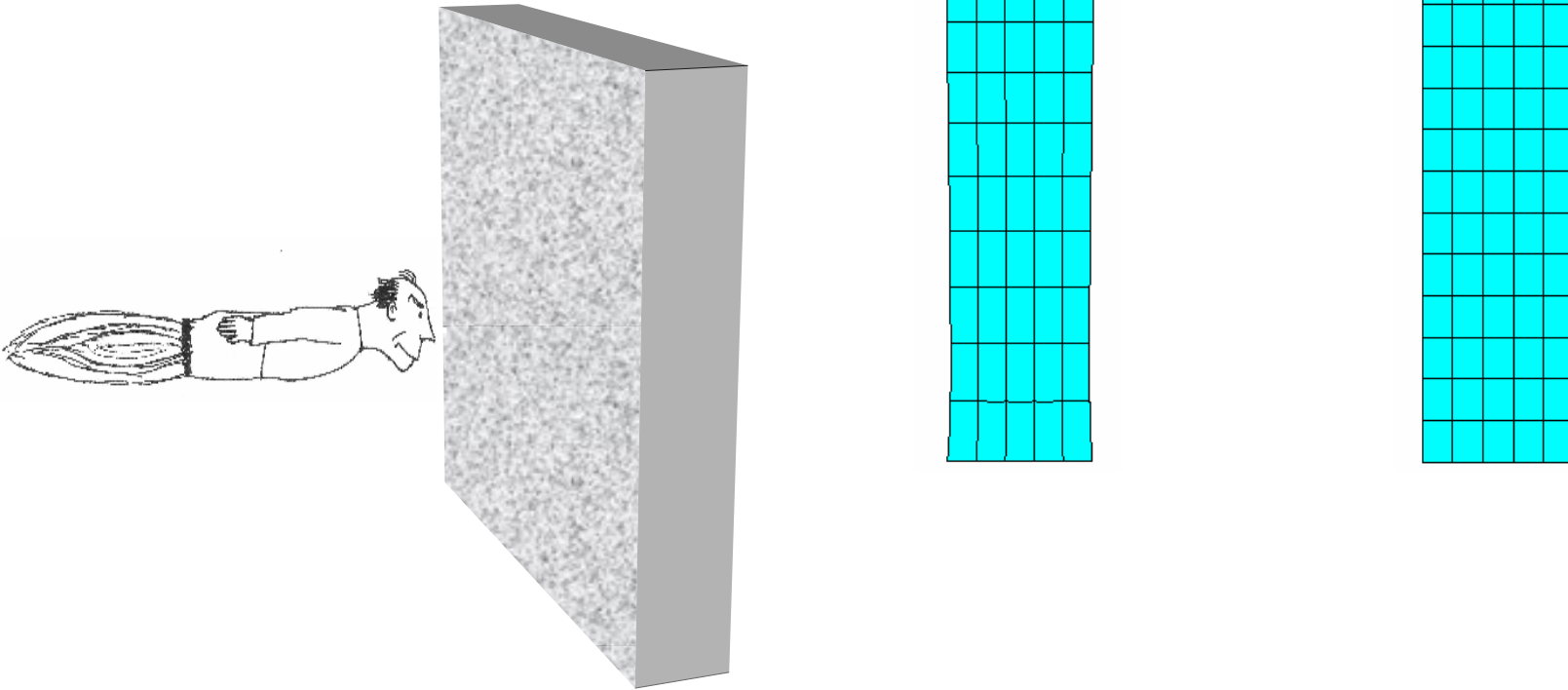
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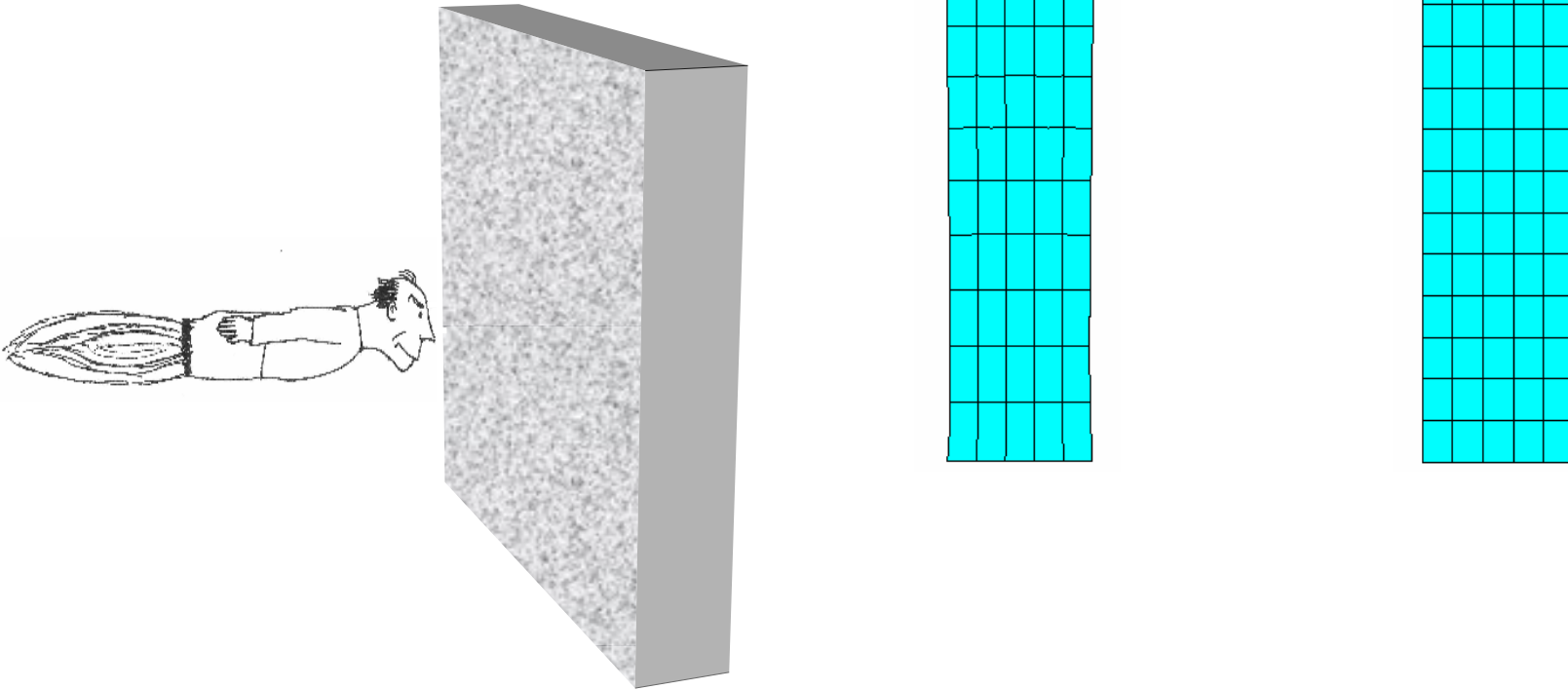
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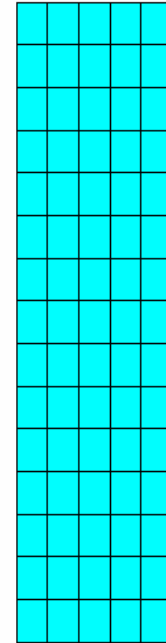
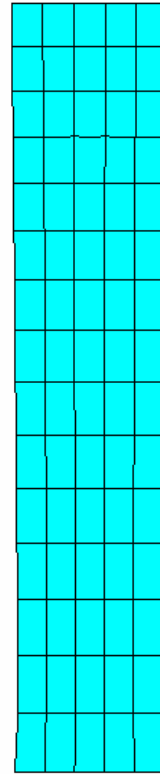
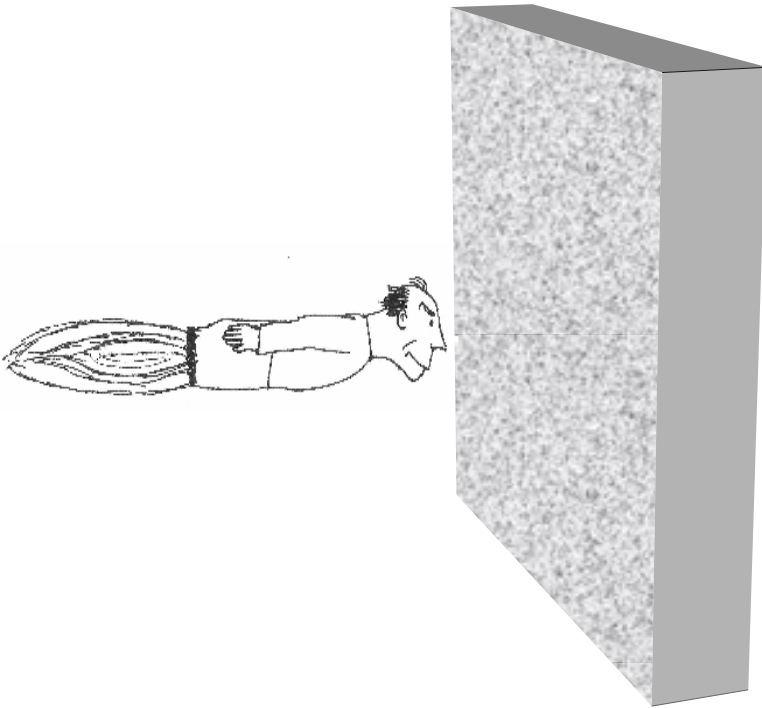
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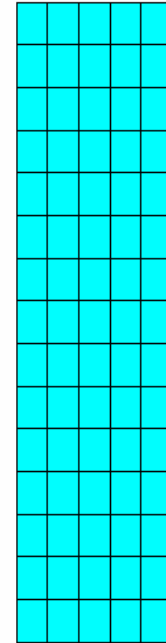
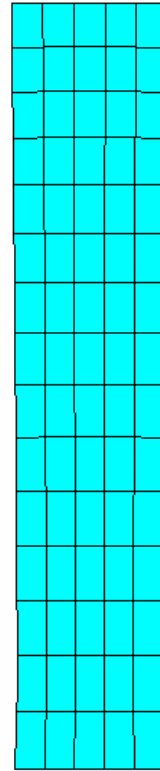
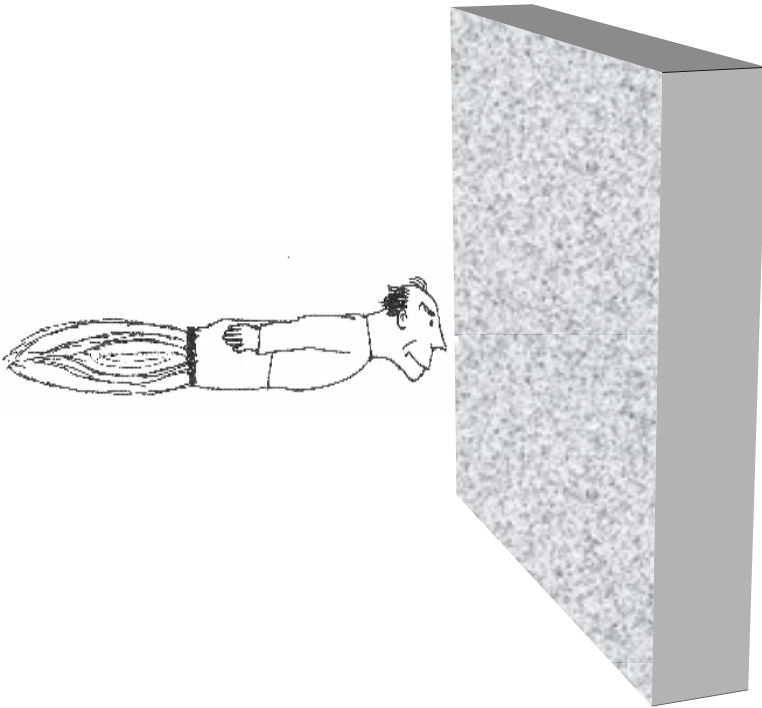
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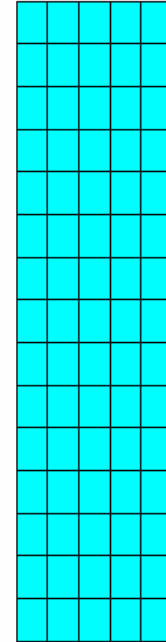
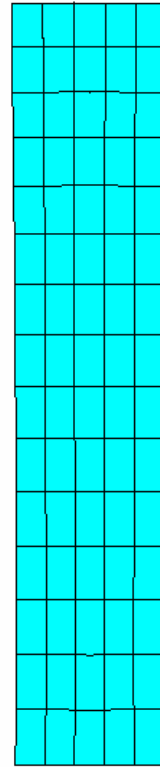
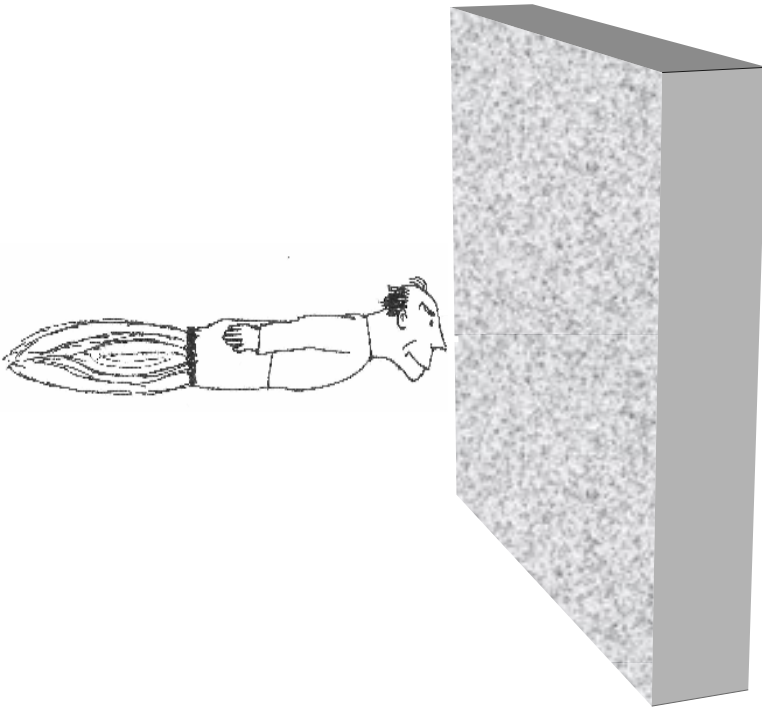
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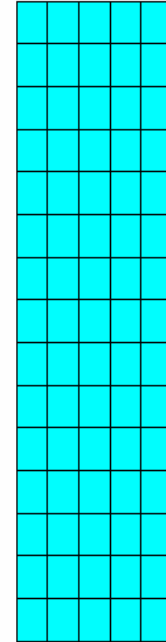
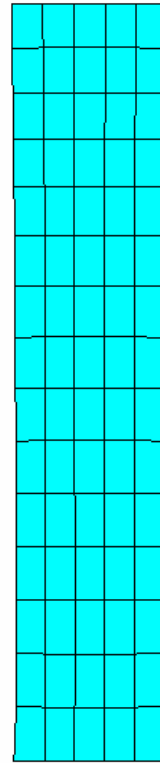
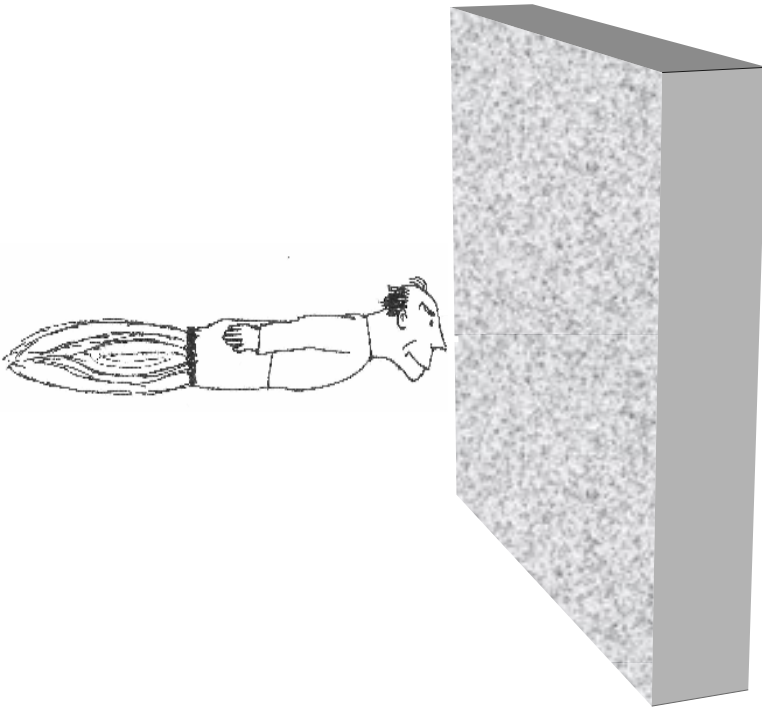
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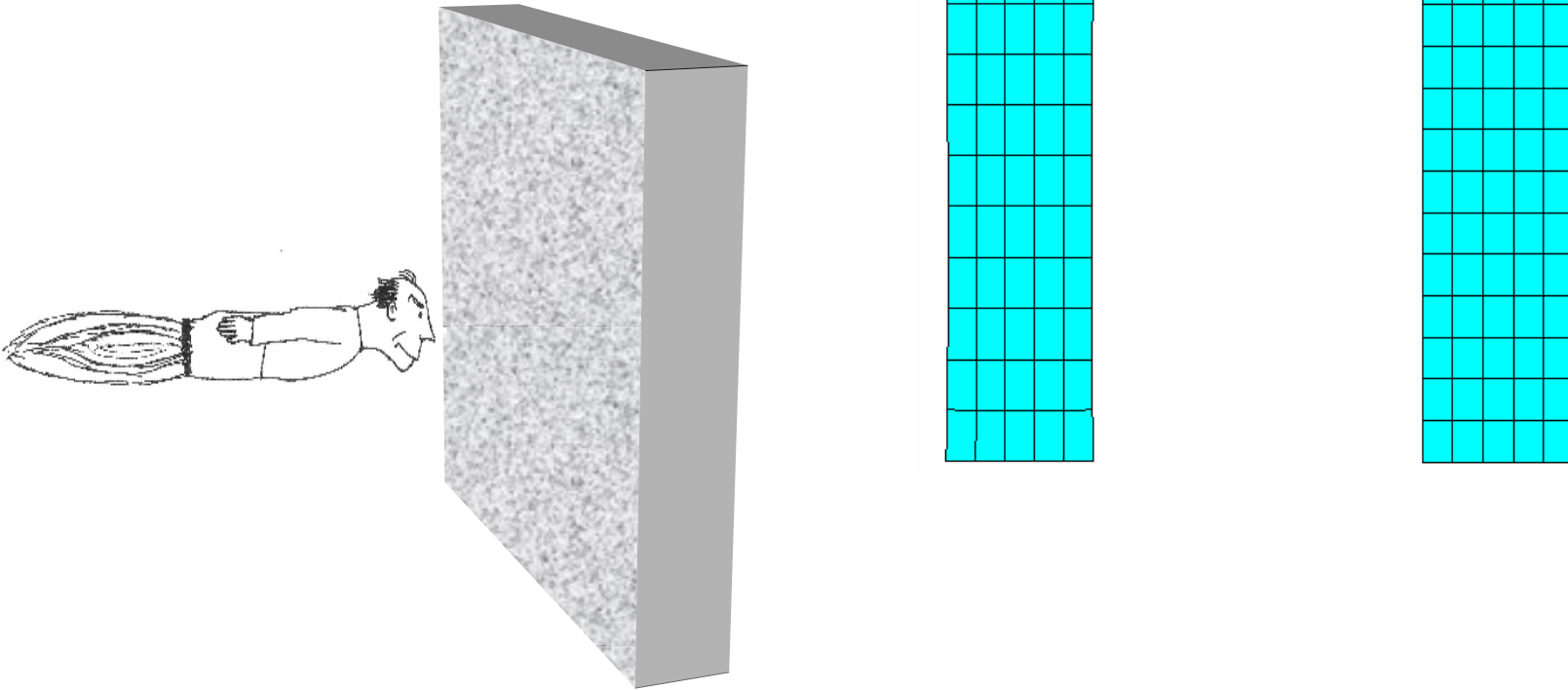
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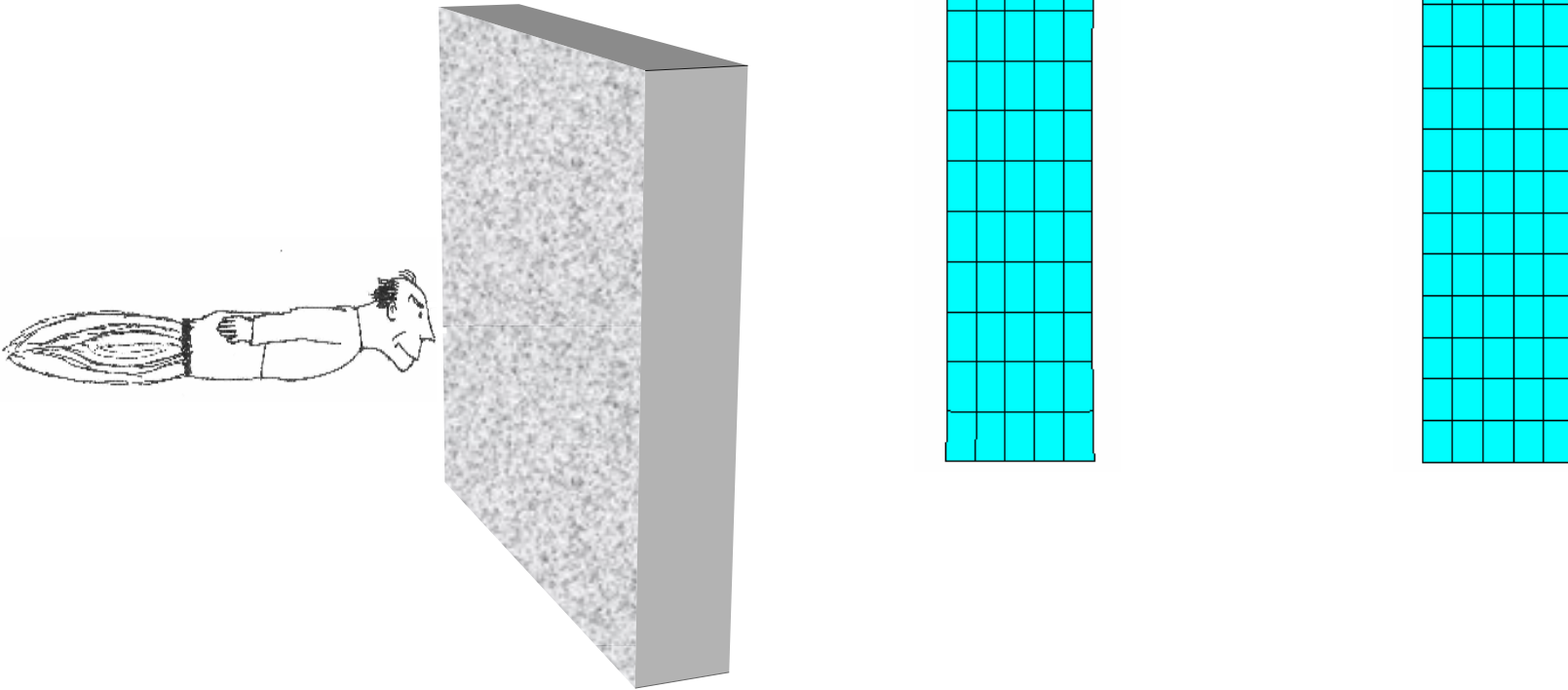
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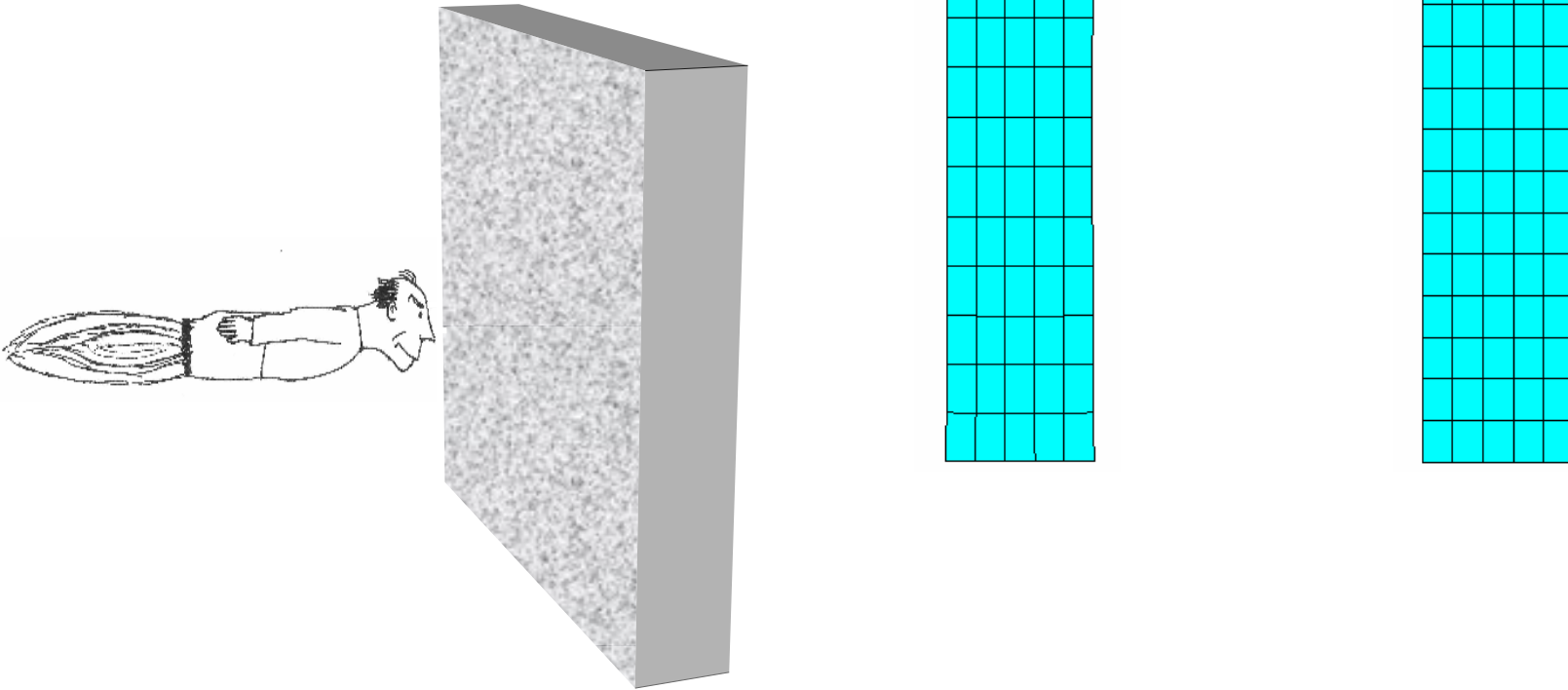
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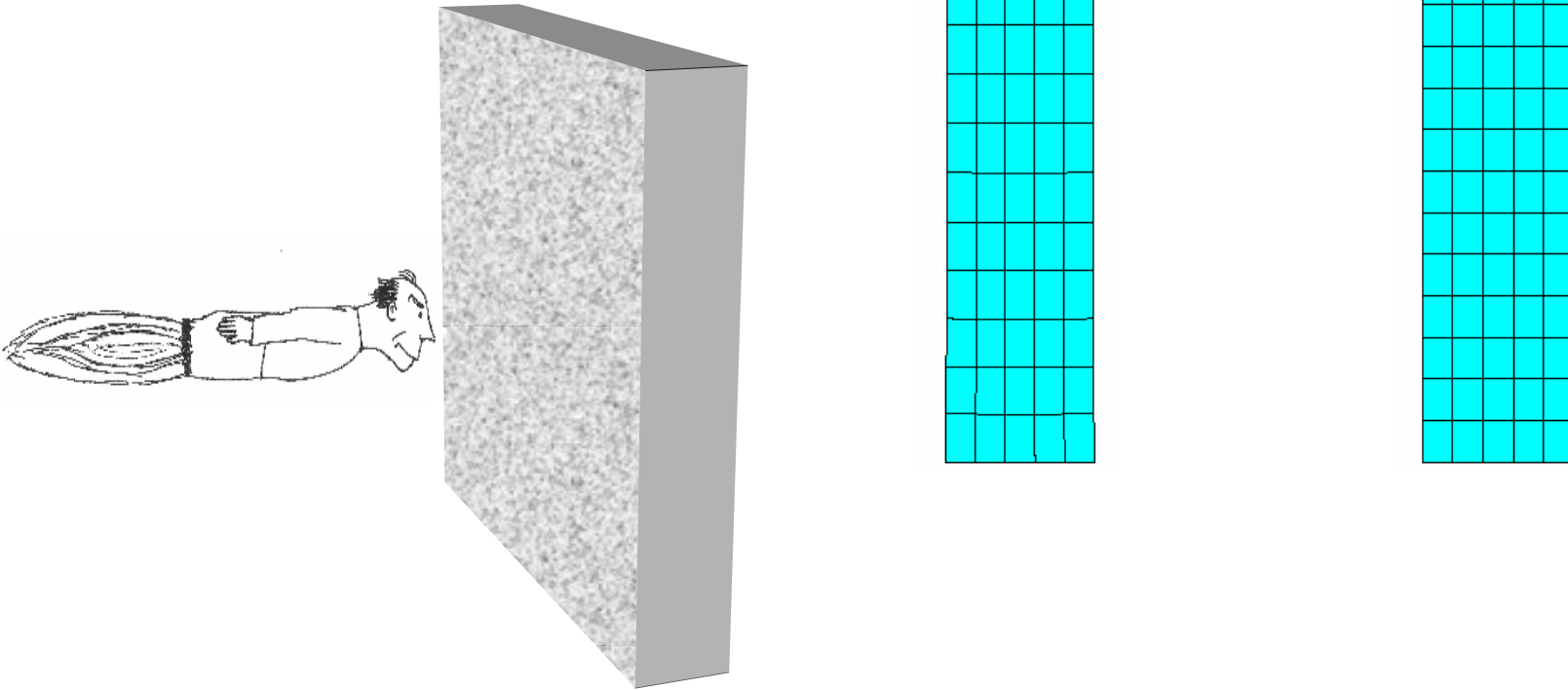
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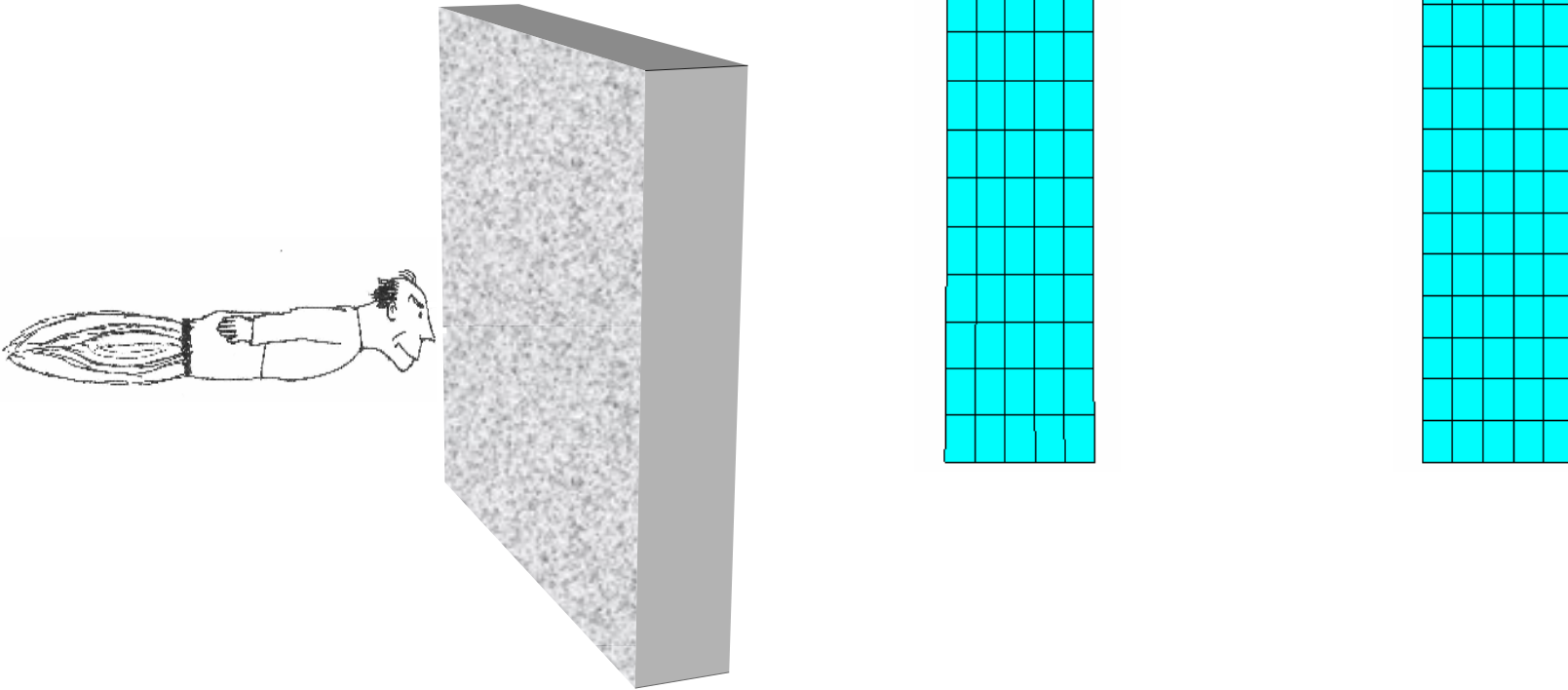
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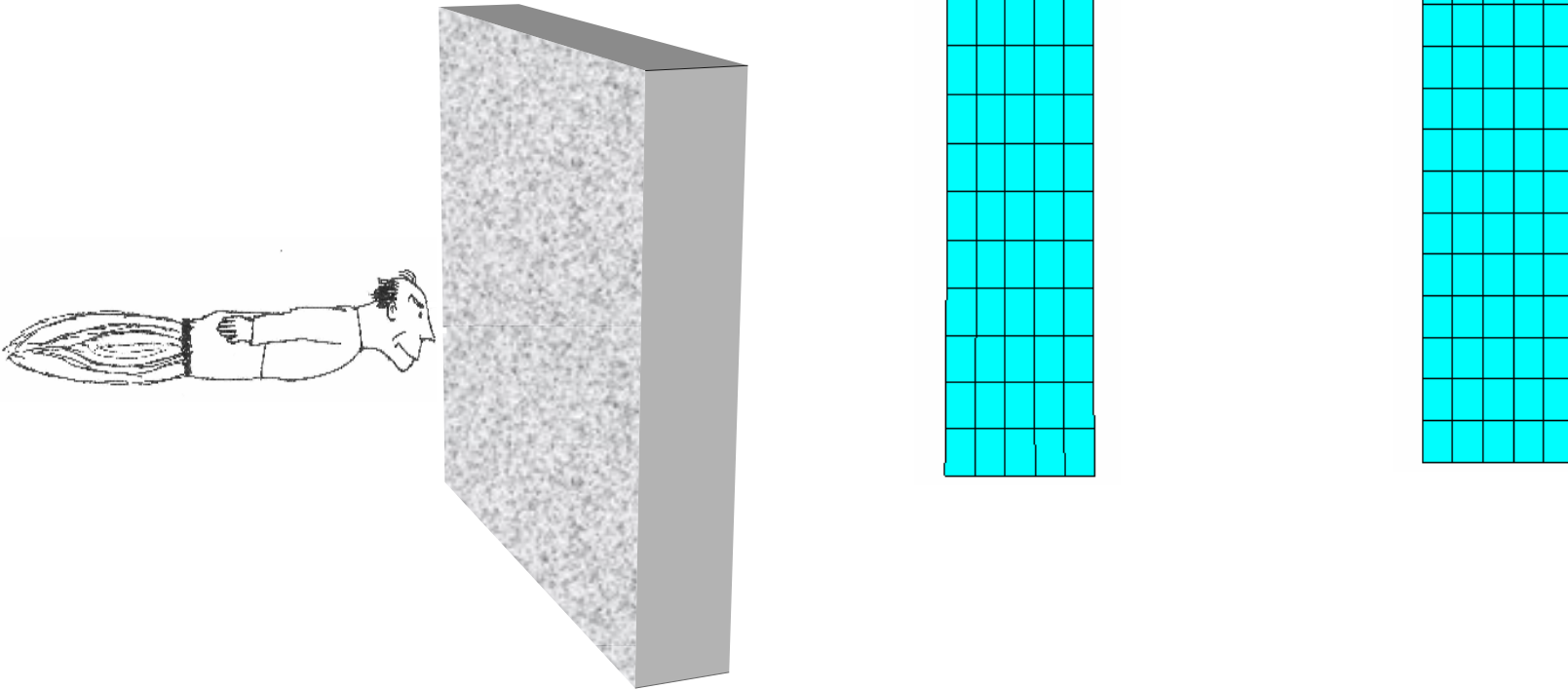
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- Wave dissipation techniques
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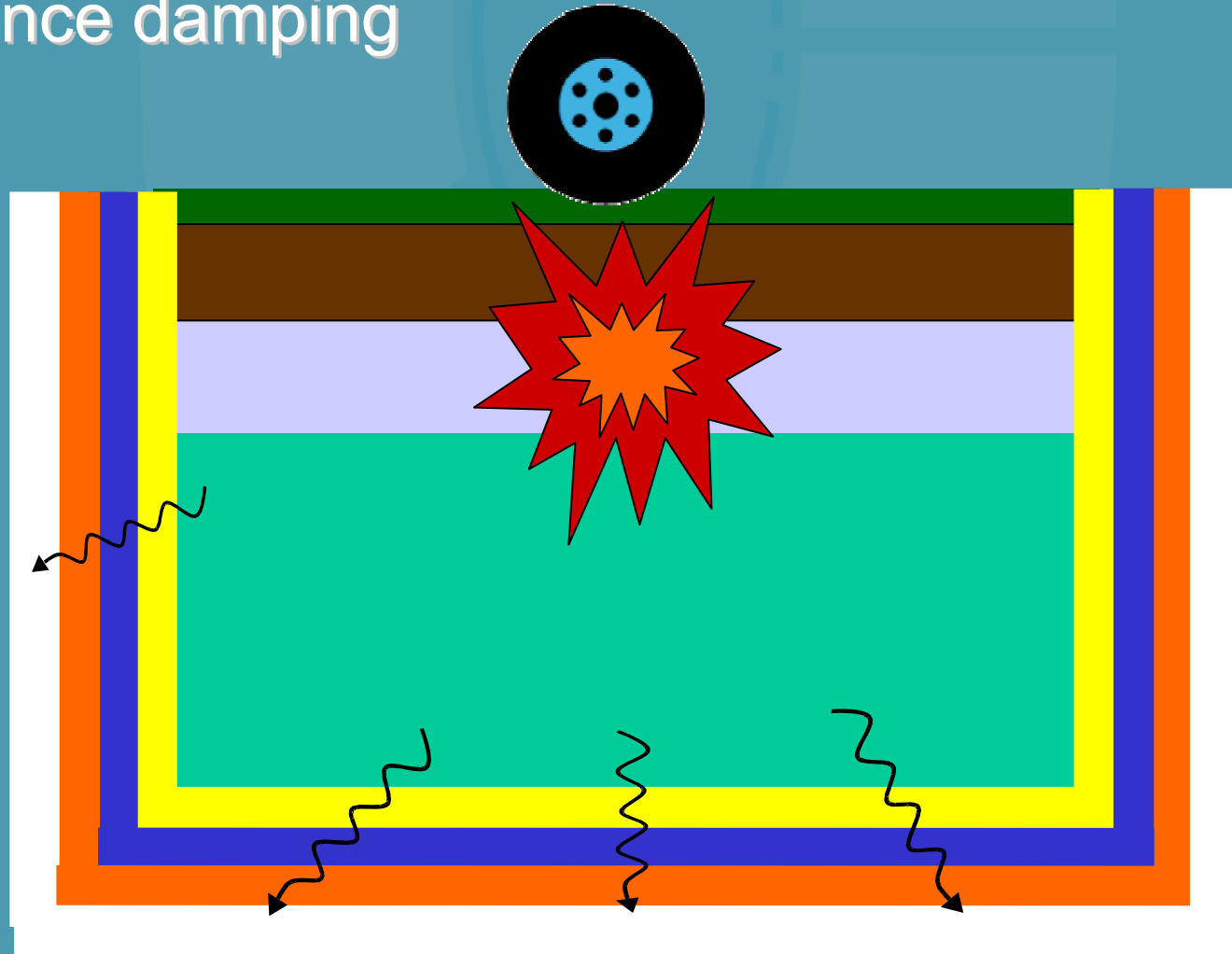


- Wave dissipation techniques
 - rigid boundaries

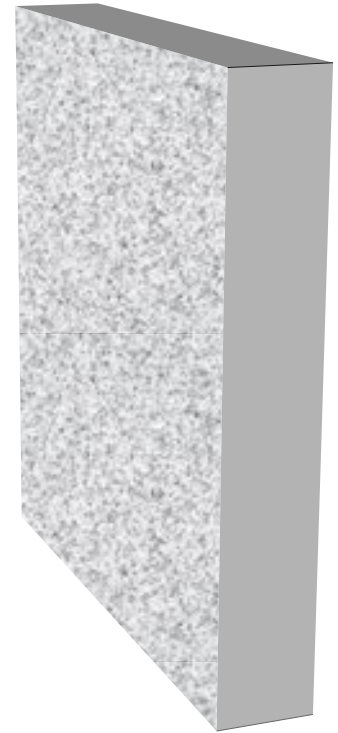
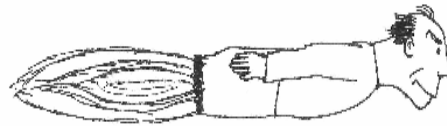
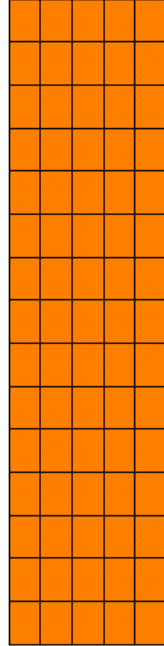
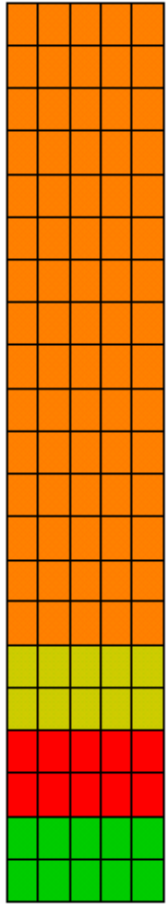


- infinite systems
 - impedance damping

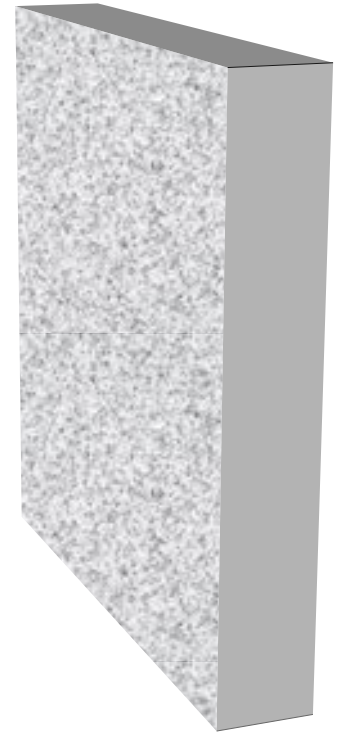
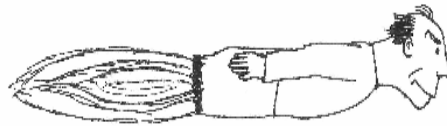
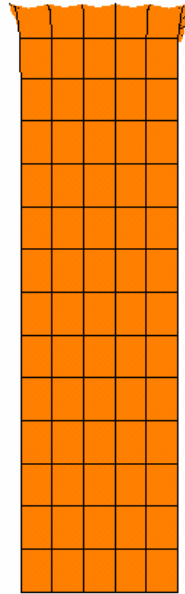
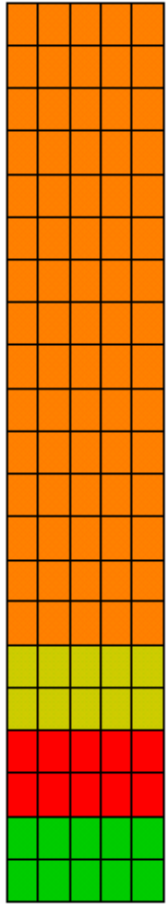
$$Z = A \sqrt{E\rho}$$



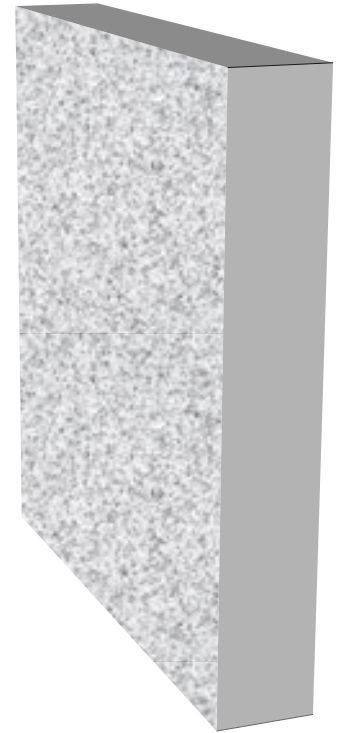
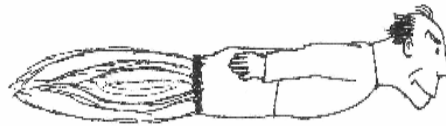
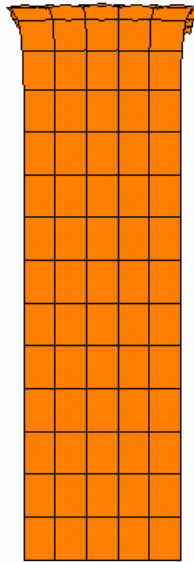
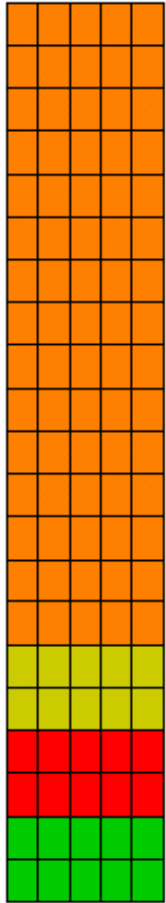
- Wave dissipation techniques
 - silent boundaries



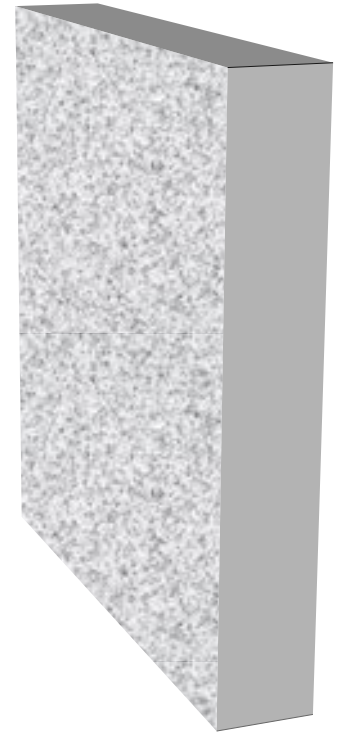
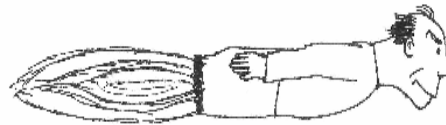
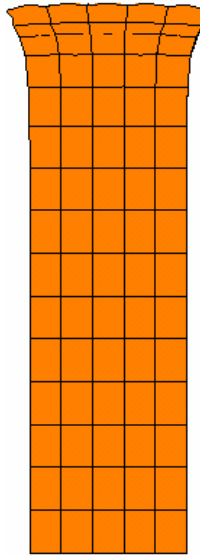
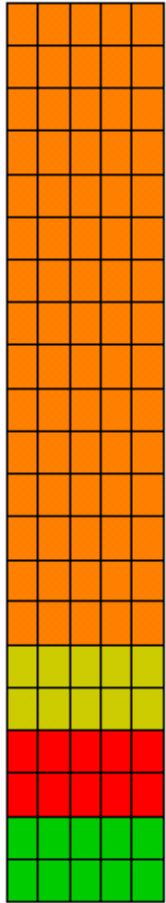
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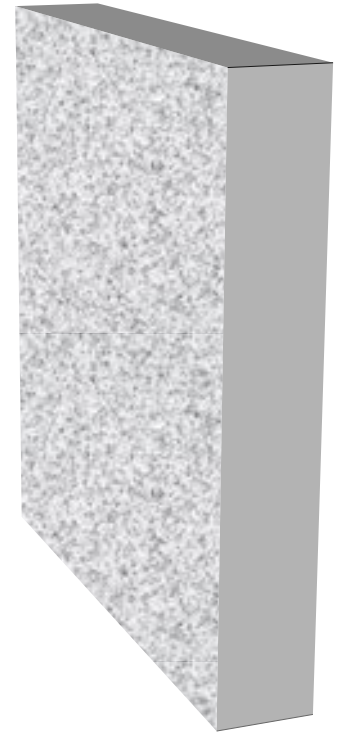
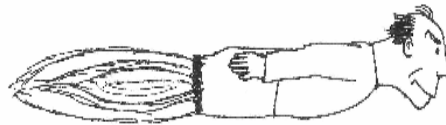
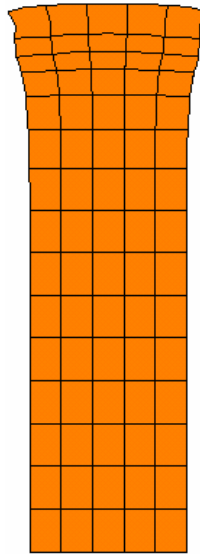
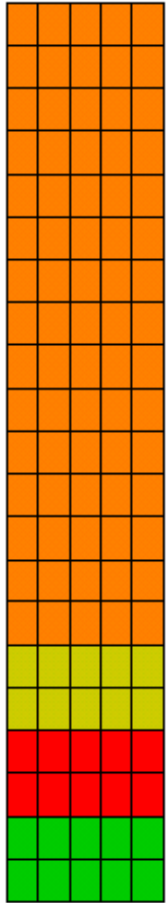
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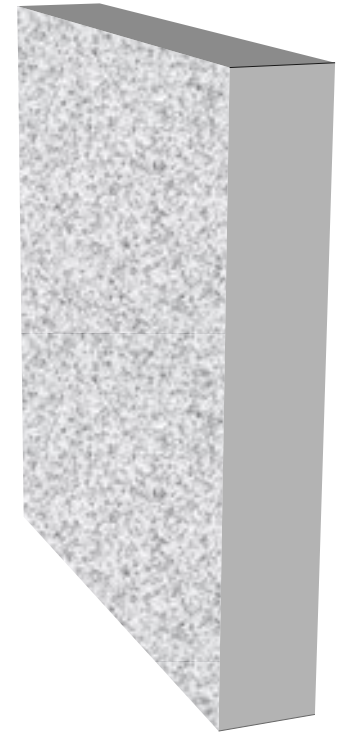
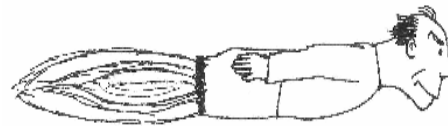
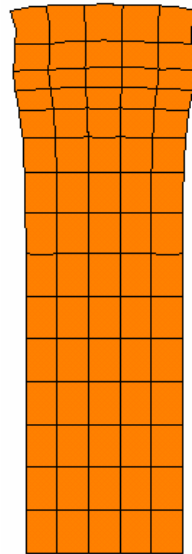
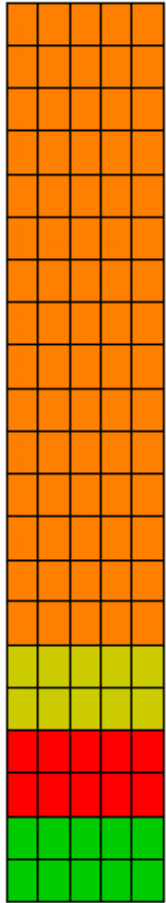
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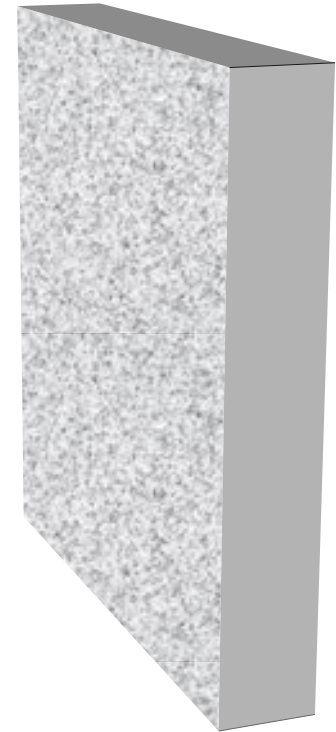
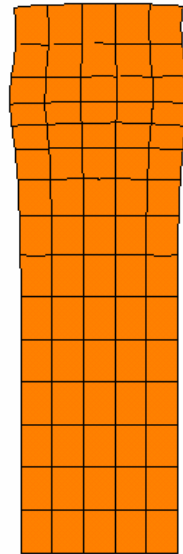
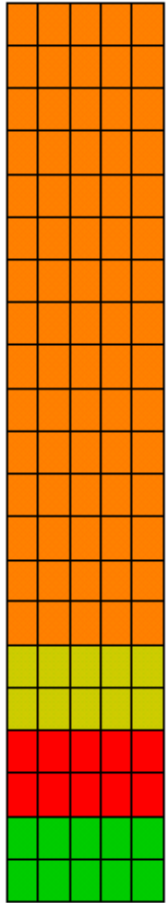
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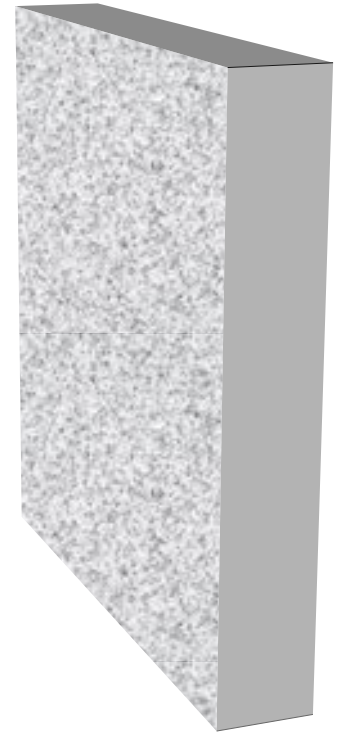
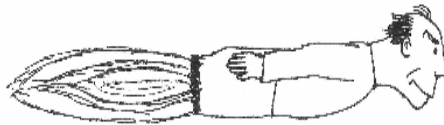
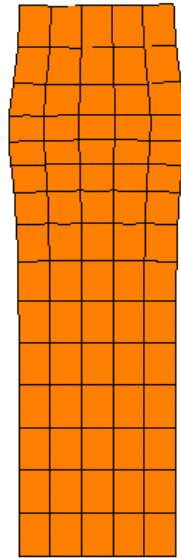
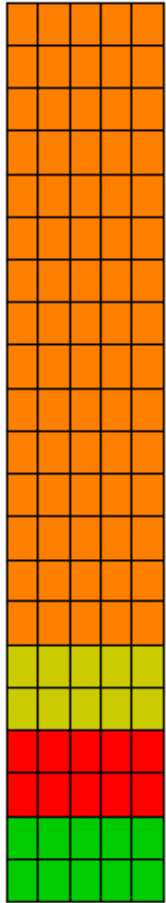
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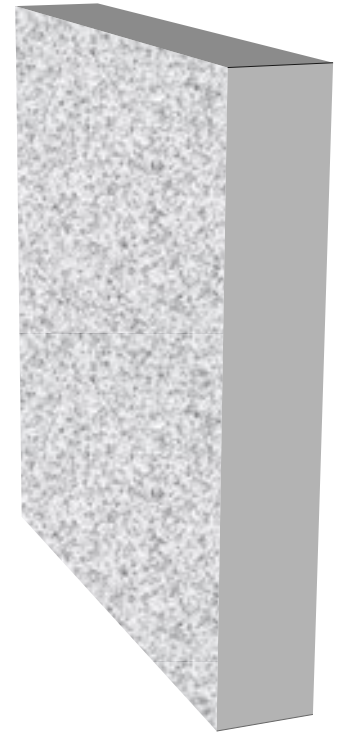
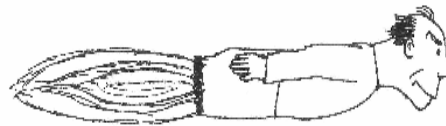
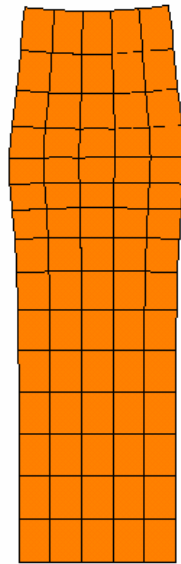
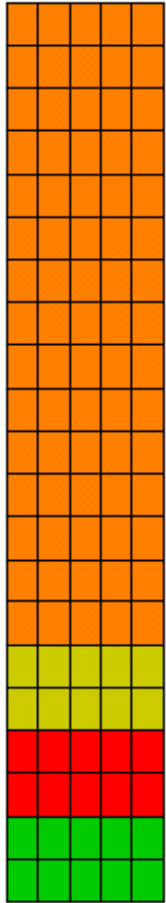
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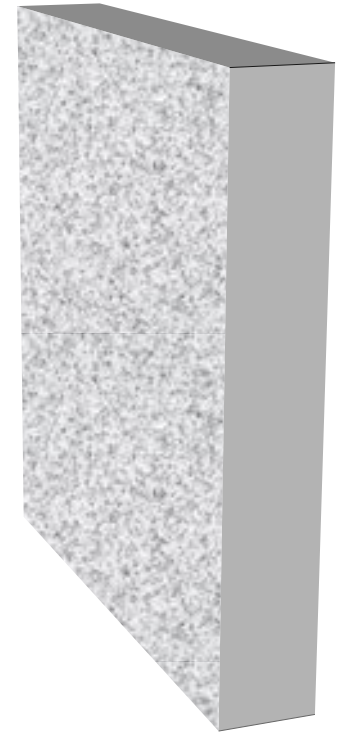
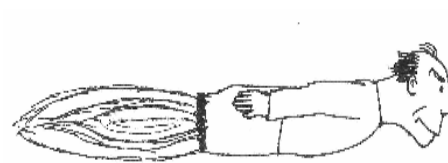
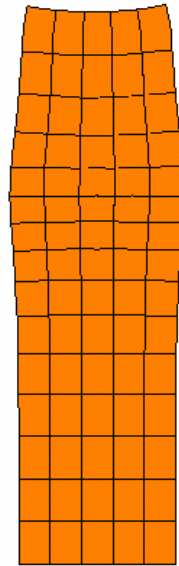
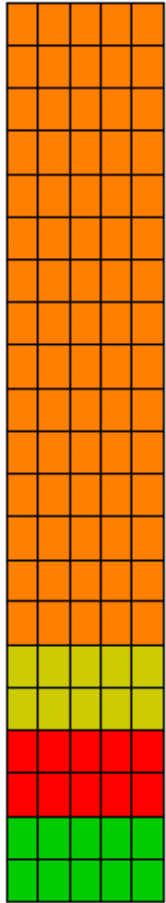
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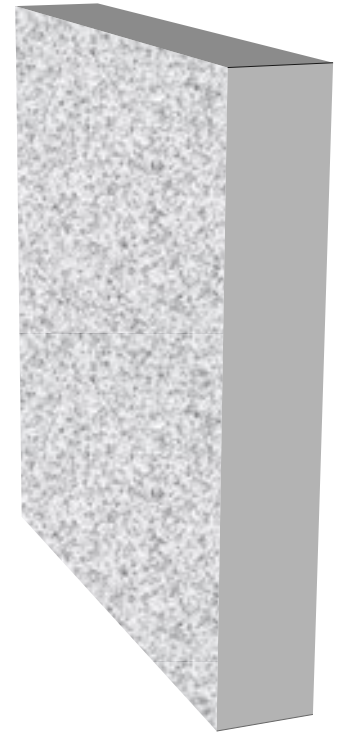
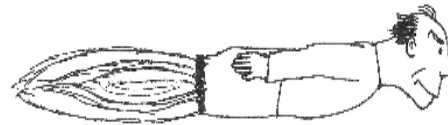
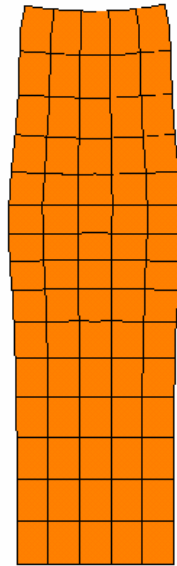
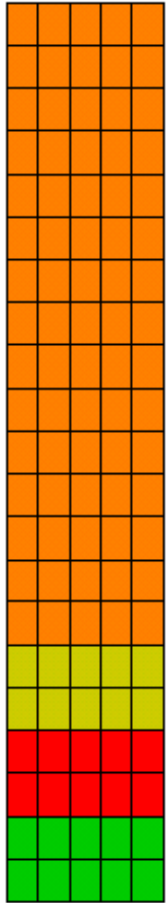
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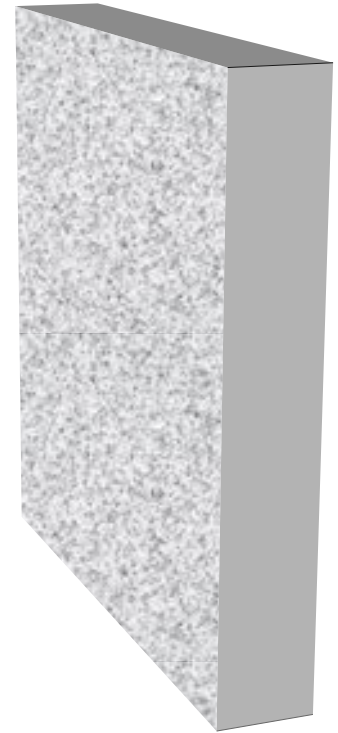
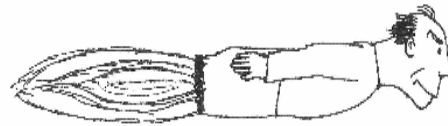
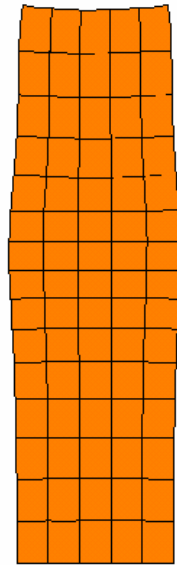
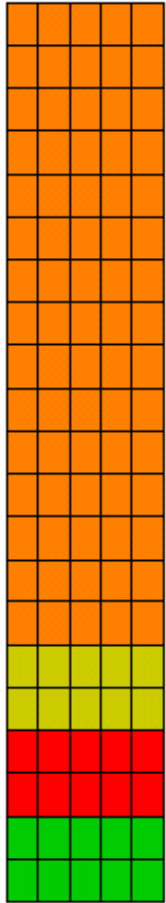
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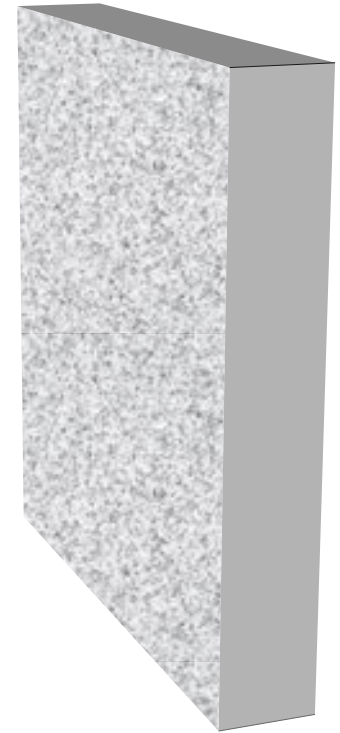
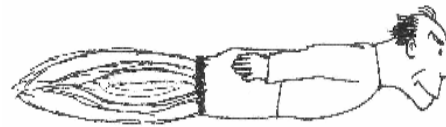
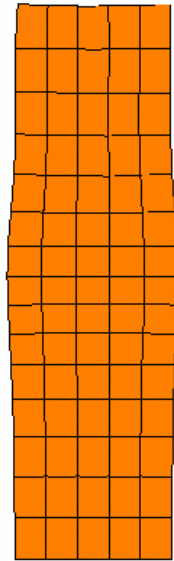
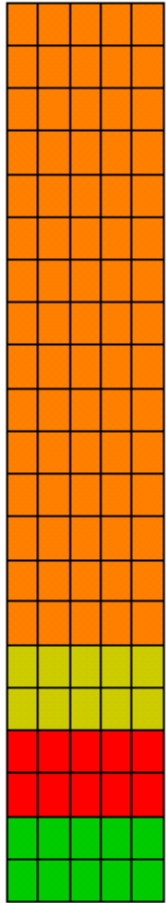
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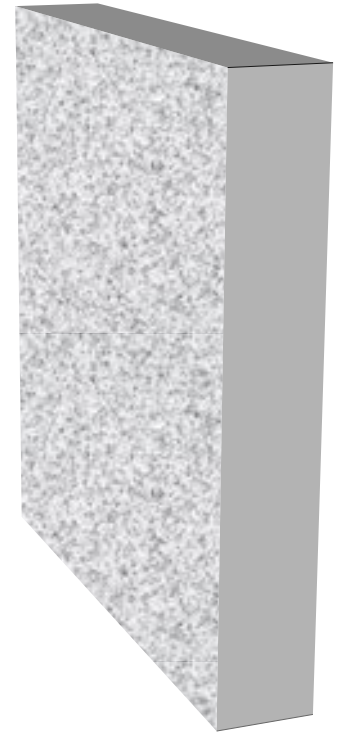
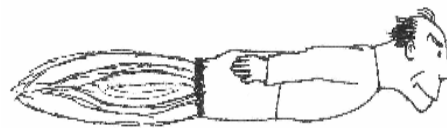
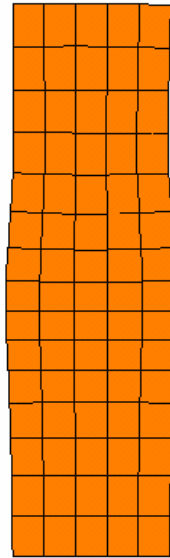
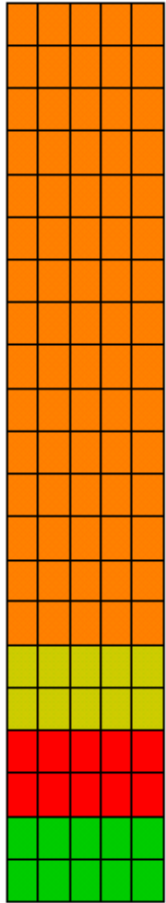
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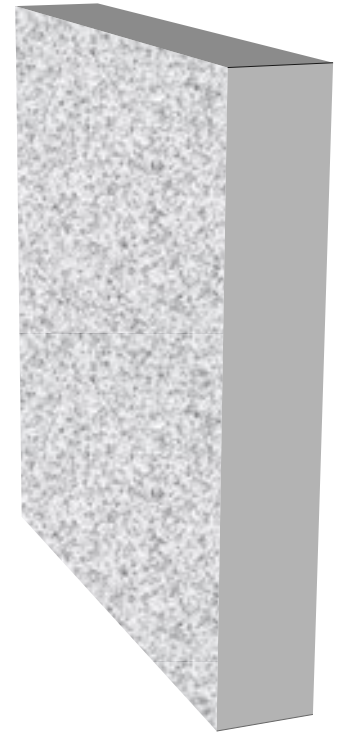
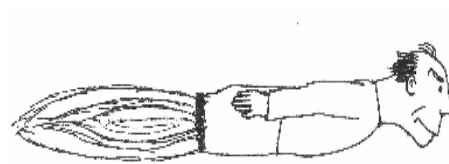
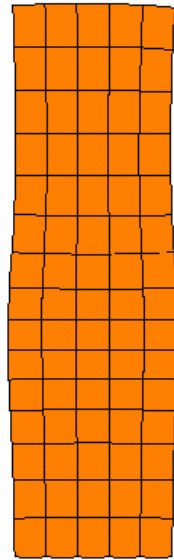
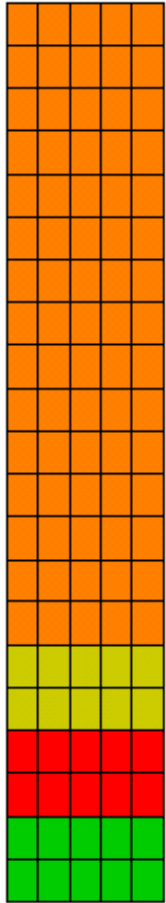
- Wave dissipation techniques
 - silent boundaries



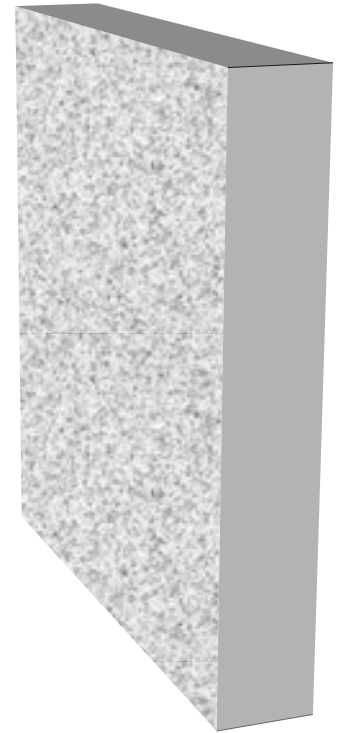
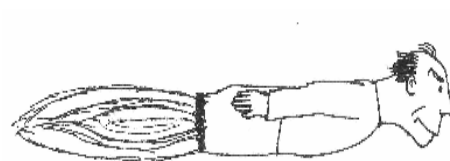
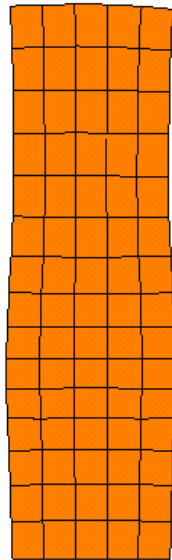
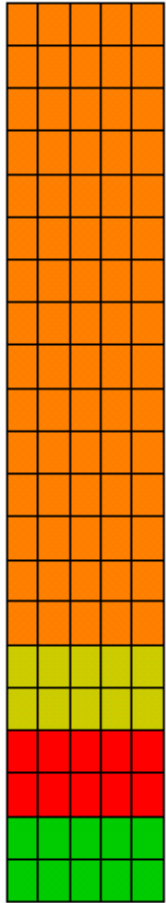
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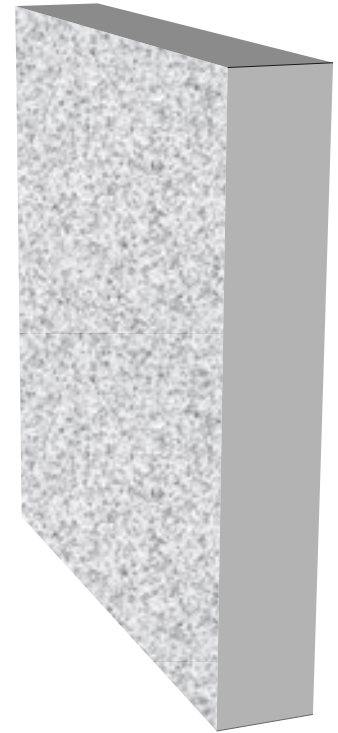
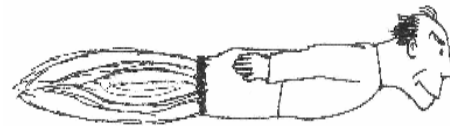
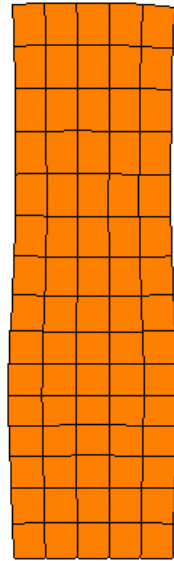
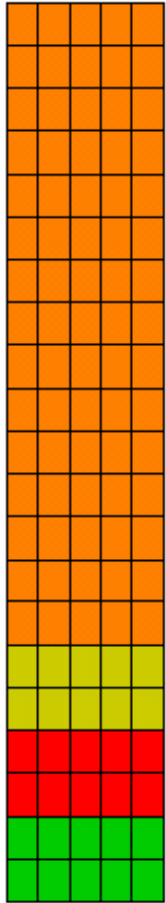
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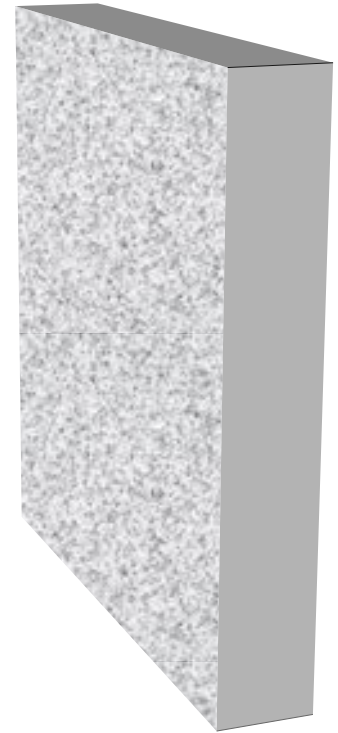
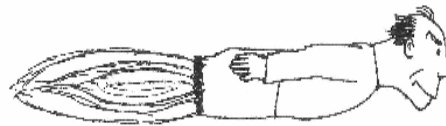
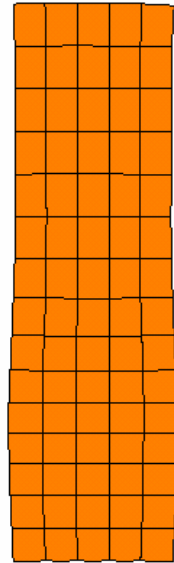
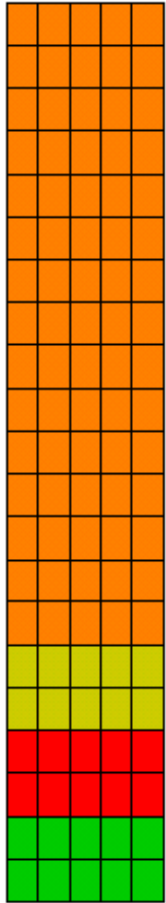
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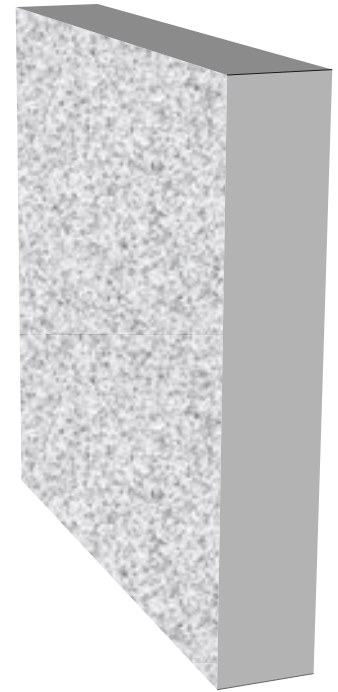
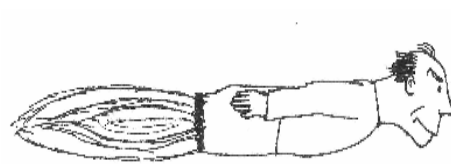
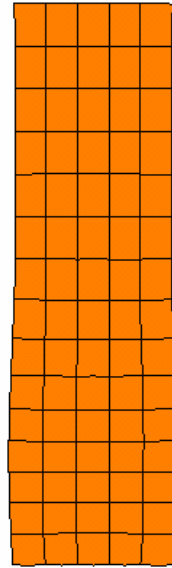
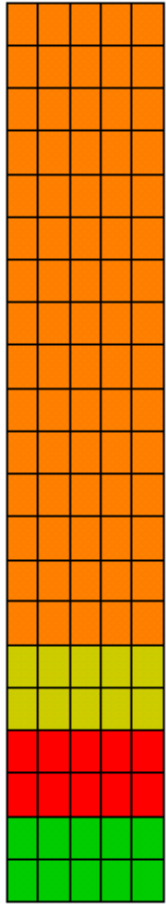
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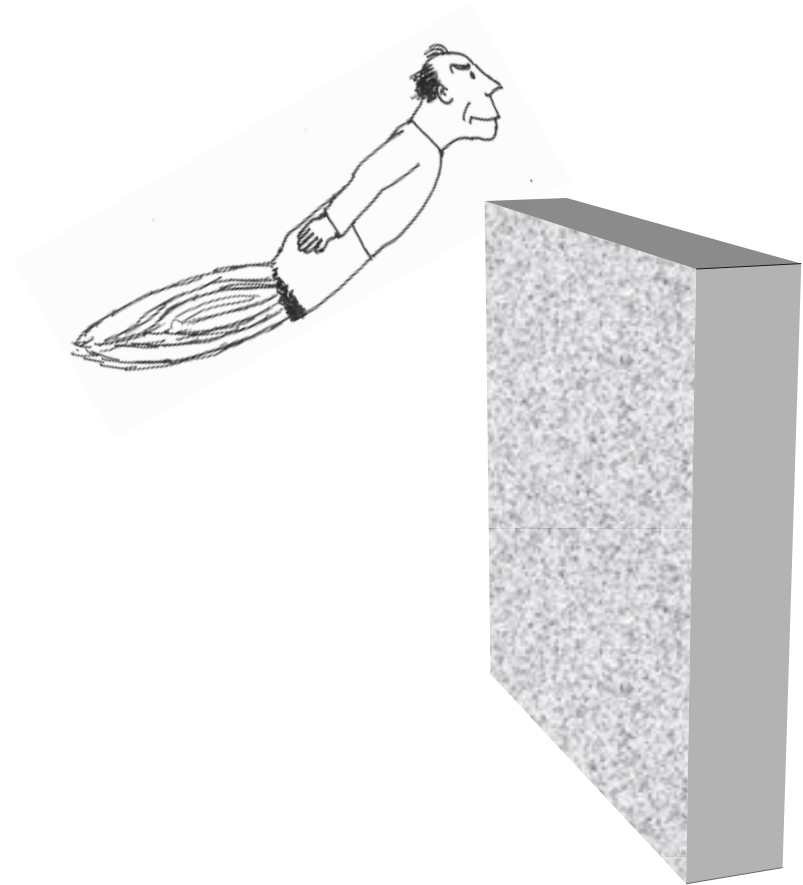
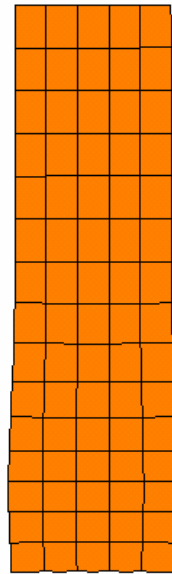
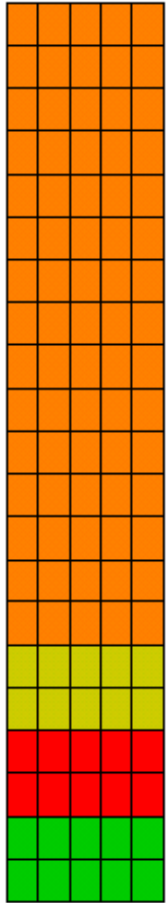
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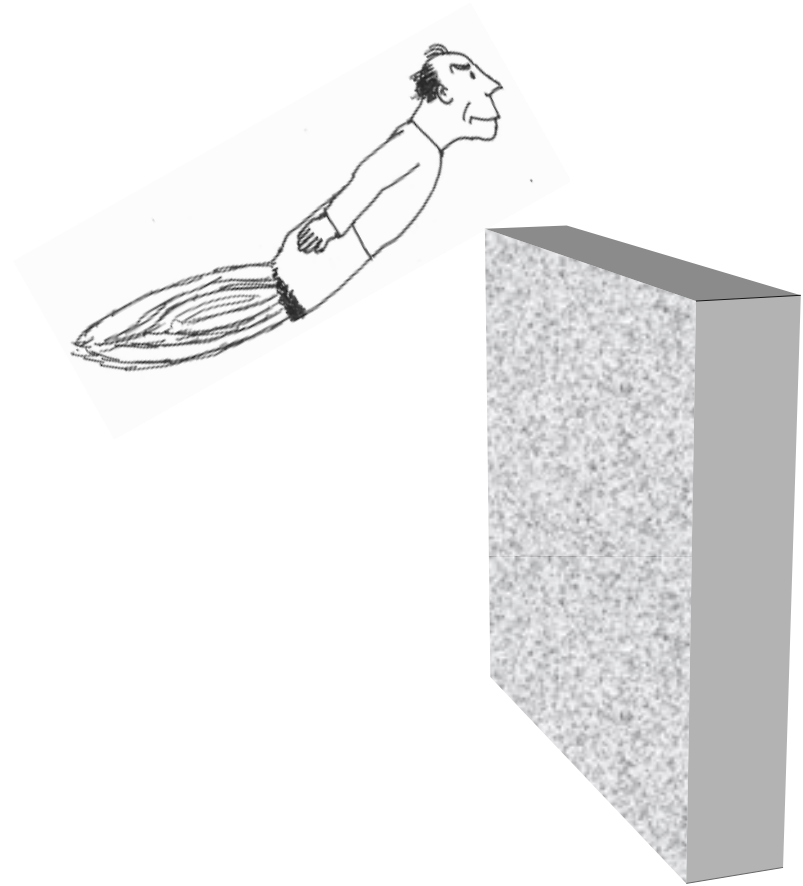
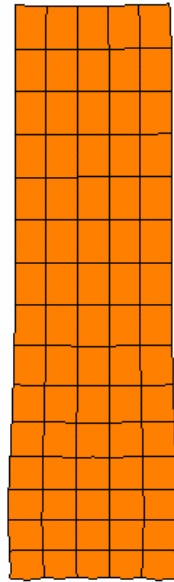
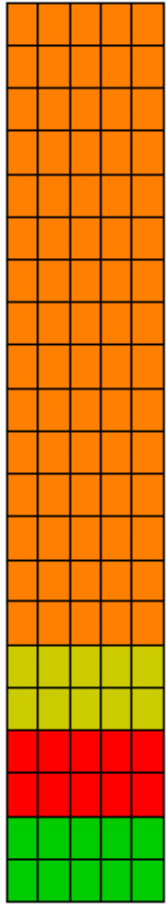
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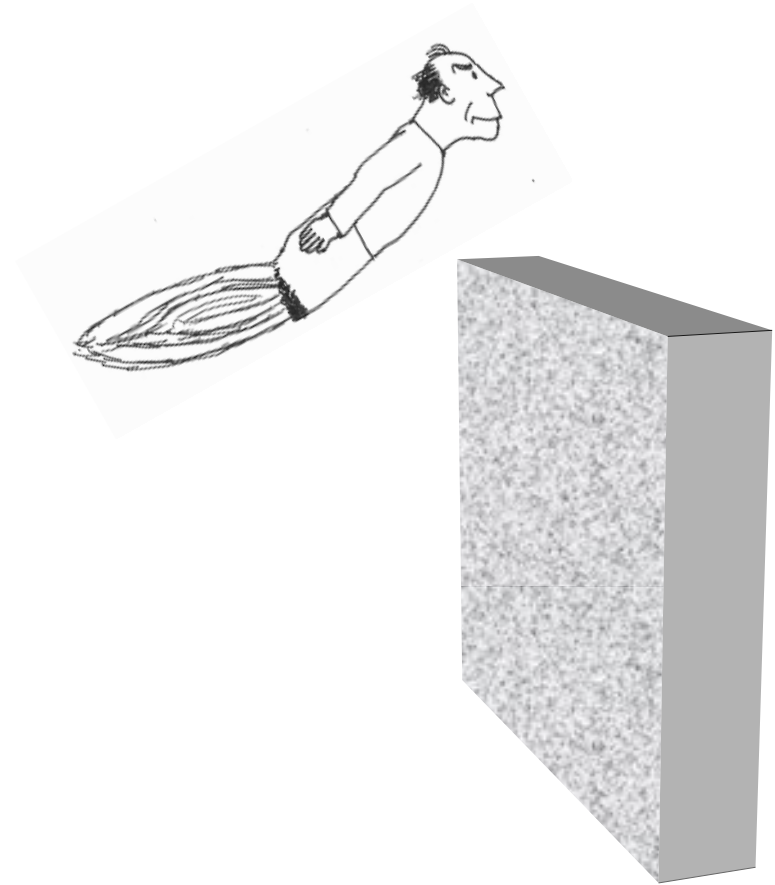
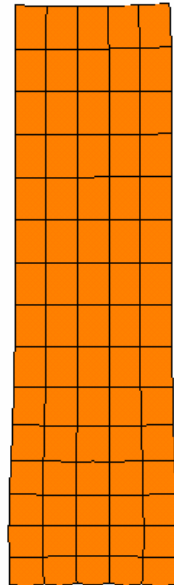
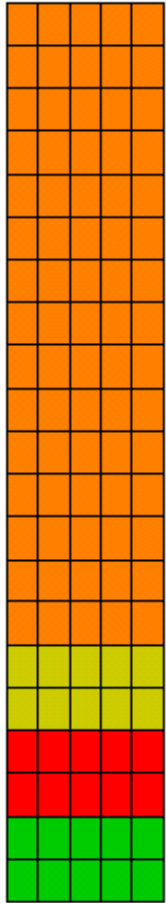
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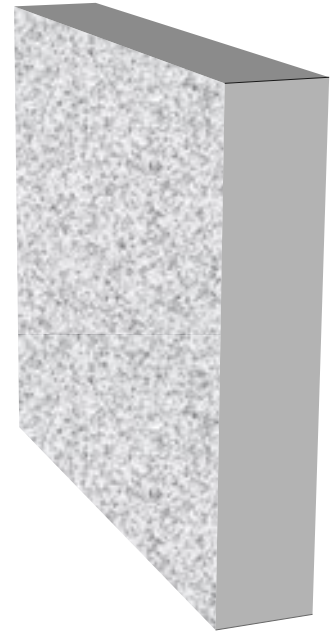
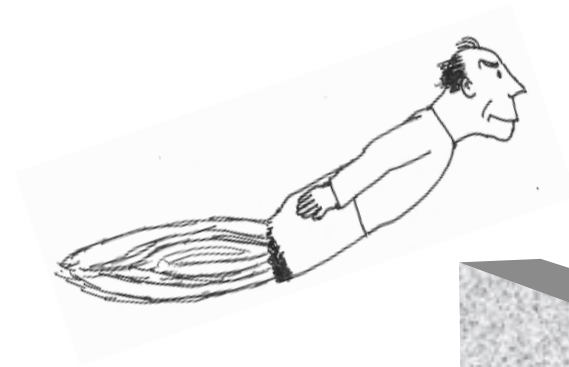
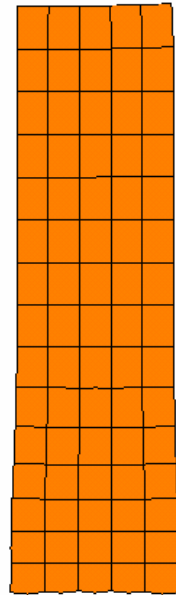
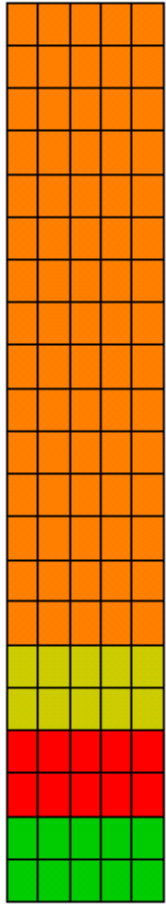
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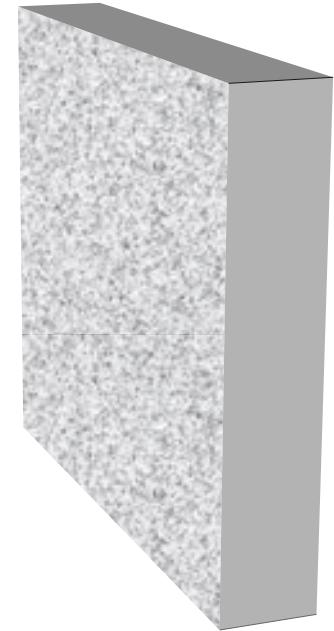
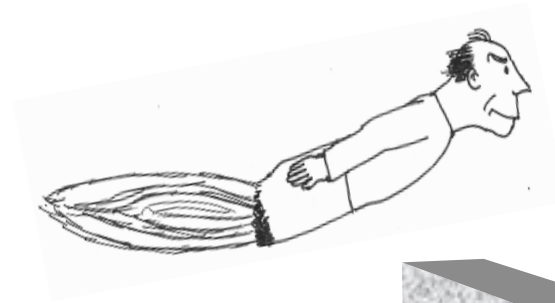
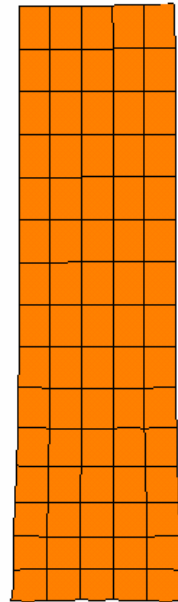
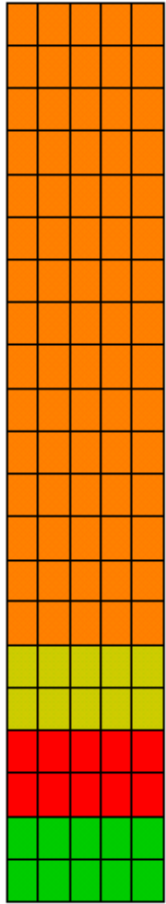
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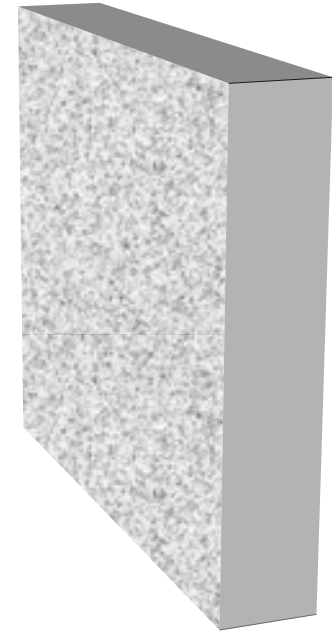
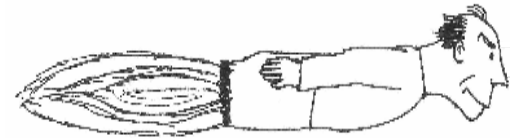
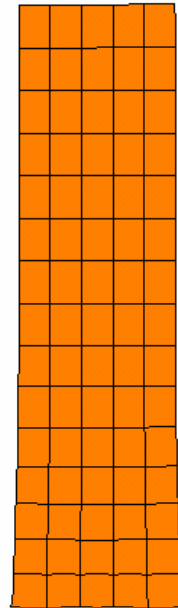
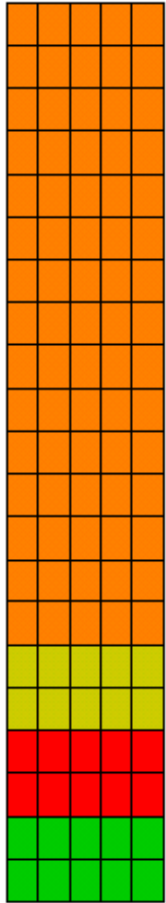
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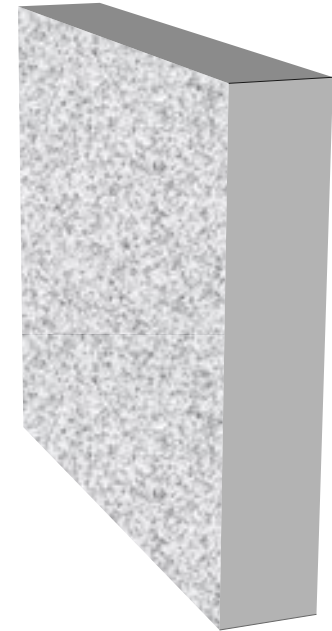
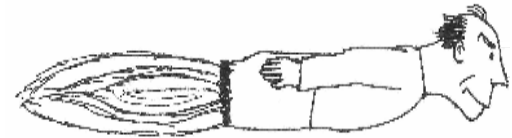
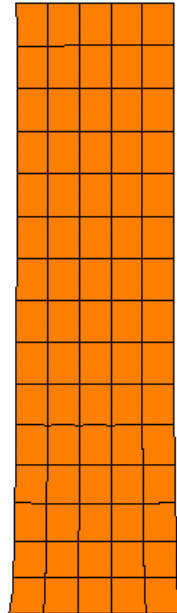
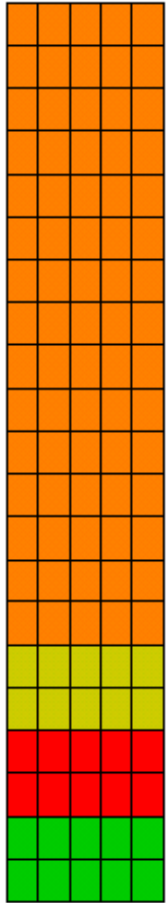
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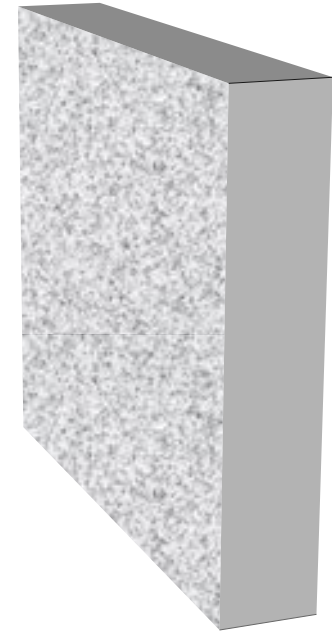
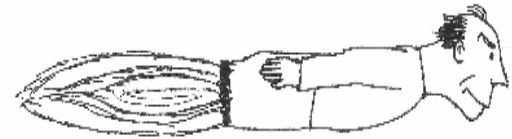
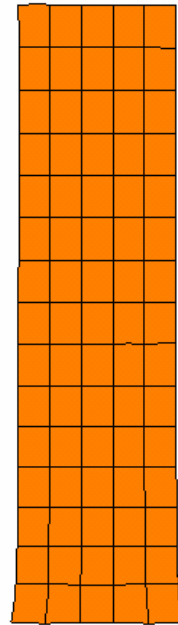
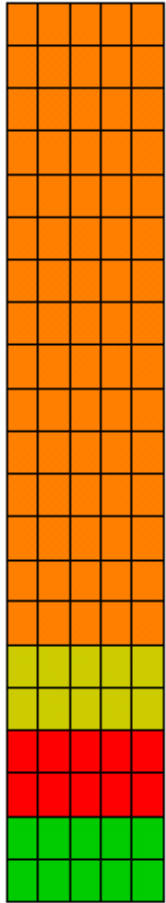
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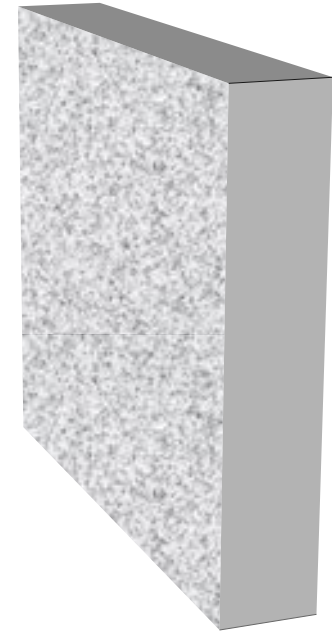
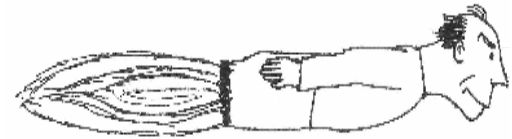
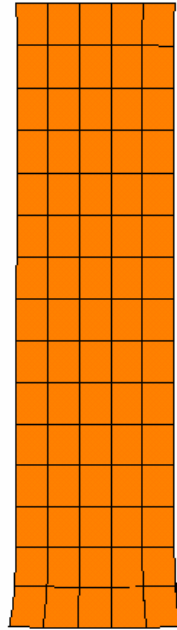
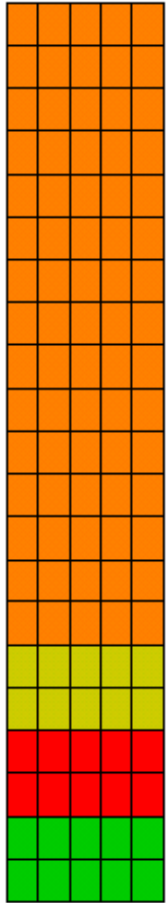
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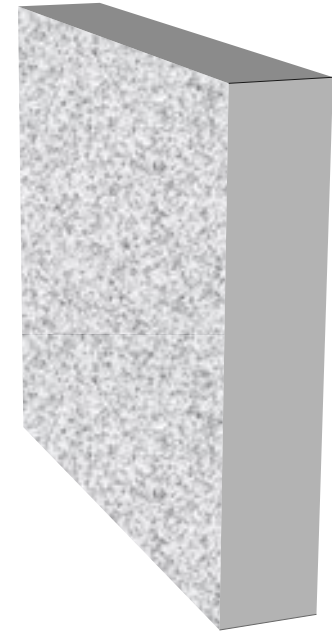
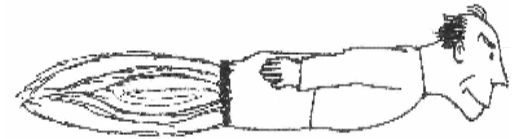
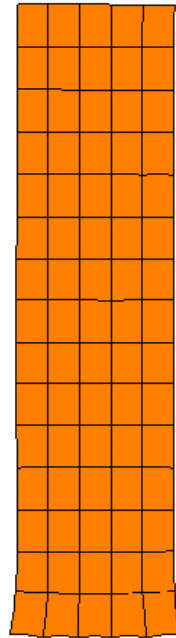
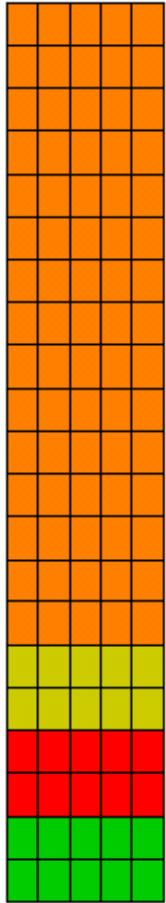
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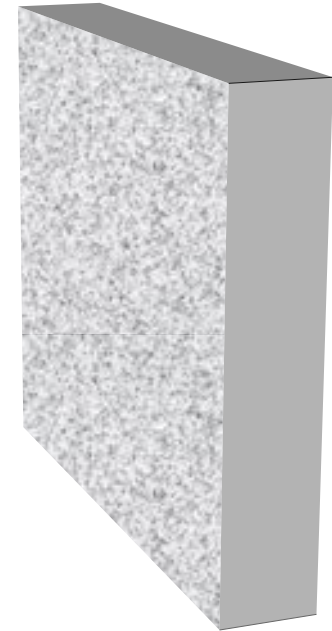
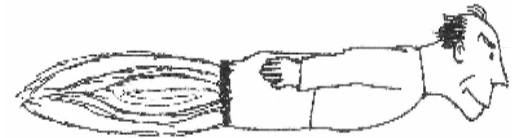
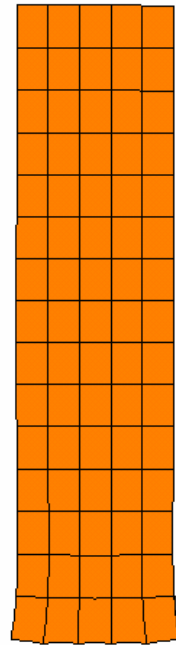
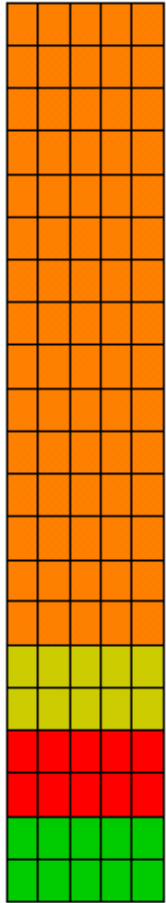
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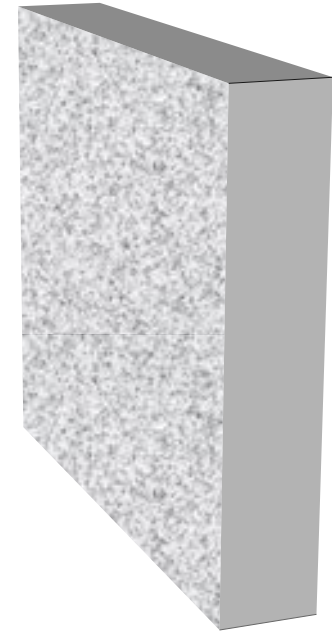
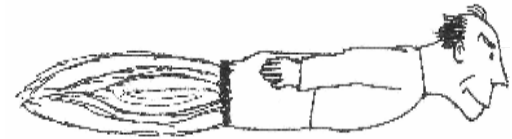
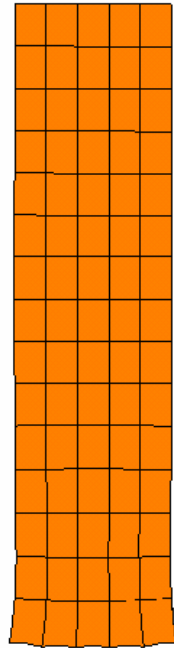
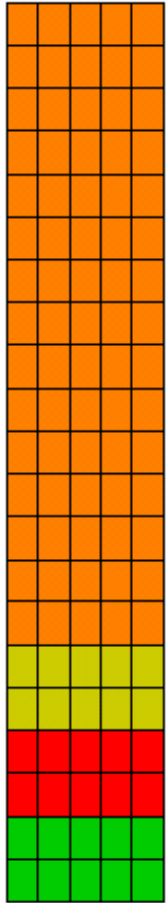
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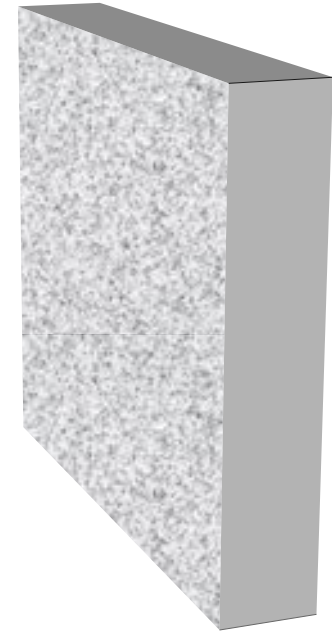
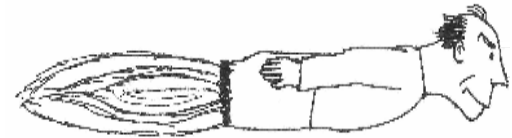
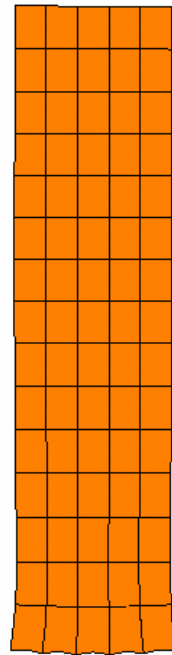
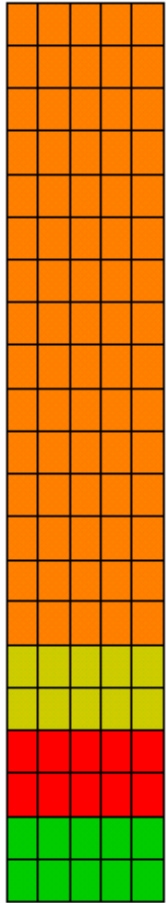
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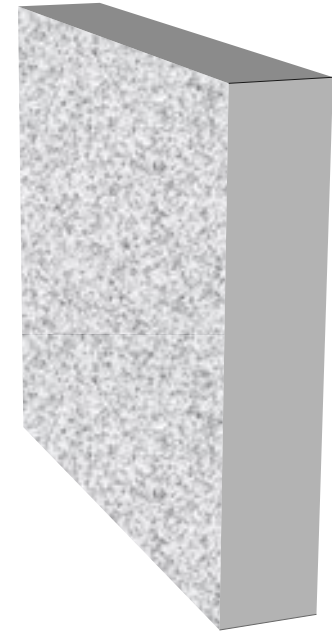
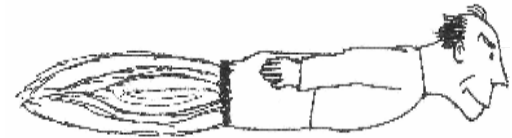
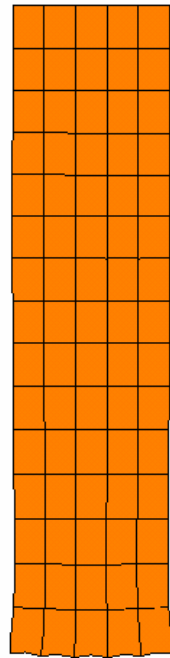
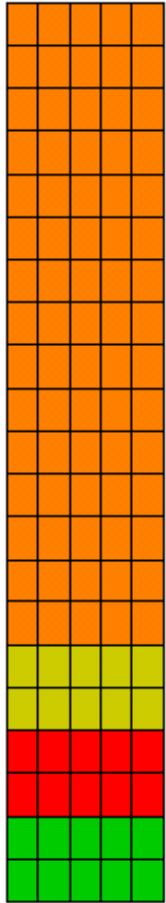
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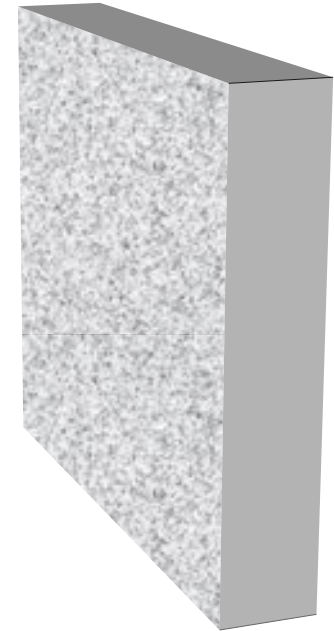
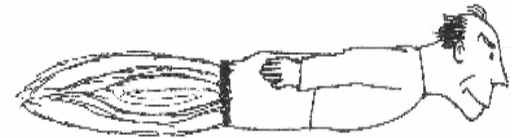
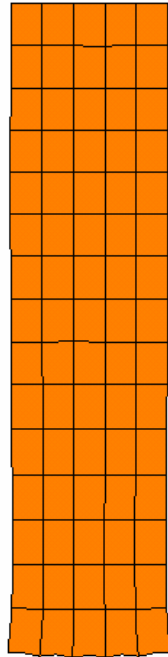
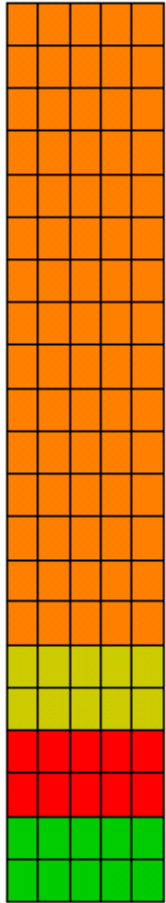
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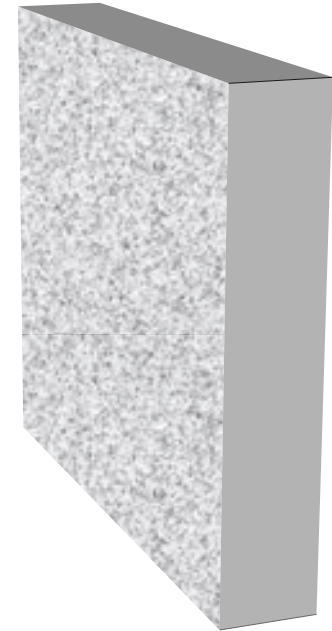
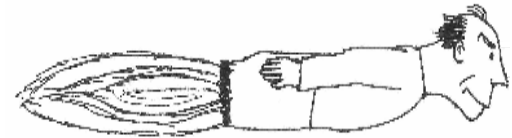
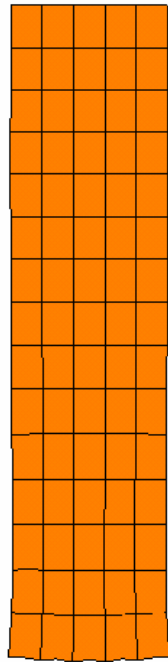
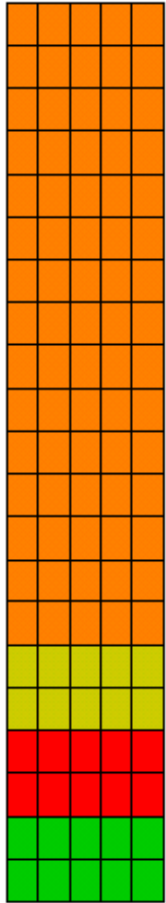
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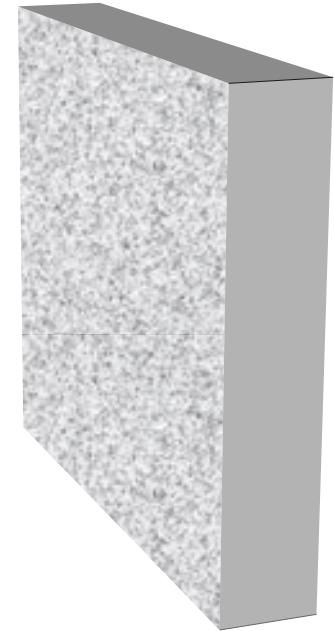
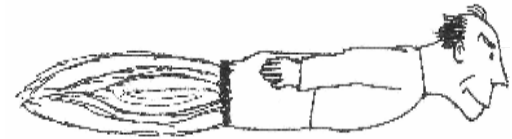
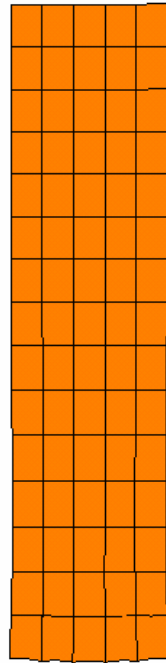
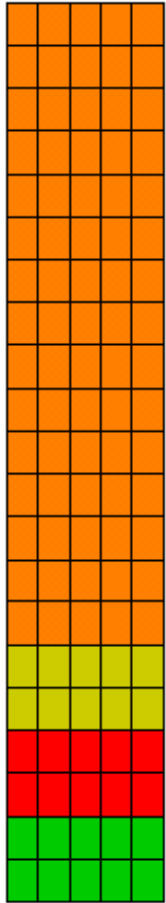
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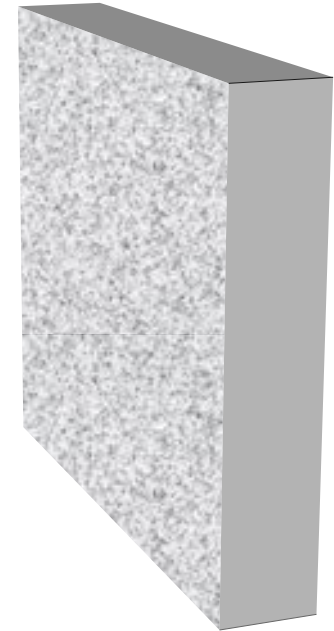
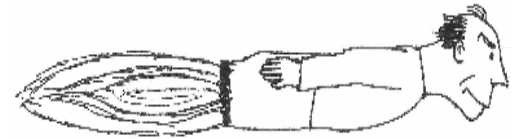
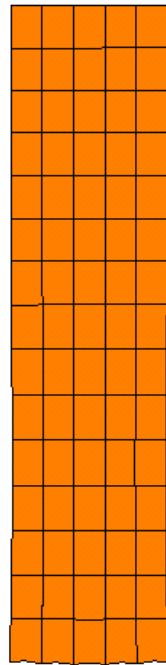
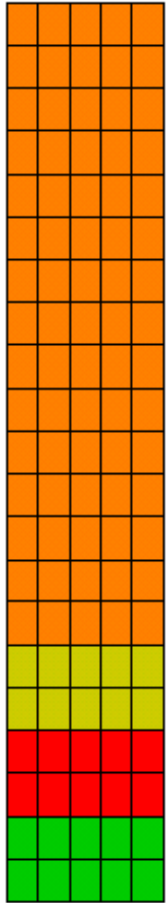
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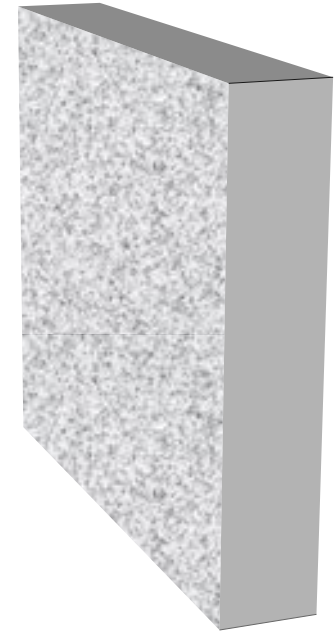
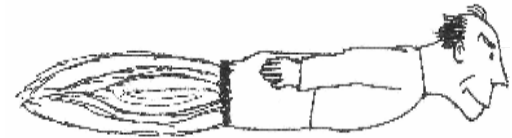
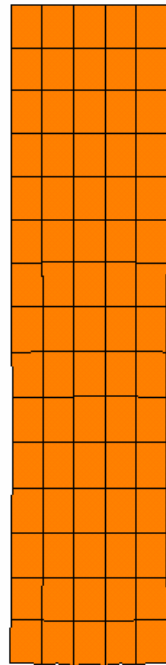
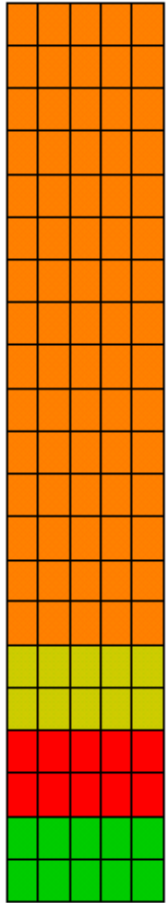
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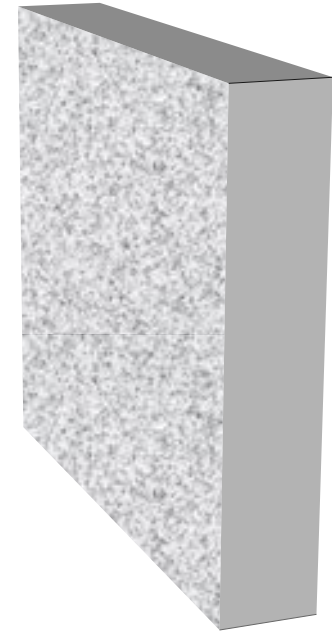
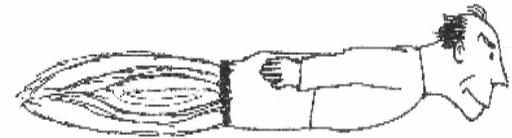
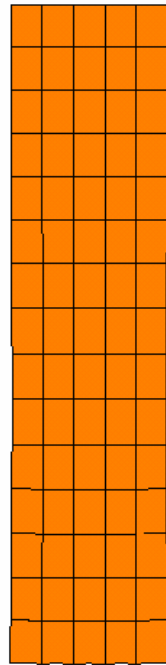
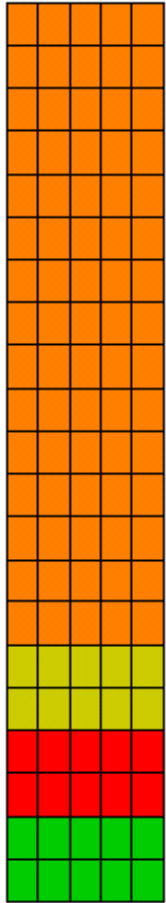
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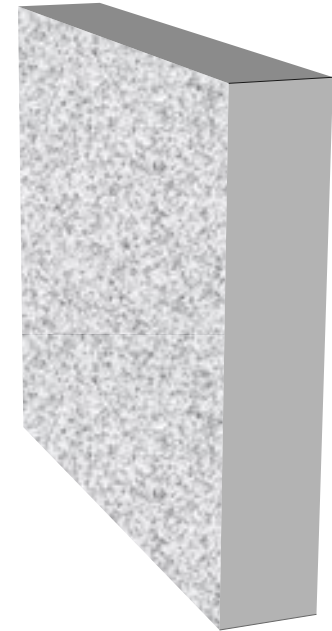
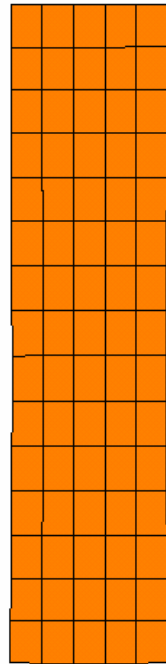
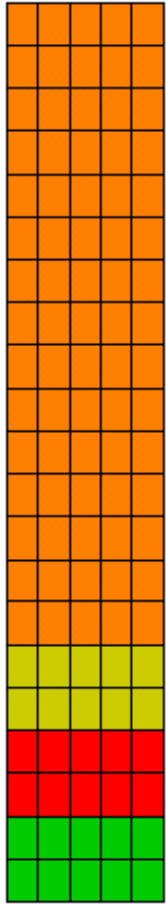
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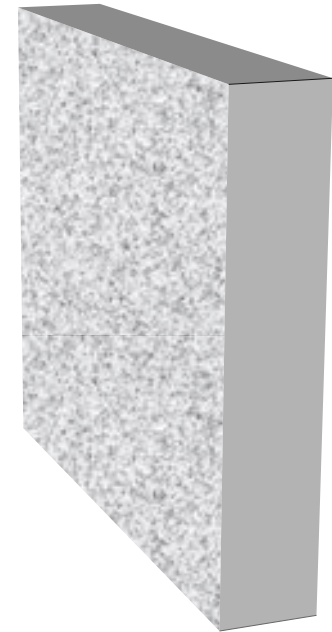
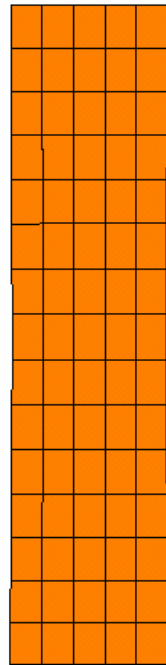
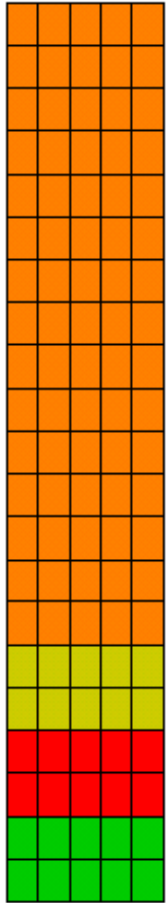
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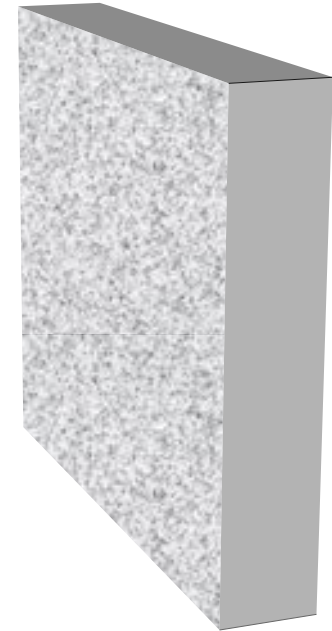
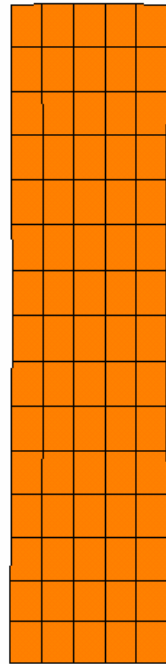
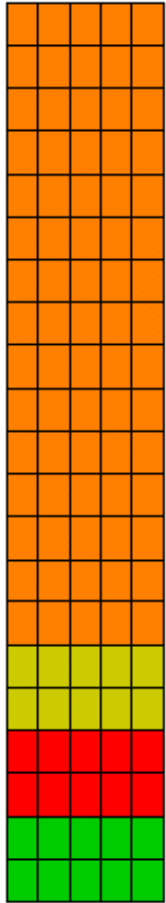
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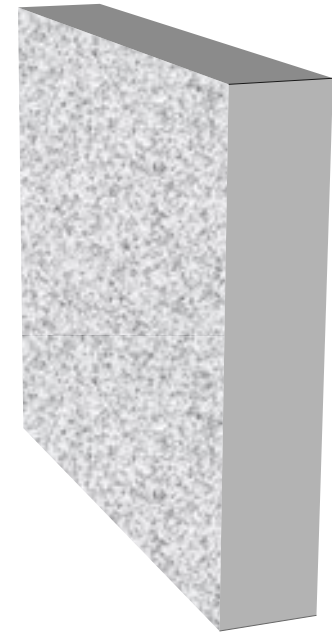
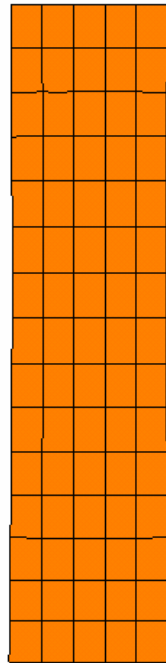
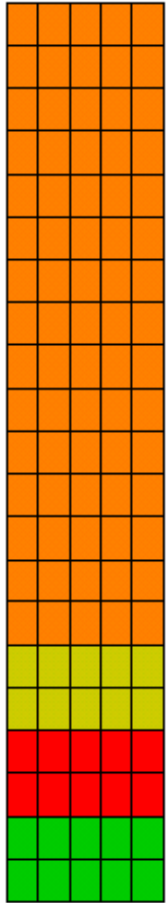
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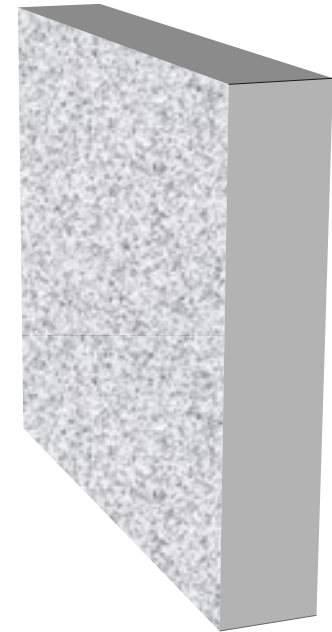
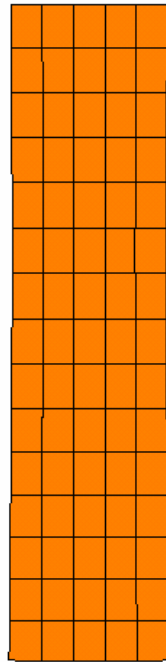
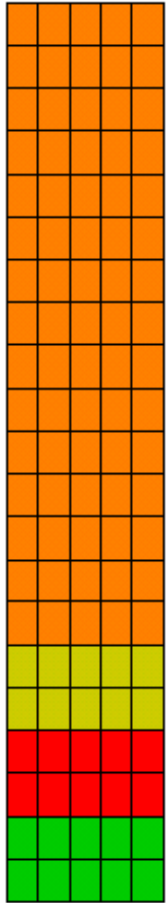
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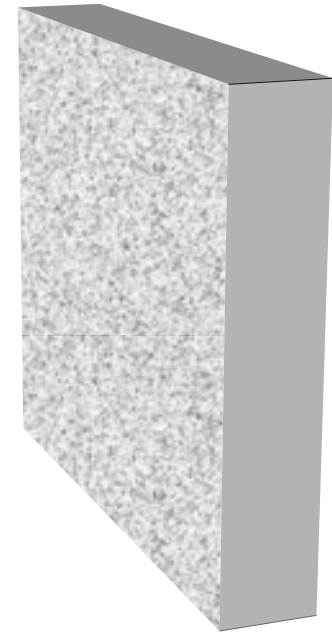
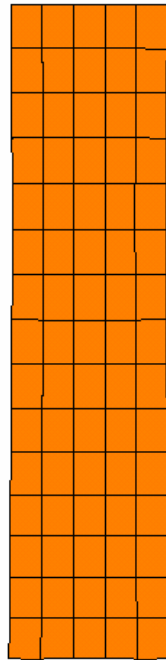
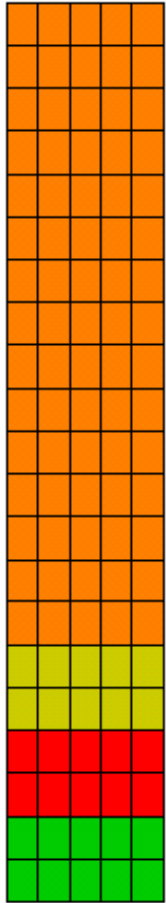
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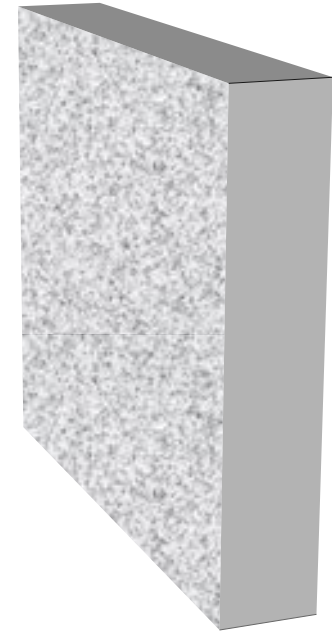
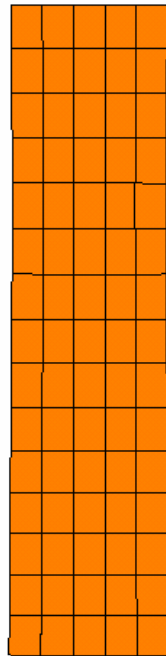
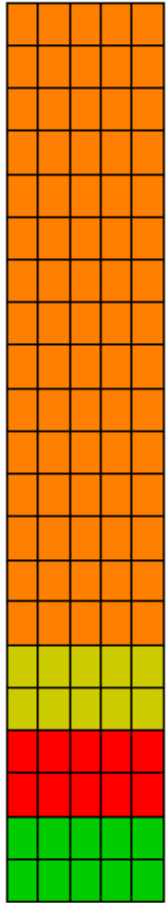
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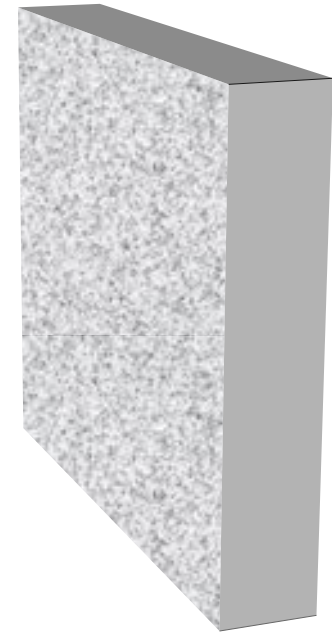
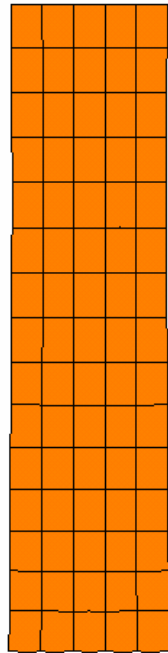
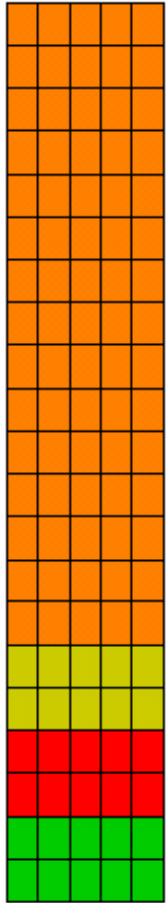
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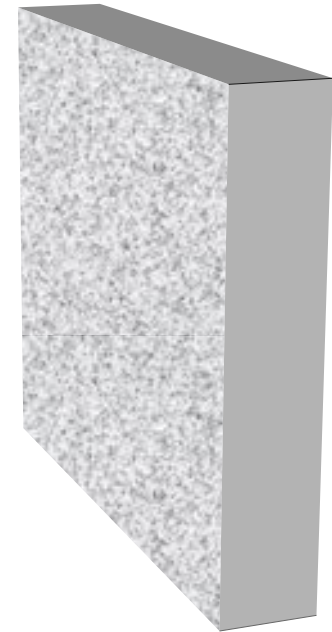
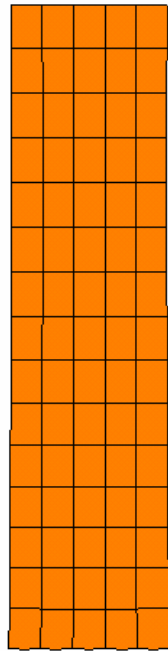
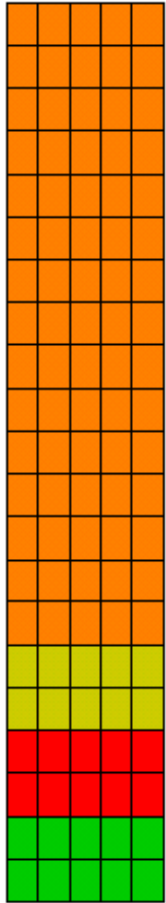
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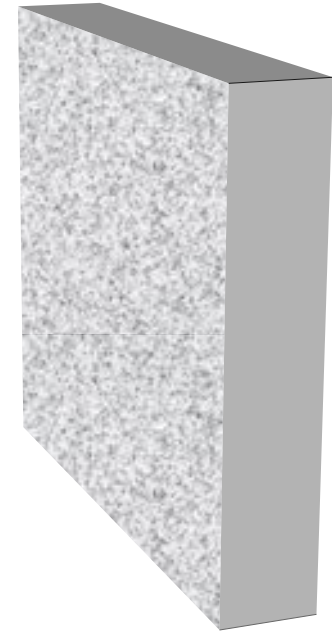
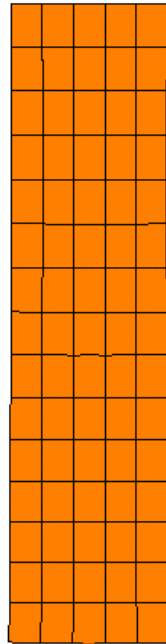
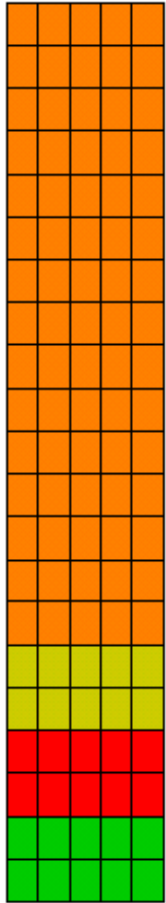
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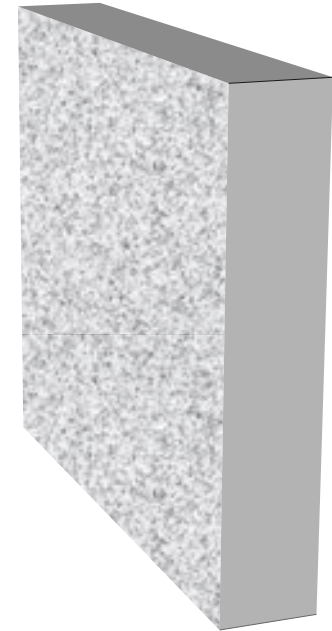
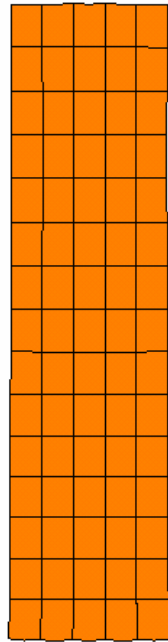
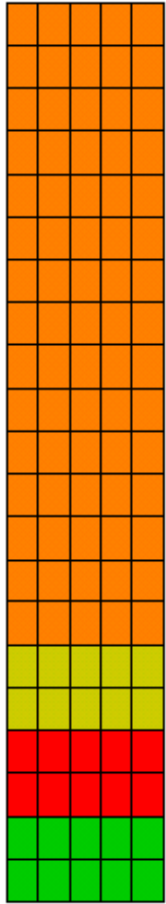
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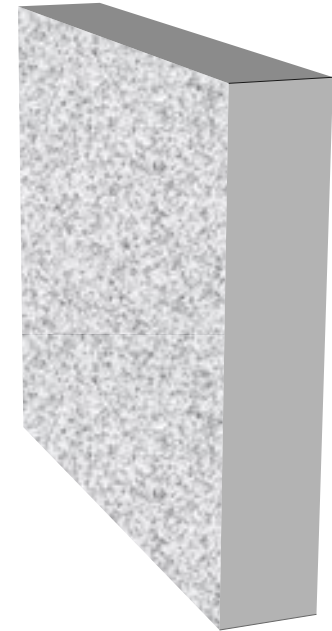
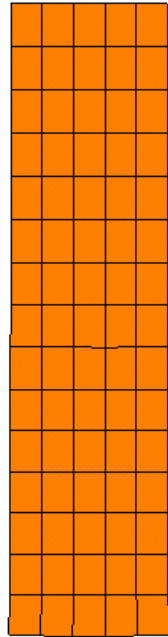
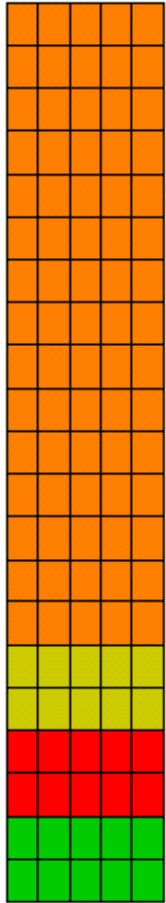
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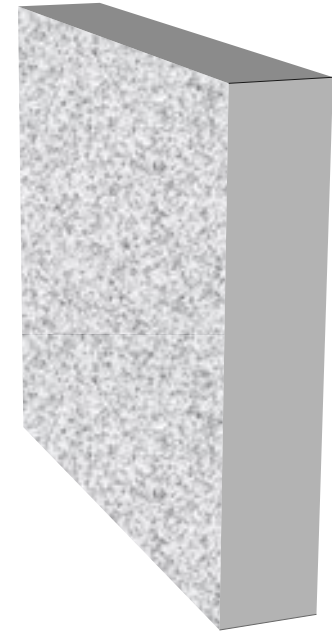
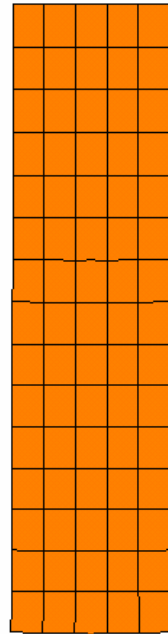
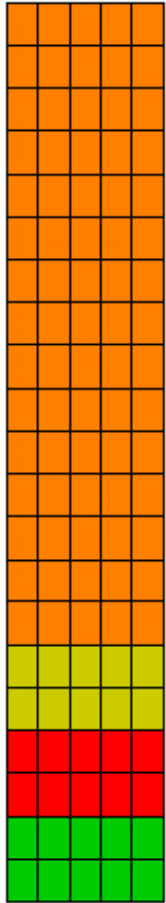
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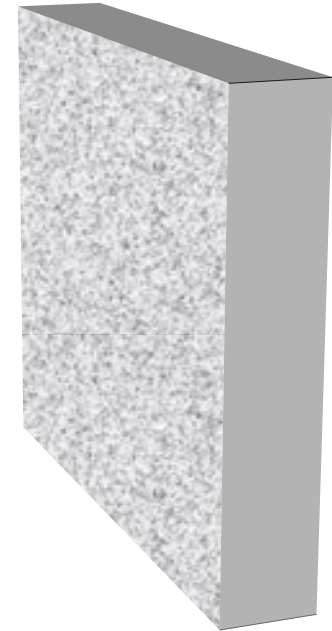
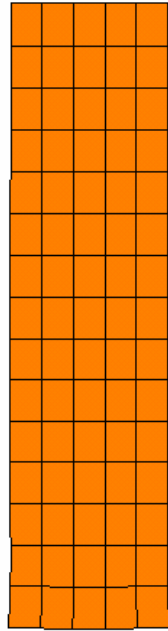
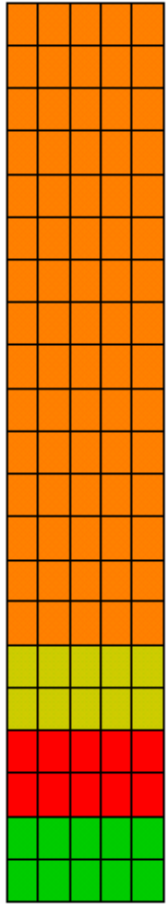
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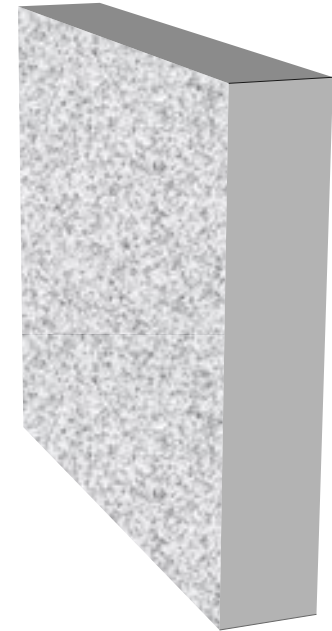
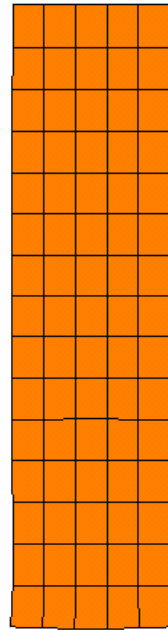
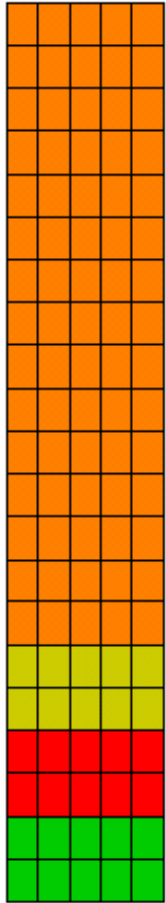
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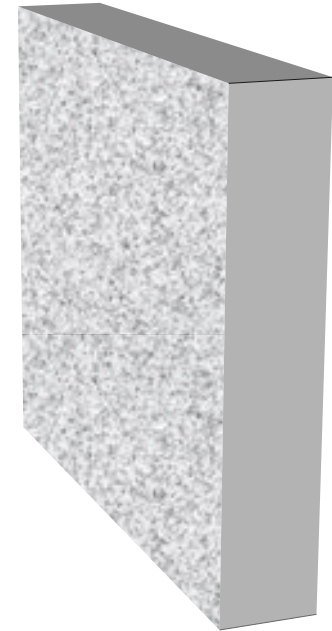
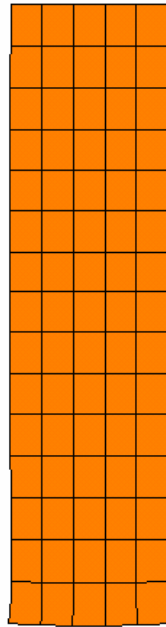
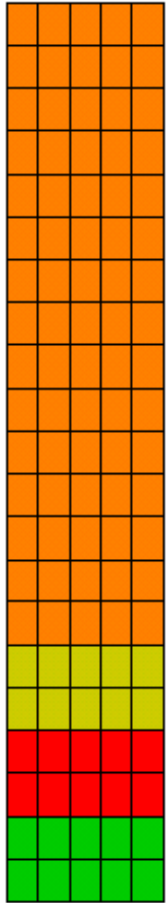
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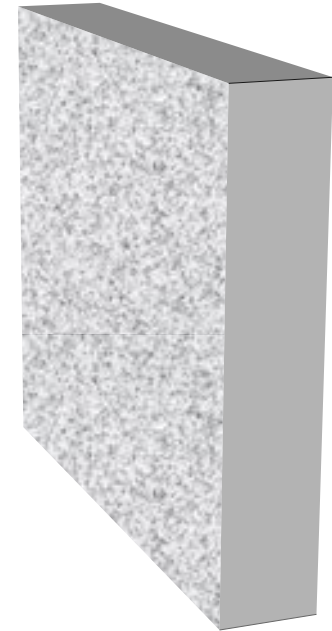
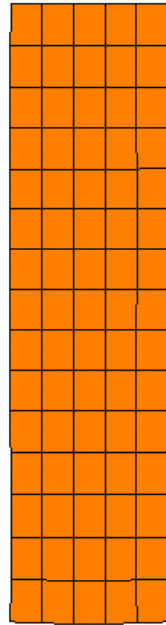
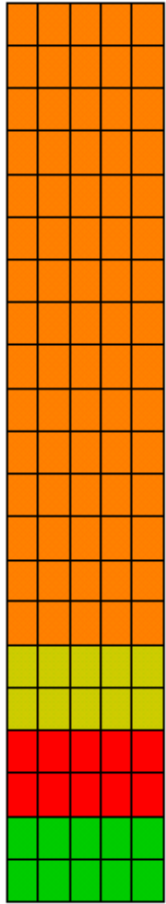
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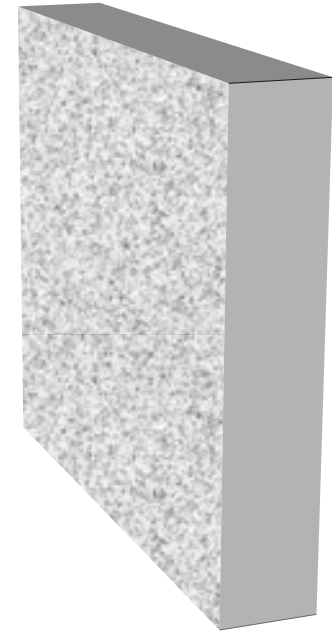
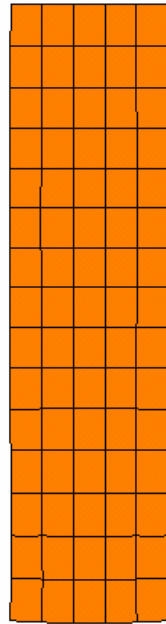
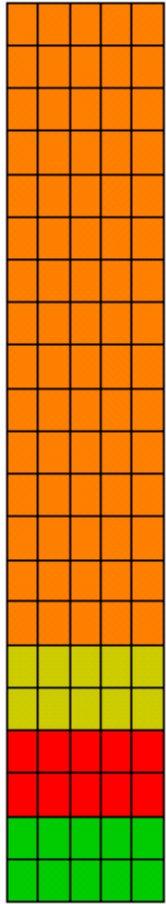
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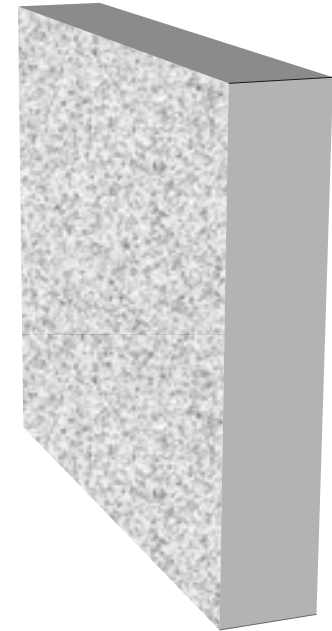
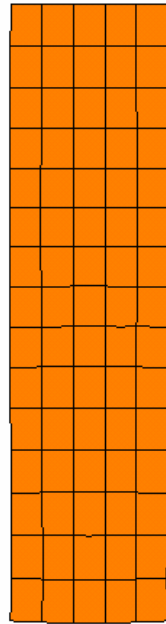
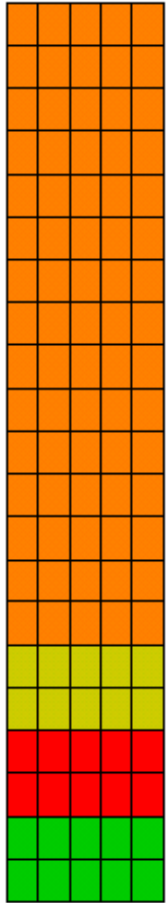
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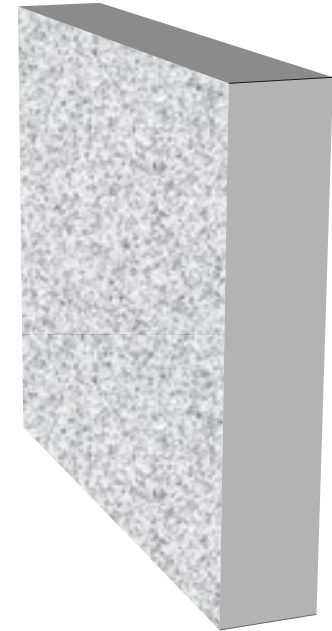
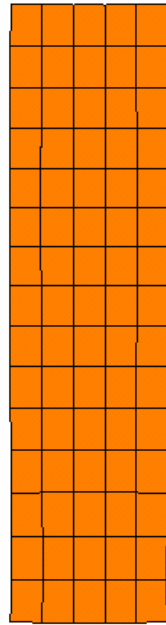
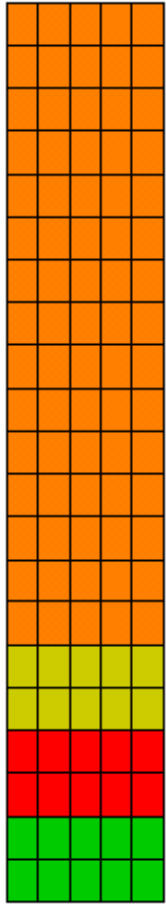
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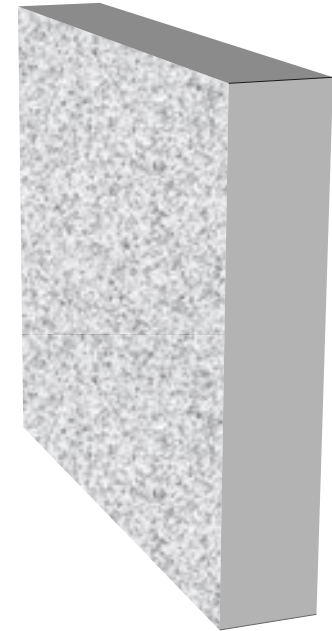
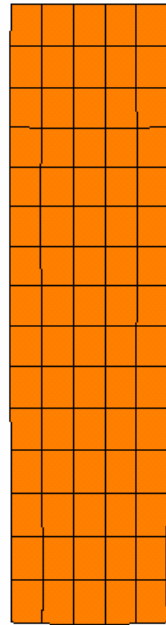
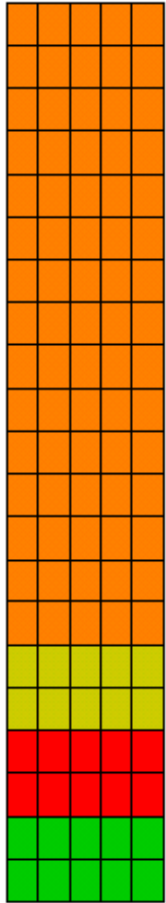
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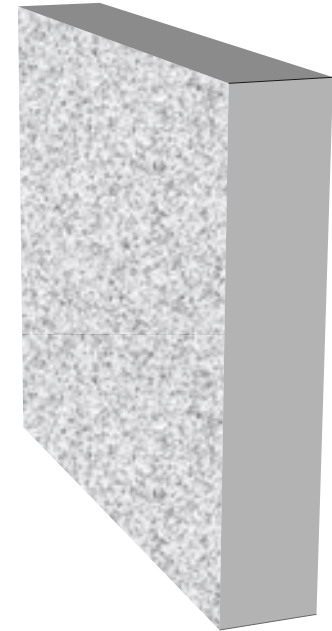
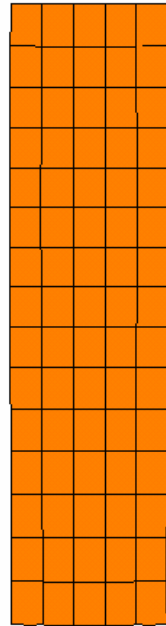
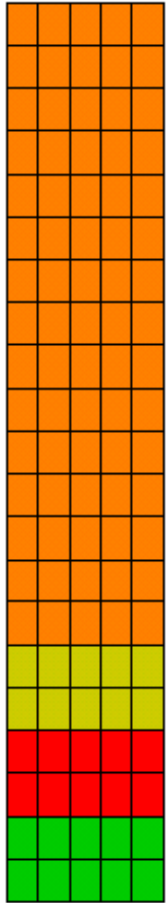
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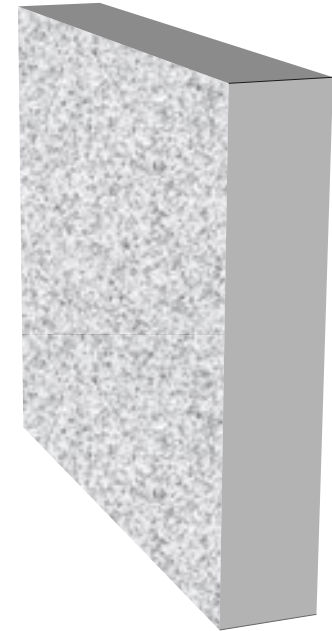
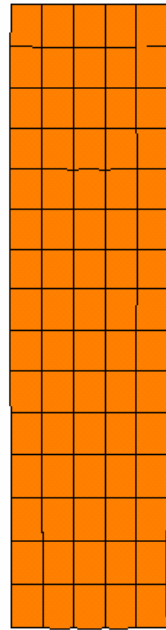
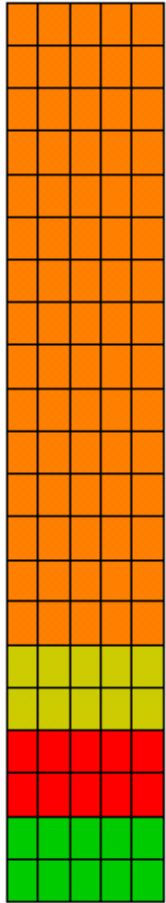
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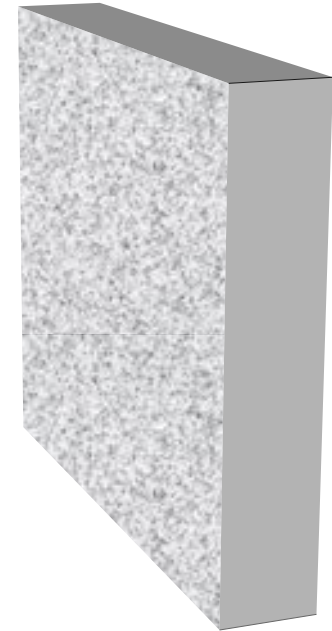
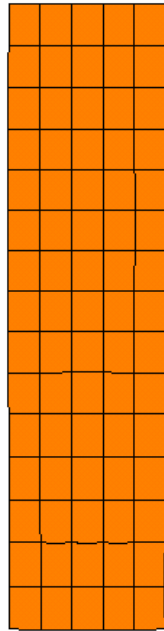
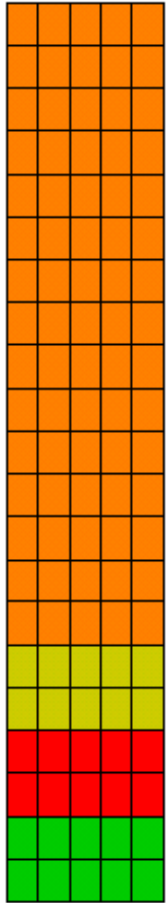
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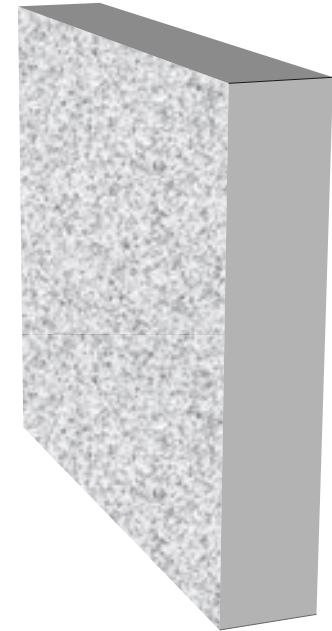
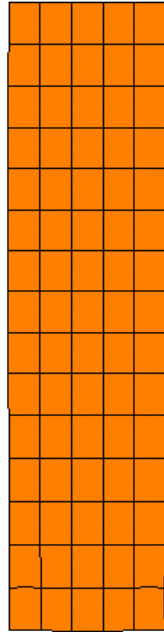
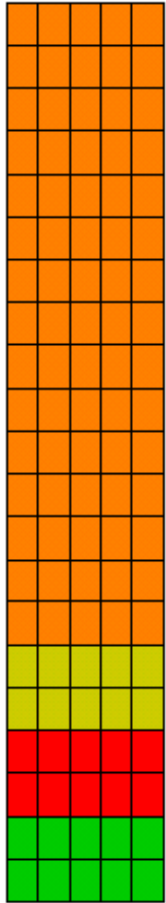
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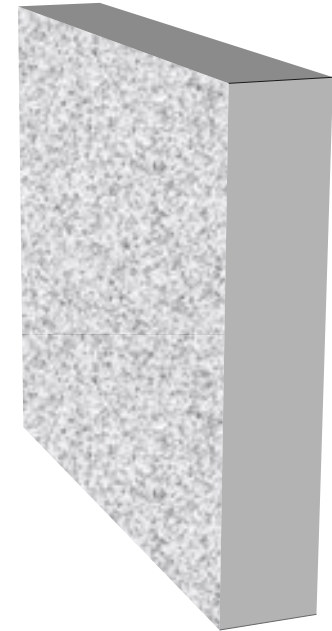
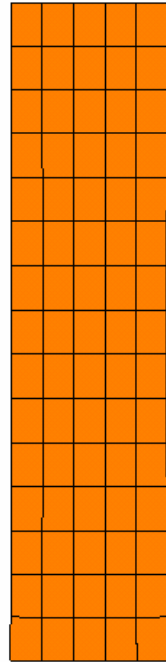
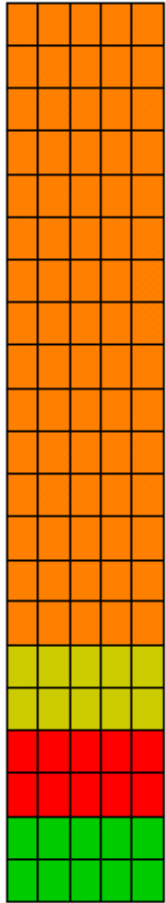
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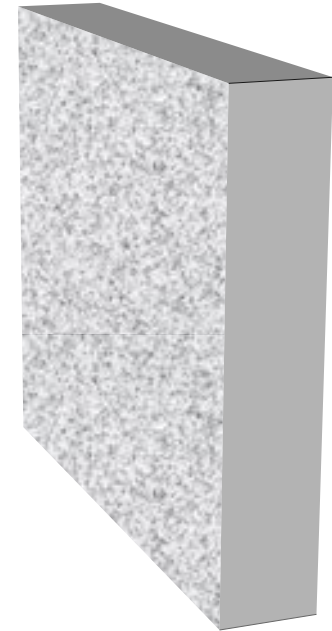
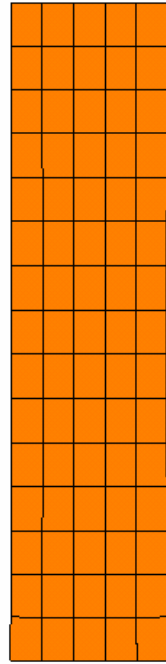
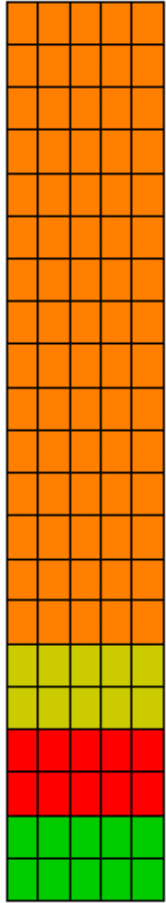
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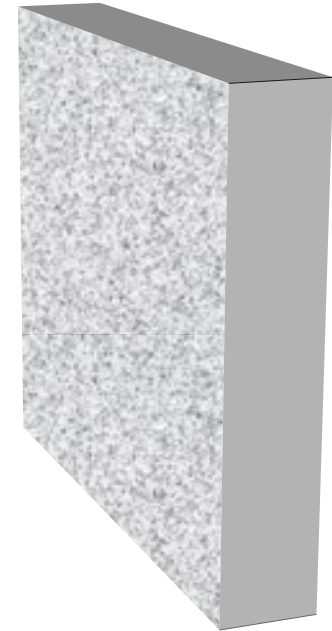
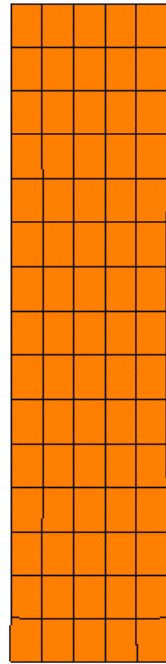
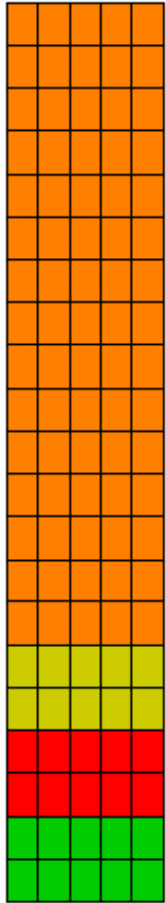
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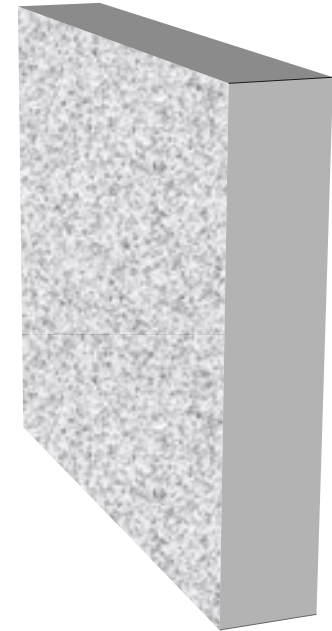
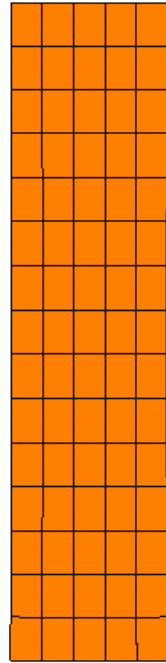
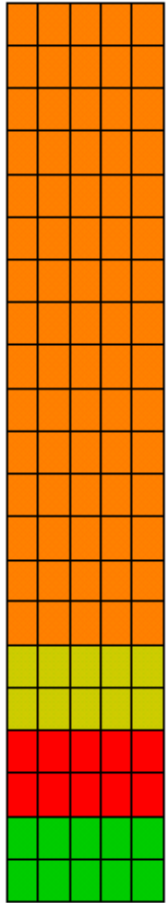
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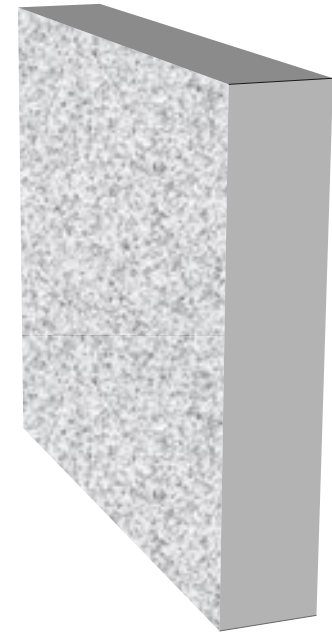
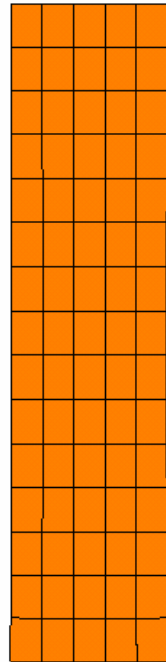
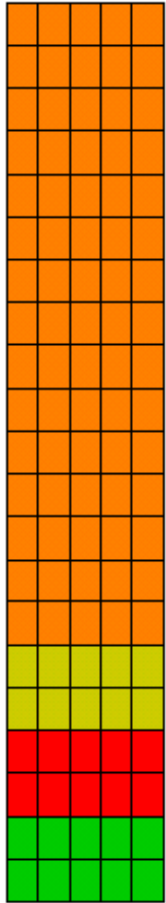
- Wave dissipation techniques
 - silent boundaries



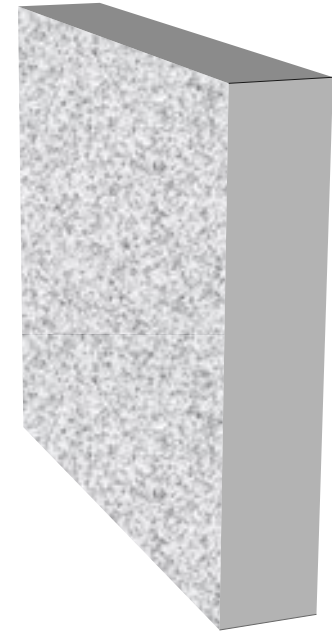
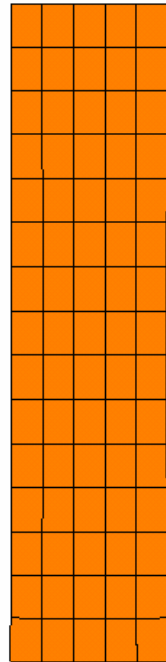
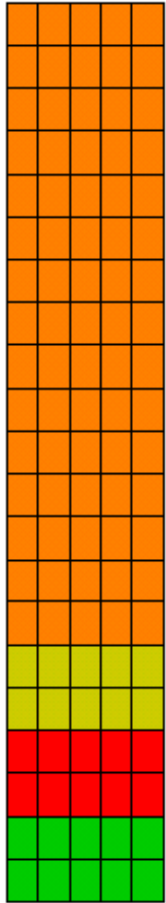
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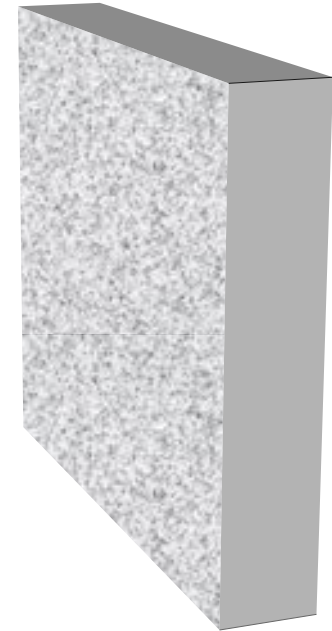
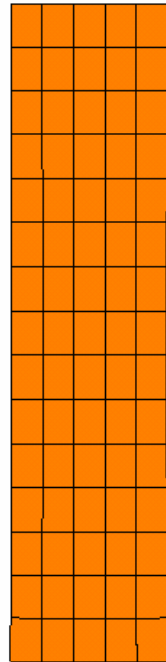
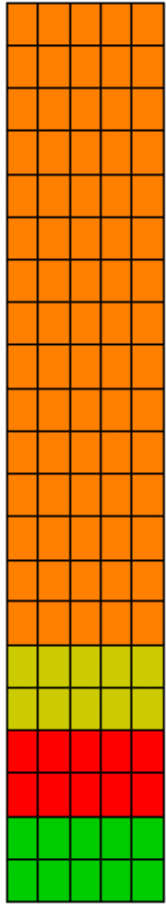
- Wave dissipation techniques
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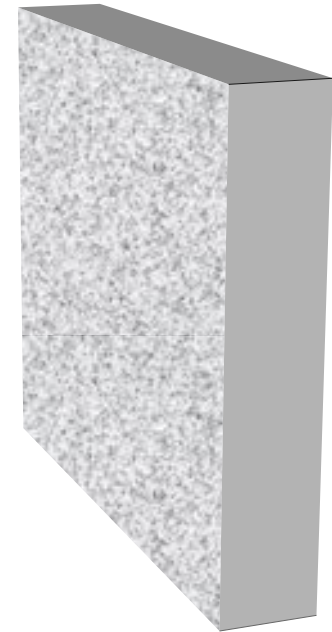
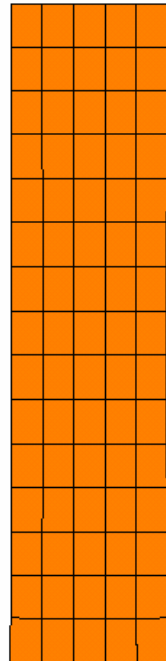
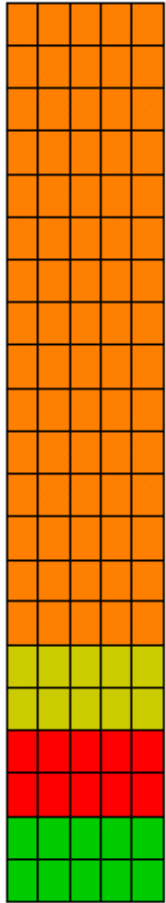
- Wave dissipation techniques
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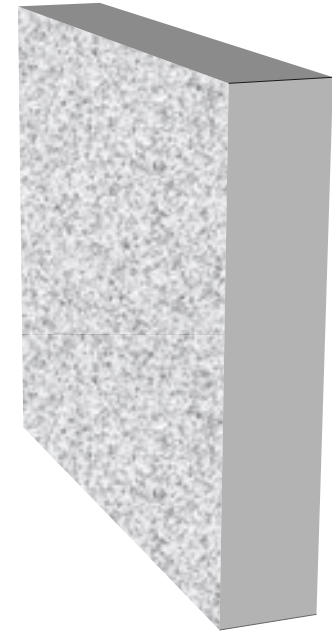
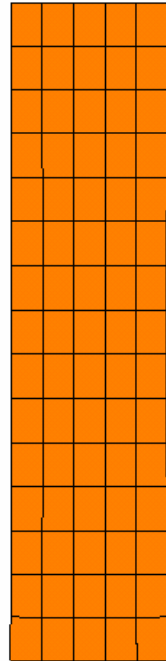
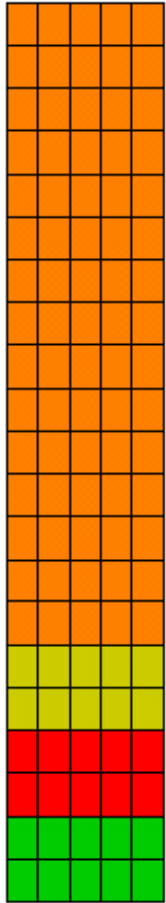
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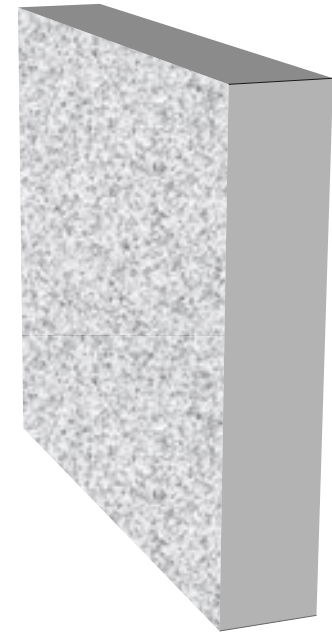
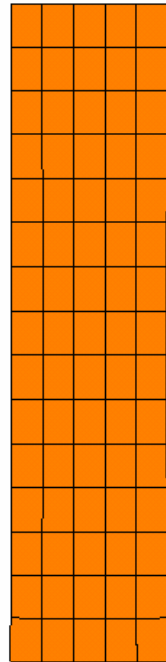
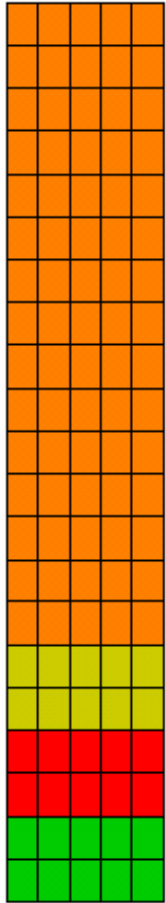
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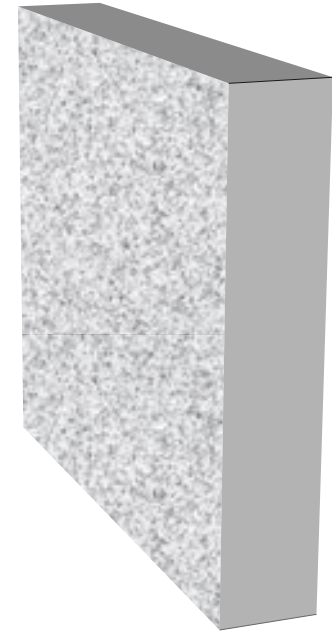
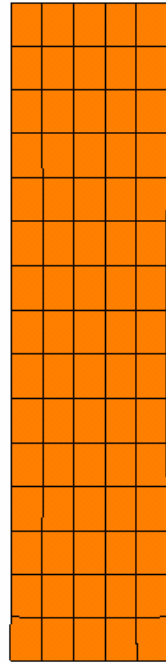
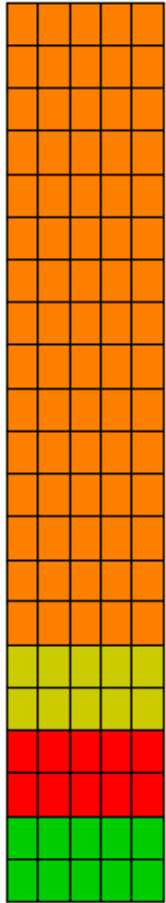
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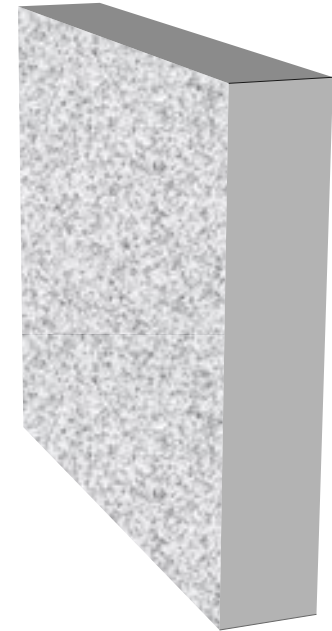
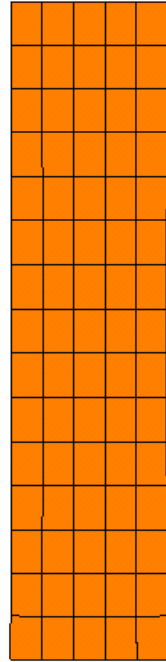
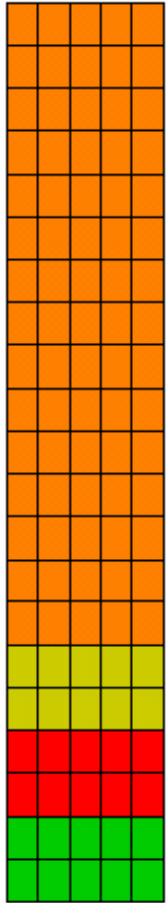
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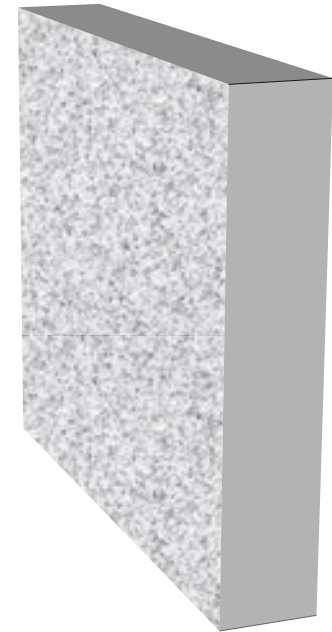
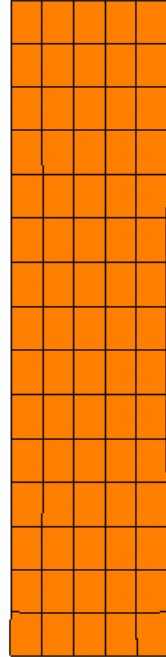
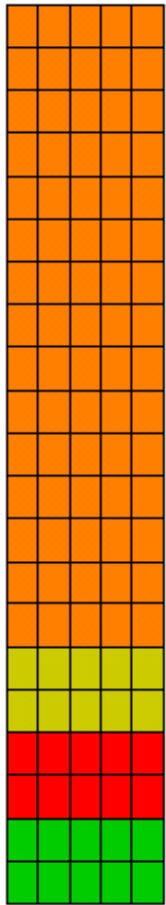
- Wave dissipation techniques
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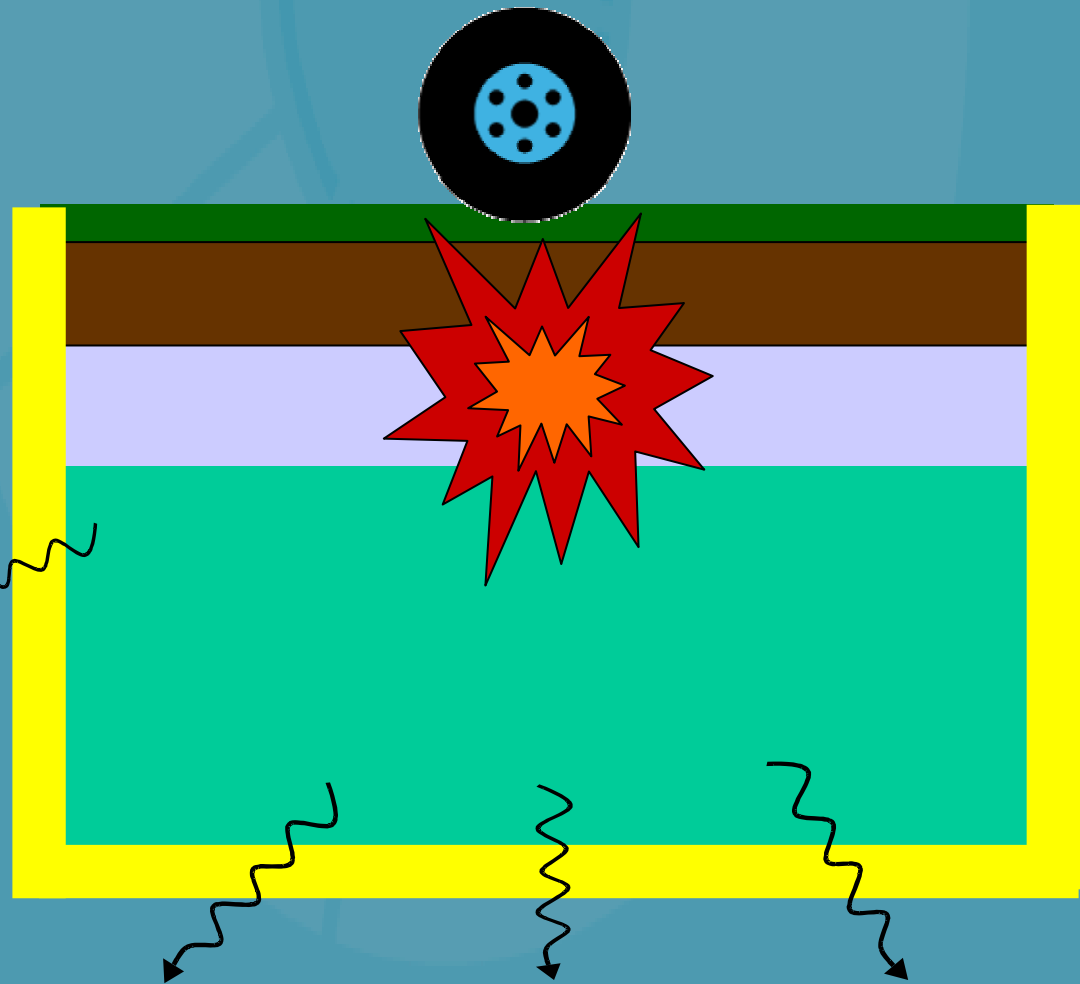
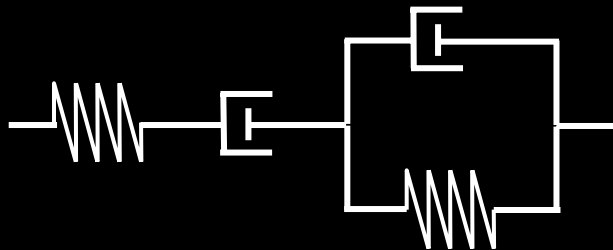
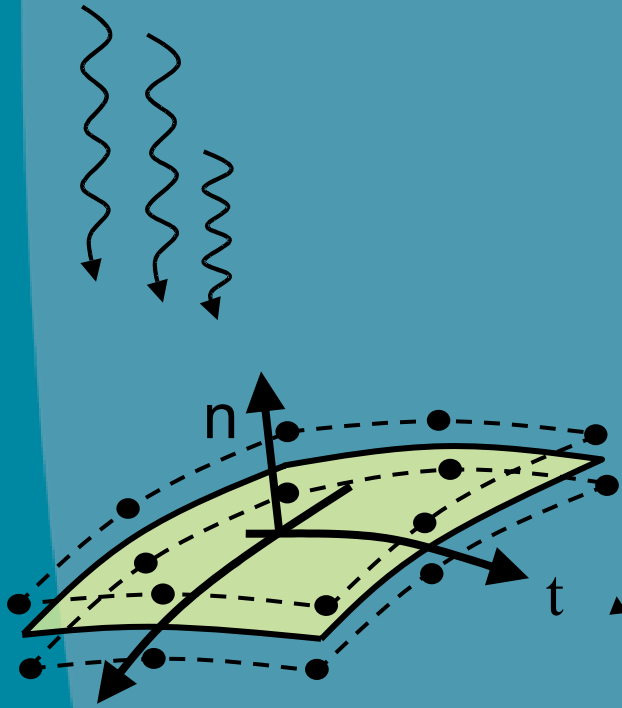
- Wave dissipation techniques
 - silent boundaries



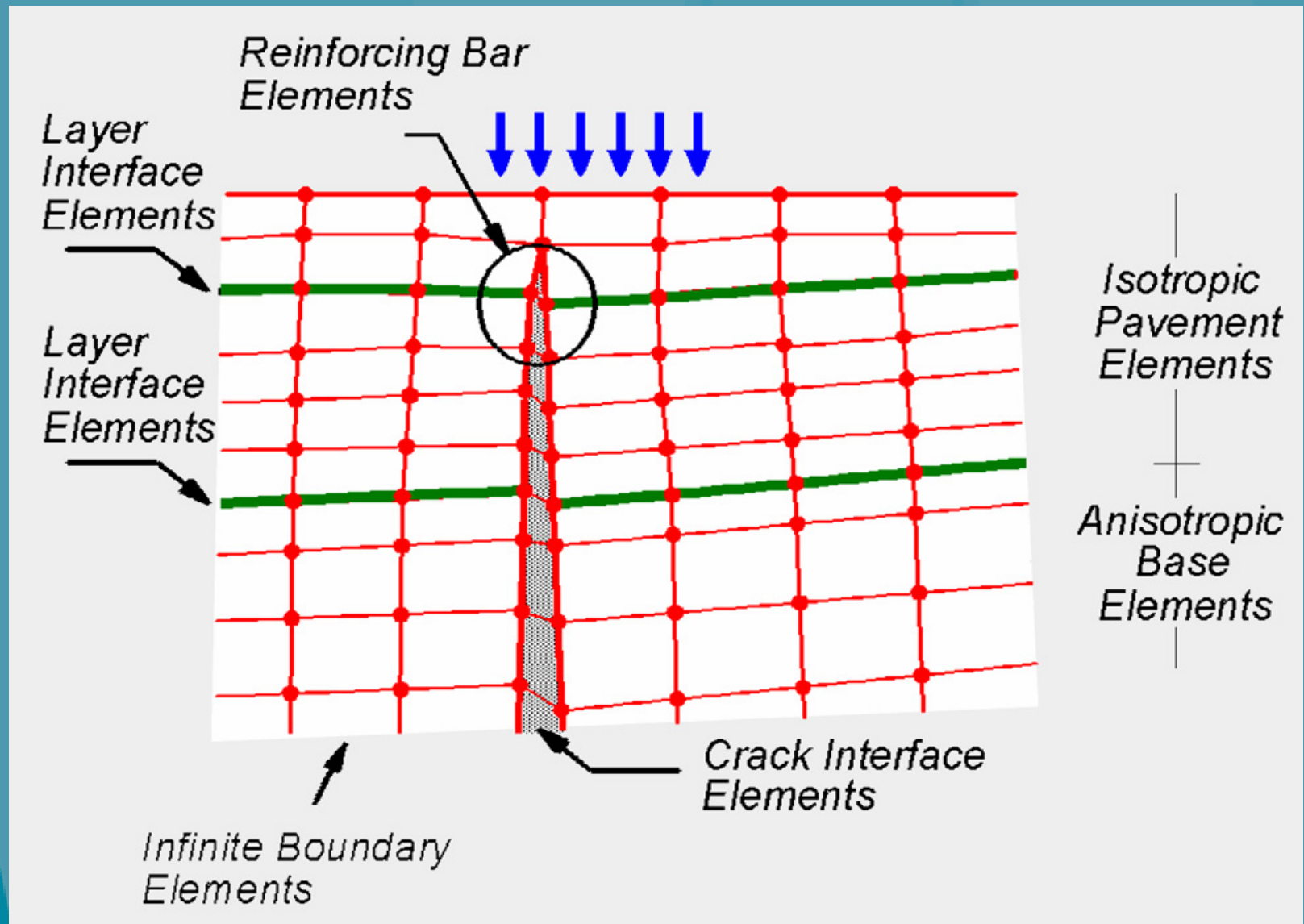
- Wave dissipation techniques
 - silent boundaries



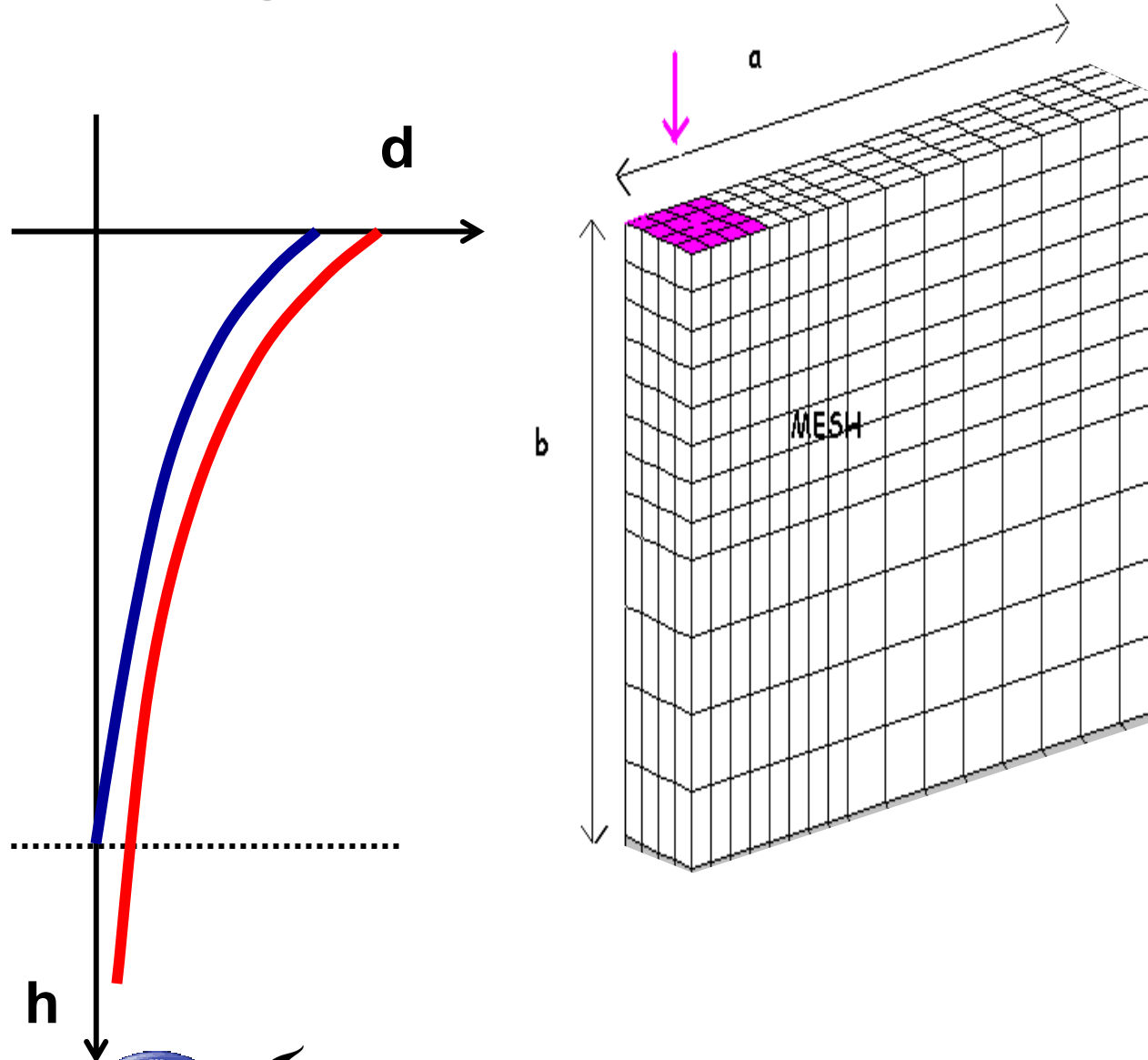
- infinite systems
 - silent boundary element



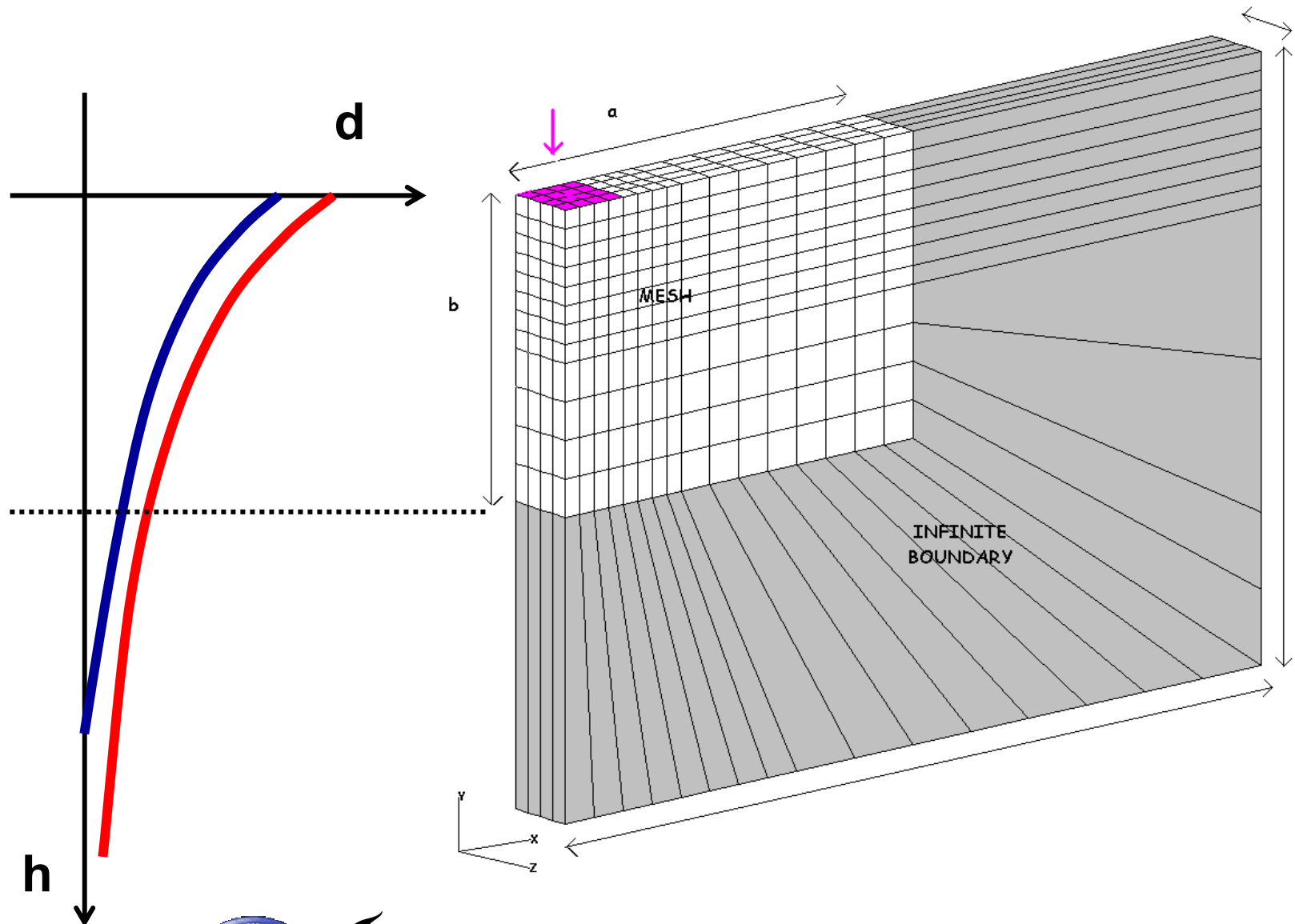
- the simulation problem: static infinite systems



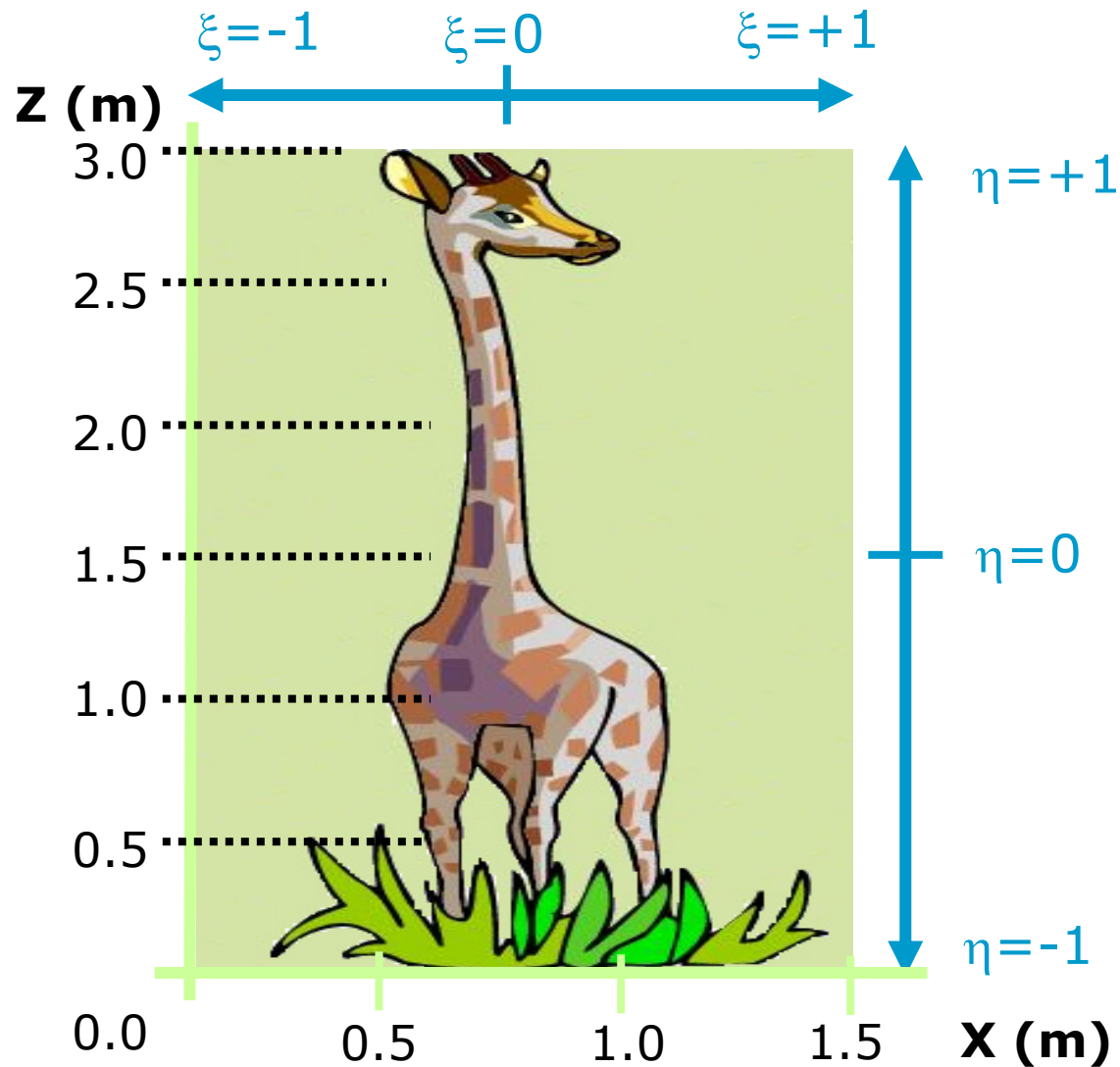
- Infinite systems



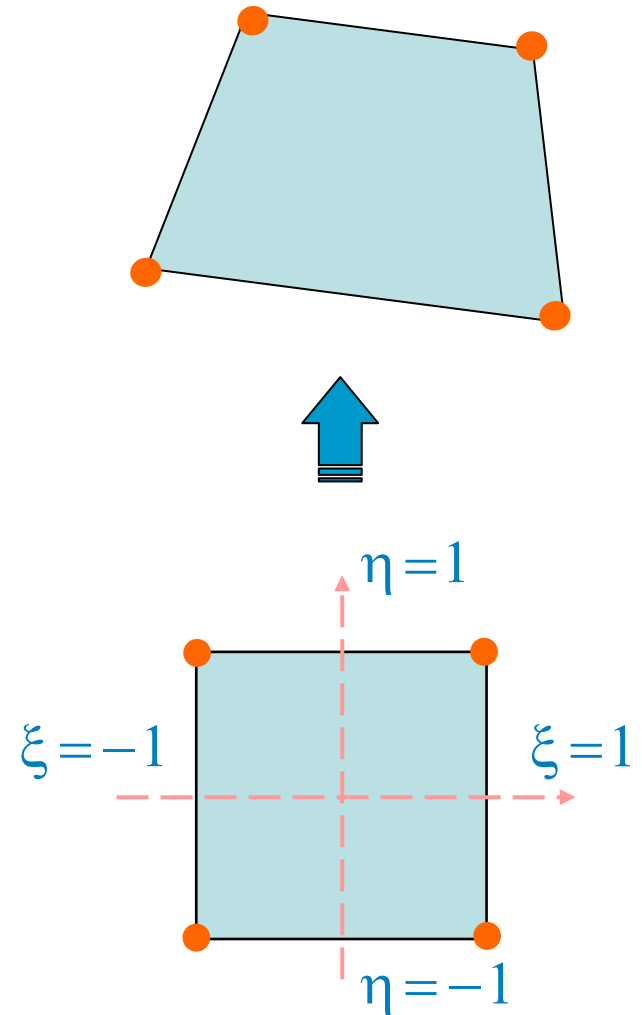
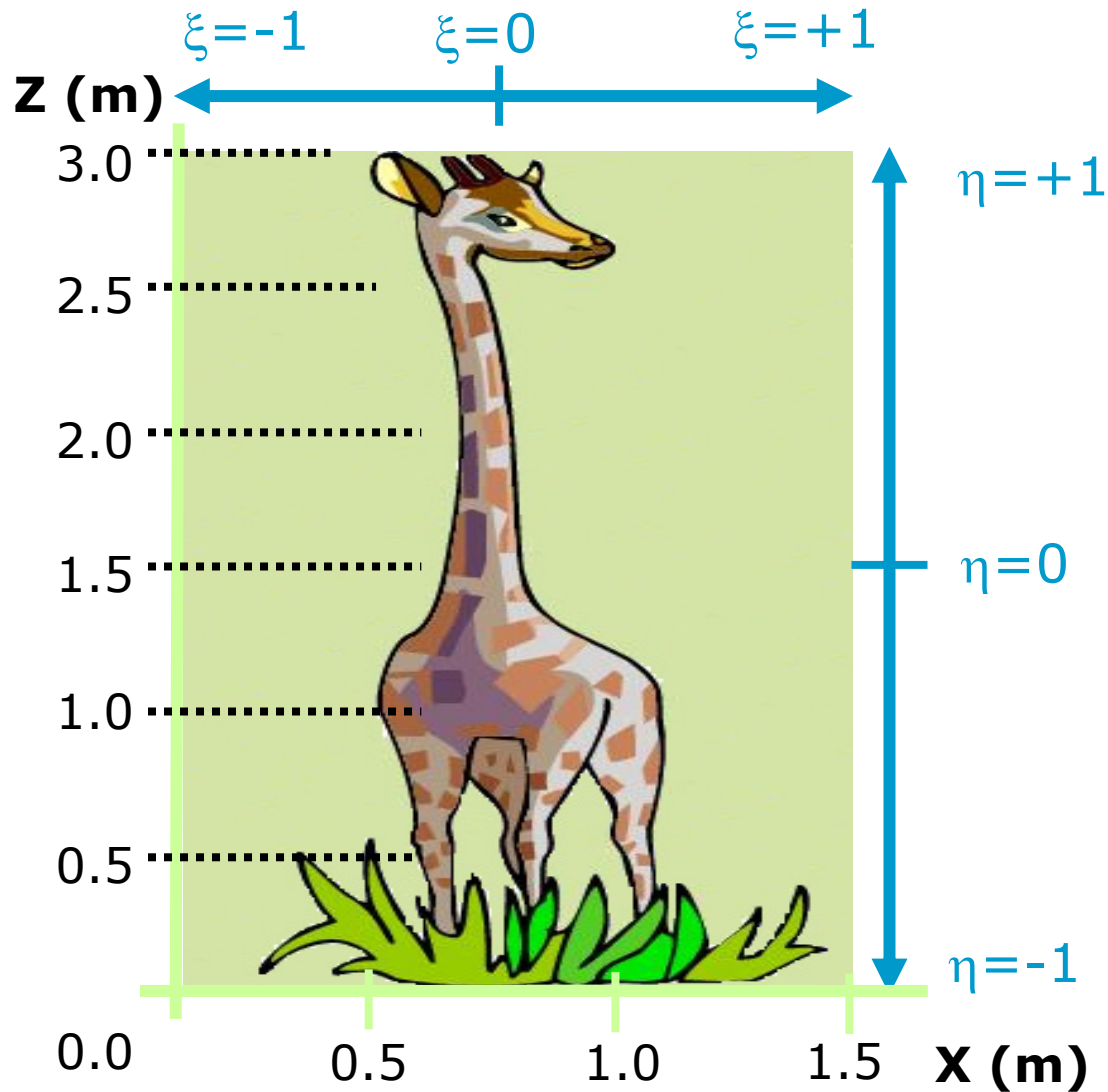
- Infinite systems



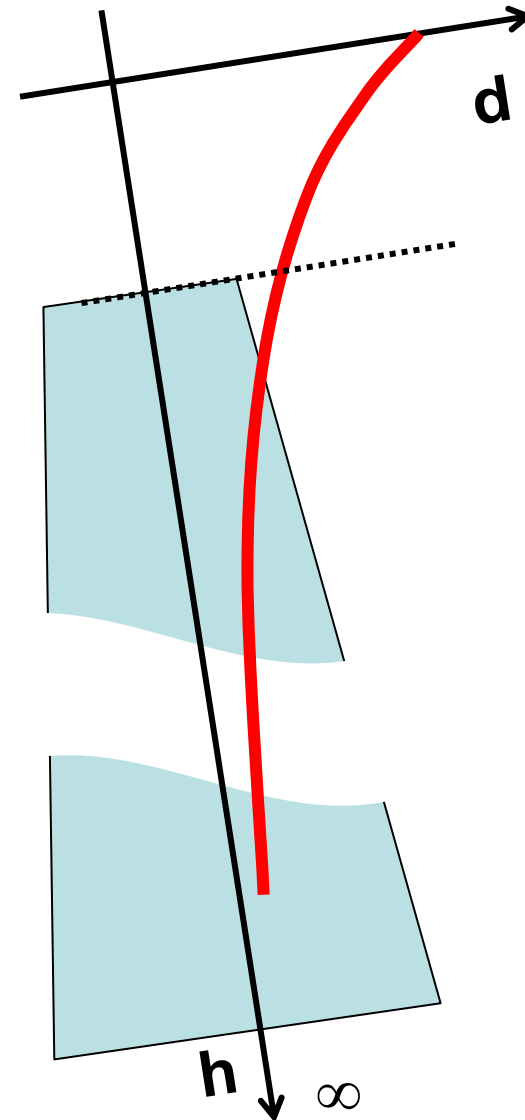
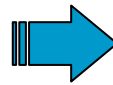
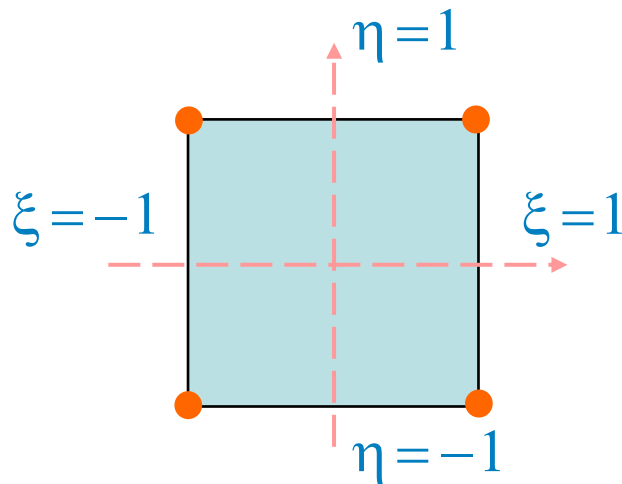
- Infinite systems: mappings



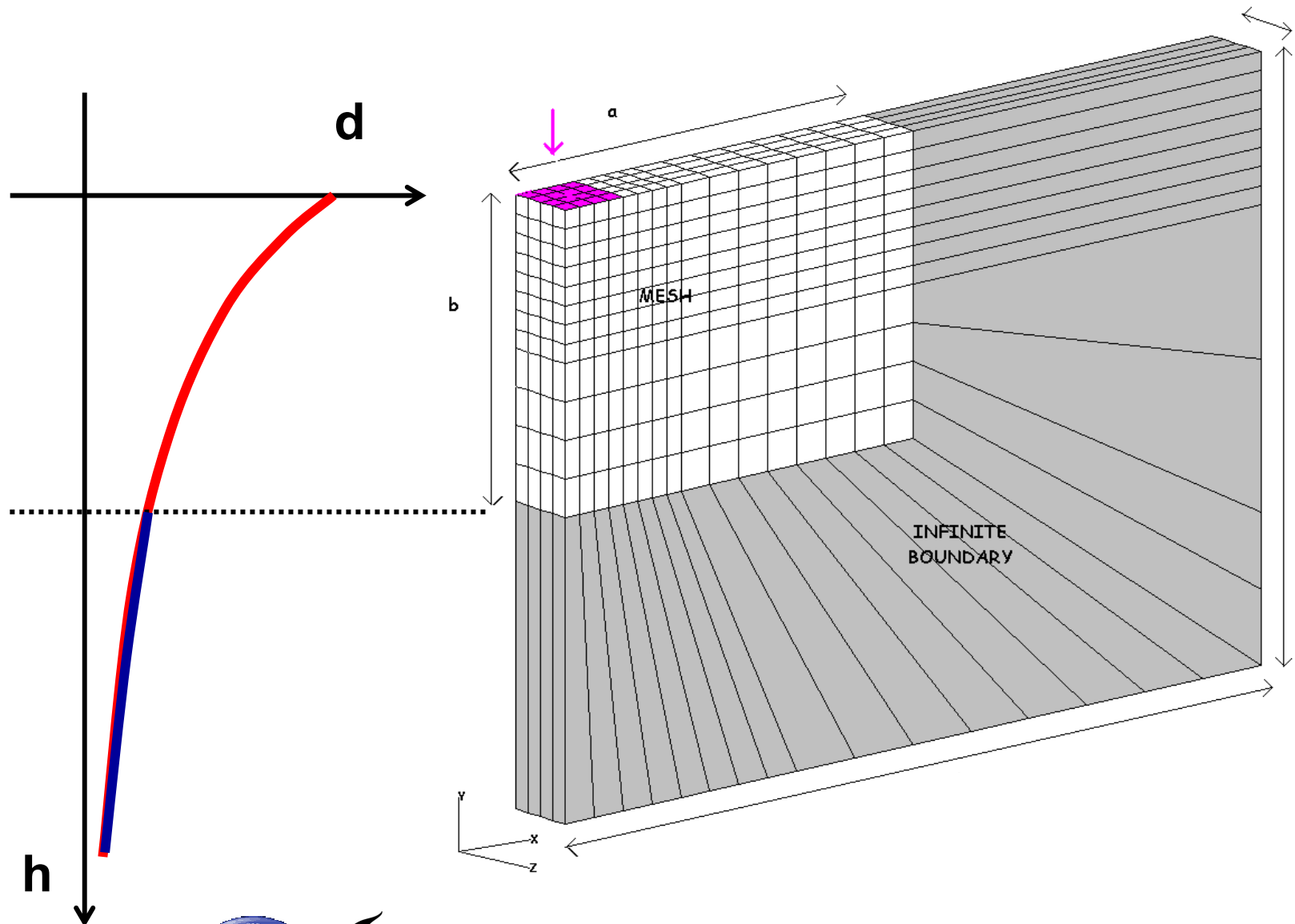
- Infinite systems: mappings



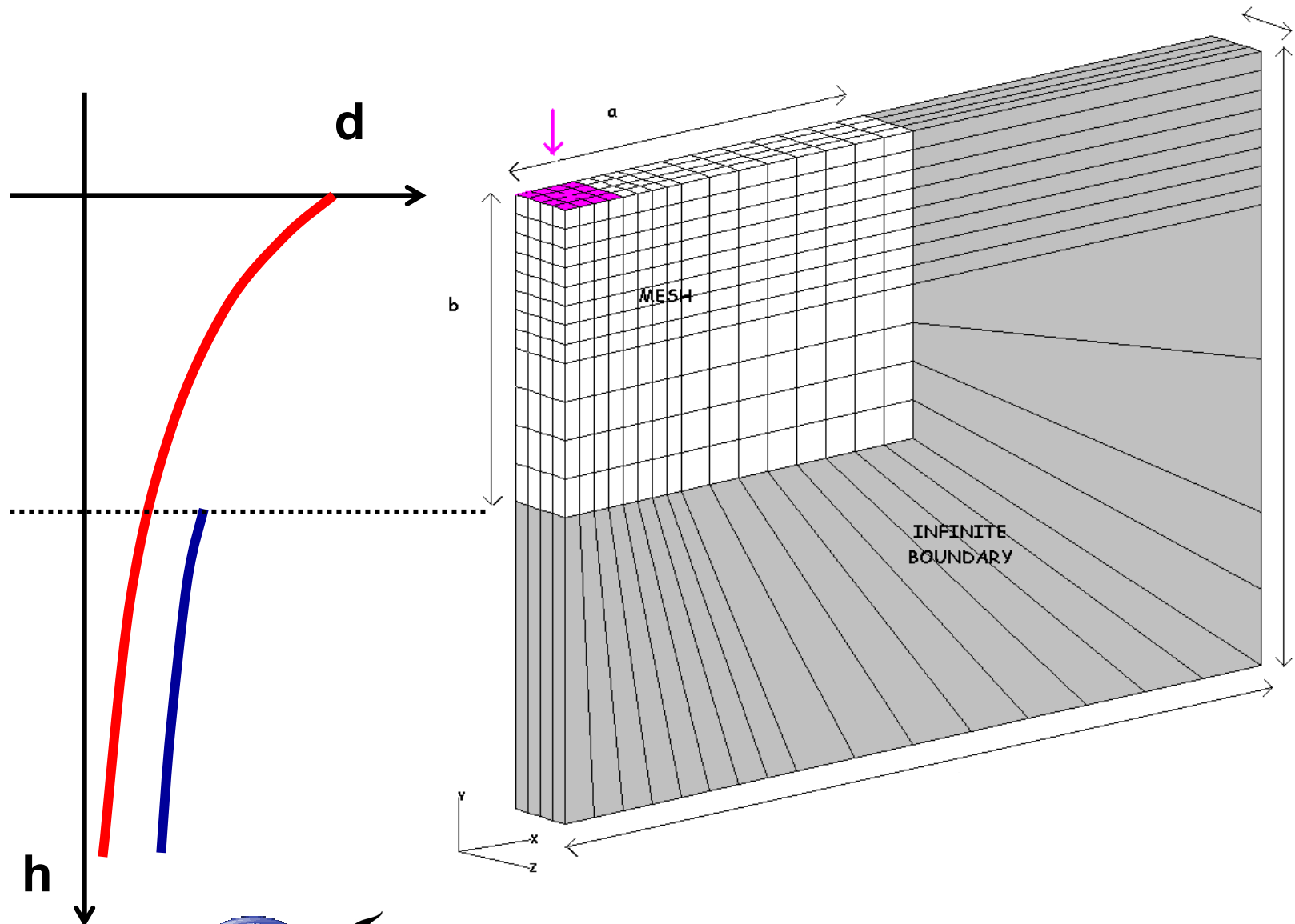
- Infinite systems
 - infinite finite elements



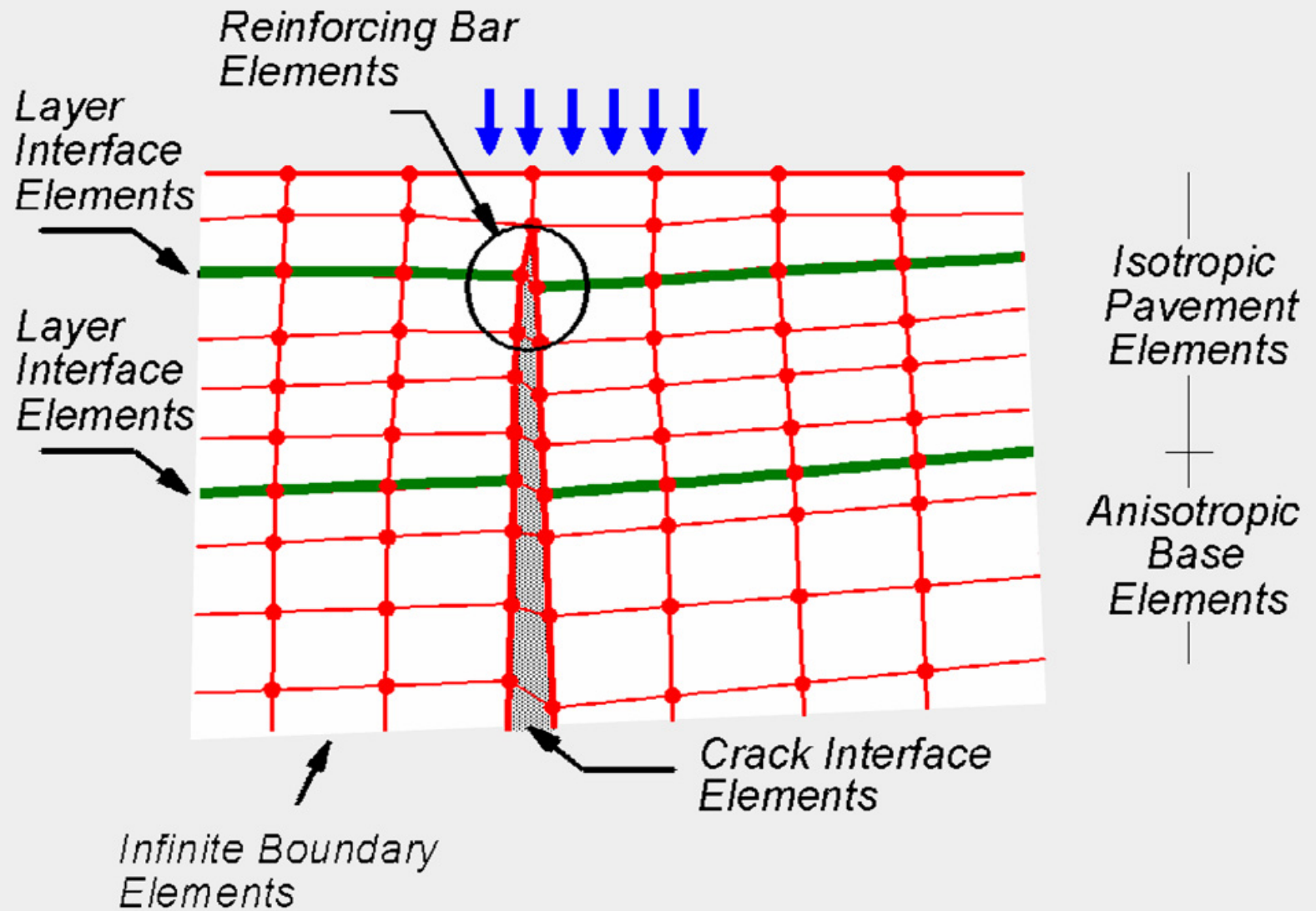
- Infinite systems



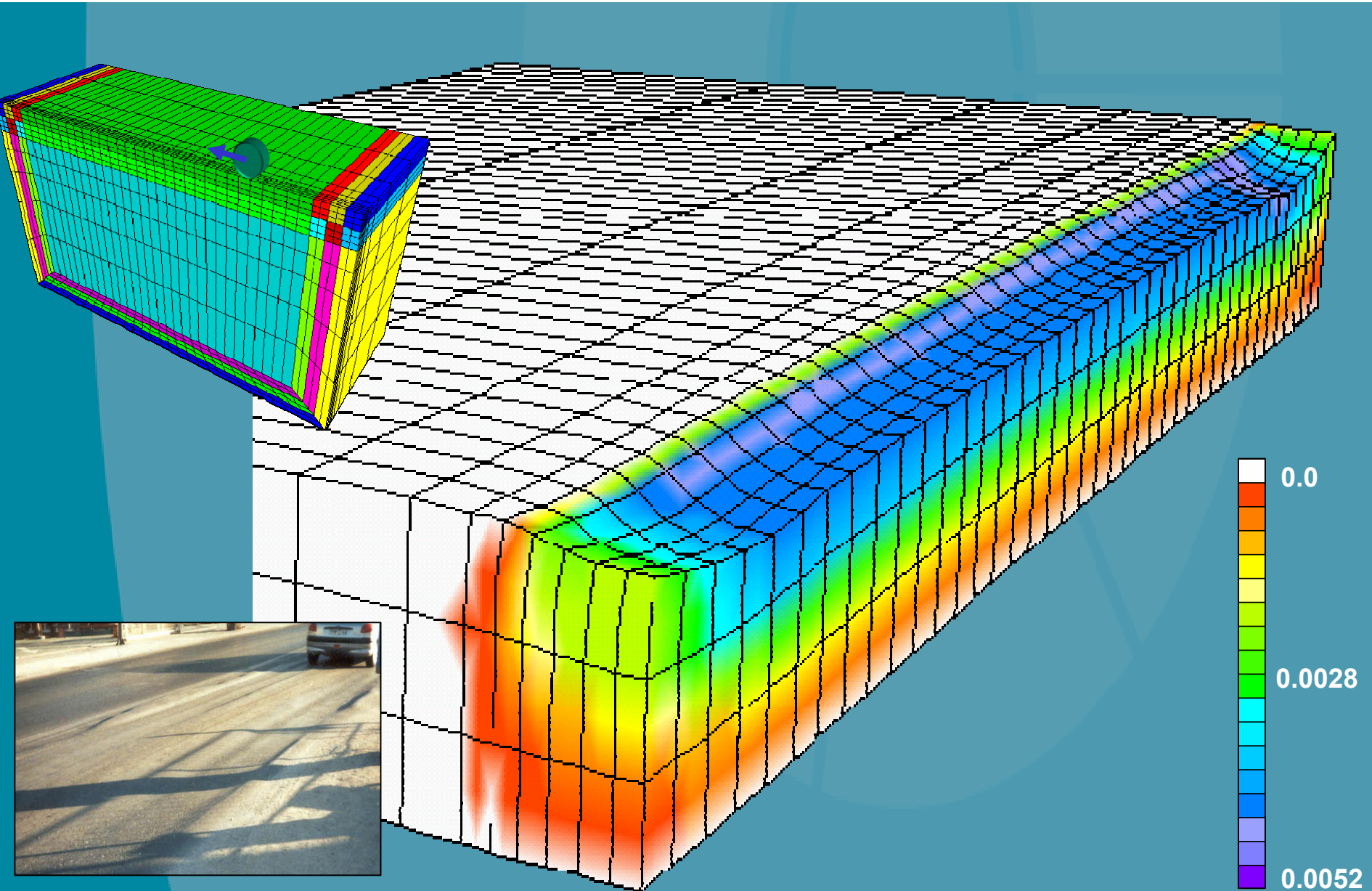
- Infinite systems



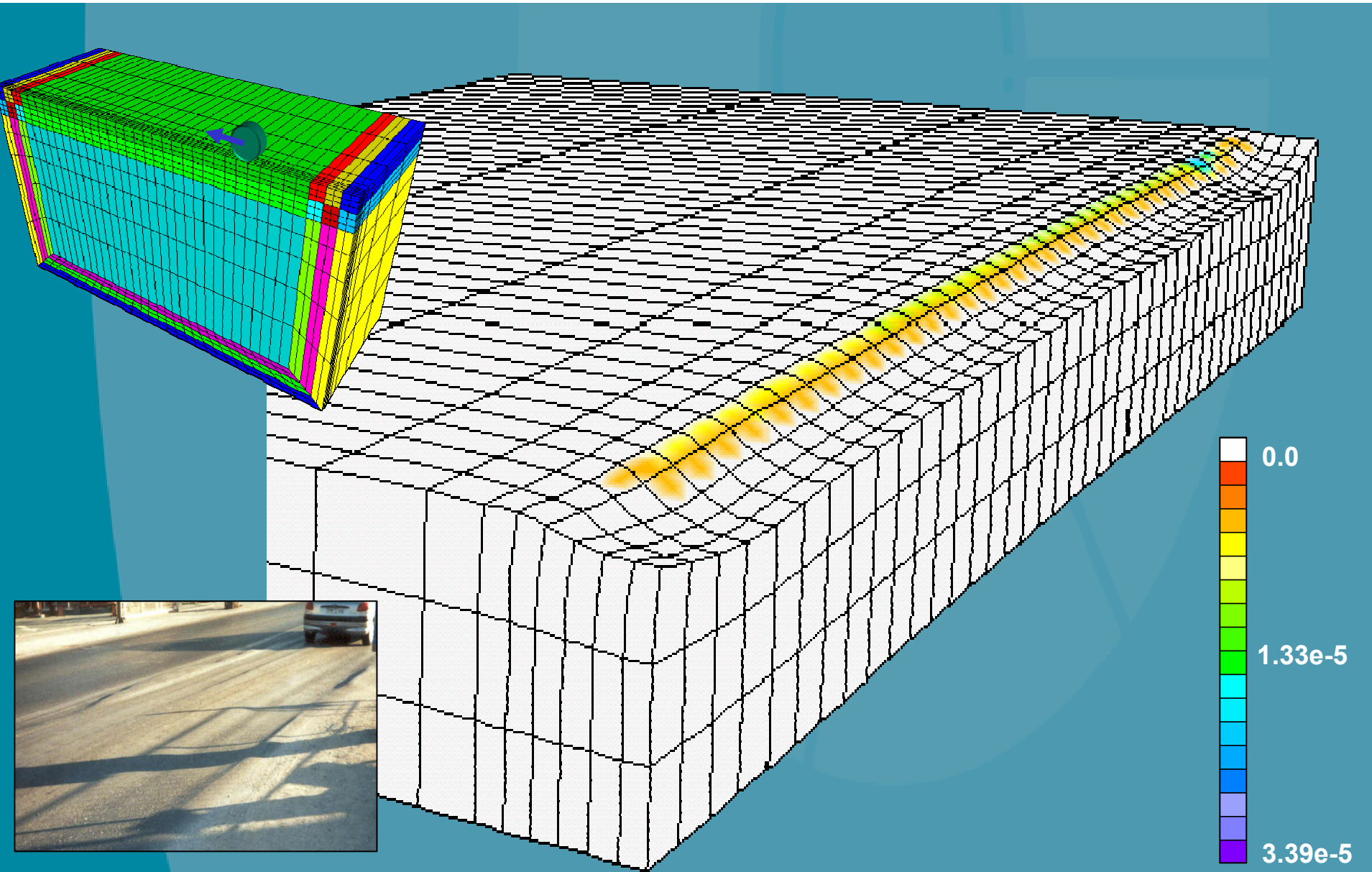
- the tools !!!



Wheel tracking simulation: effective inelastic strains

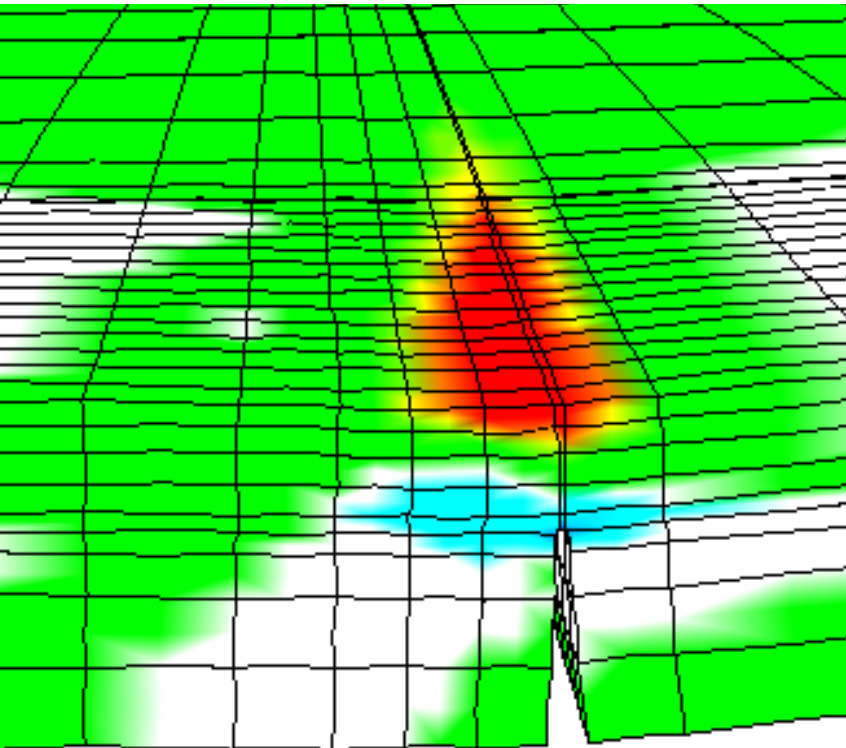


Wheel tracking simulation: longitudinal cracking



TRB Workshop 110:

Validation of Advanced Flexible Pavement Modeling with Accelerated Pavement Testing Data



Thank you !!!

Tom Scarpas, Xueyan Liu, Cor Kasbergen
Section of Structural Mechanics
TU Delft