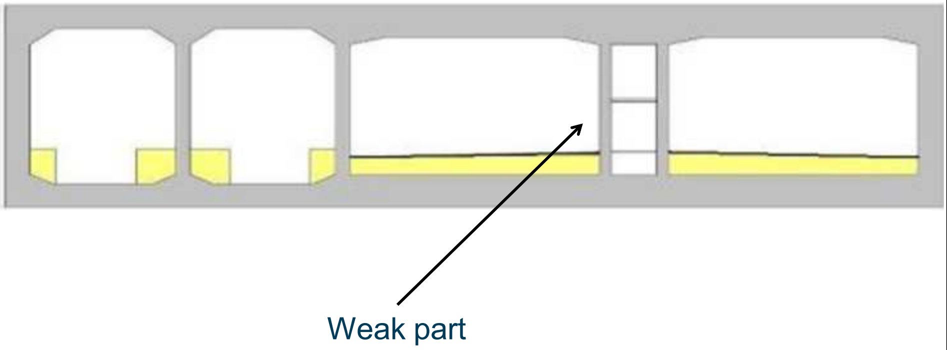
Toepassing detonatiebelasting volgens Eurocode

Marcel 't Hart

DOV lezeningenavond 29 november 2012

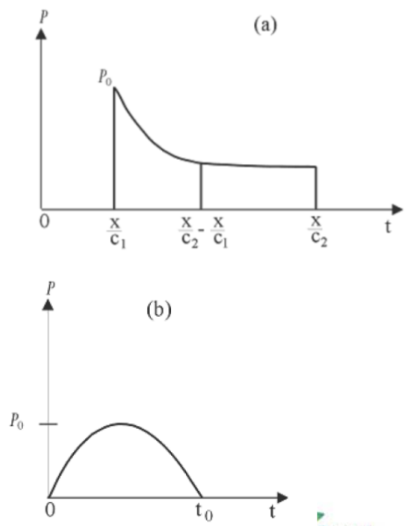
Contents

Cross-section



Eurocode

- Detonation - Global
- Deflagration - Local



Causes of a detonation

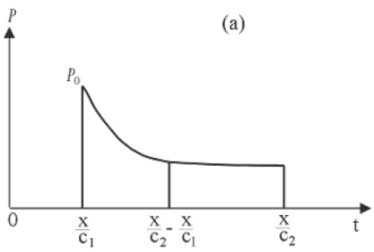
- Large parts of the tunnel tube are filled with a flamable or highly explosive gas
- Sparkle to ignite
- Combustion will lead to a shockwave which has a speed of sound in the gas, the flamefront is directly coupled to the pressure profile

Detonation in NEN-EN 1991-1-7 D.3

$$p(x,t) = p_0 \exp\left\{-\left(t - \frac{|x|}{c_1}\right)/t_0\right\} \text{ voor } \frac{|x|}{c_1} \le t \le \frac{|x|}{c_2} - \frac{|x|}{c_1}$$

$$p(x,t) = p_0 \exp\left\{-\left(\frac{|x|}{c_2} - 2\frac{|x|}{c_1}\right)/t_0\right\} \text{ voor } \frac{|x|}{c_2} - \frac{|x|}{c_1} \le t \le \frac{|x|}{c_2}$$

$p(x,t) = 0$ voor alle andere omstandigheden



p_0	Peak pressure, 2000kN/m^2
c_1	Speed of the pressurewave ~1800 m/s
c_2	Akoustic speed of hot gas ~800 m/s
t_0	Constant of time 0.01s
$\|x\|$	Distance to the centre of the explosion
t	Time

First engineering approach

Apply p_0 as a static load

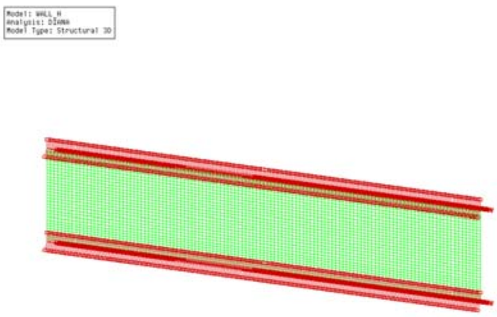
↓

FAILS

↓

Be smarter, use DIANA

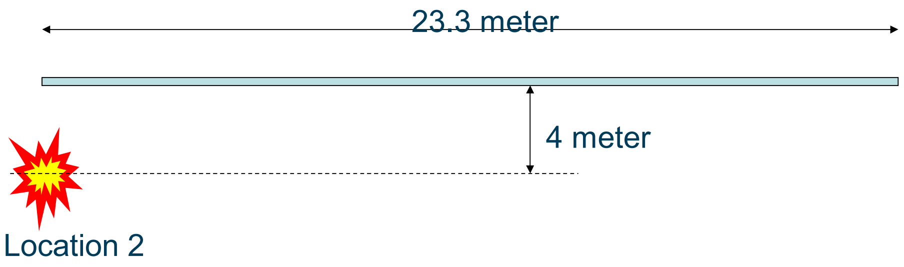
Model – intermediate wall



20000
Quadratic curved shell elements (CQ40S)

- Clamped supported
- Regular concrete
- E = 30000MPa
- ν = 0.15
- d =0.5m

Loading



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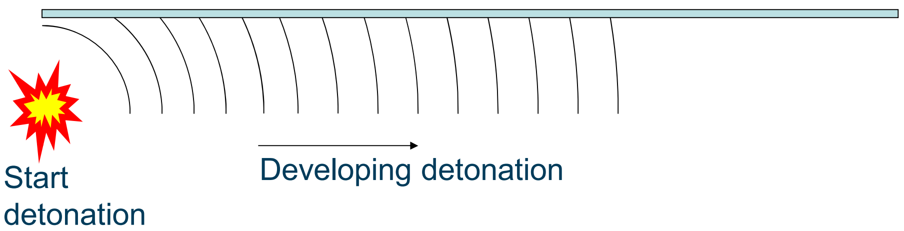
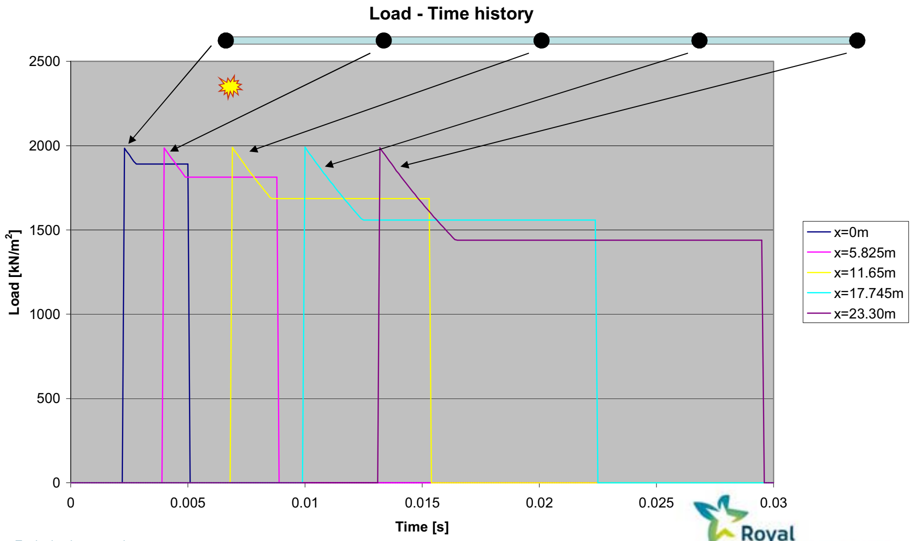


Load – Time history



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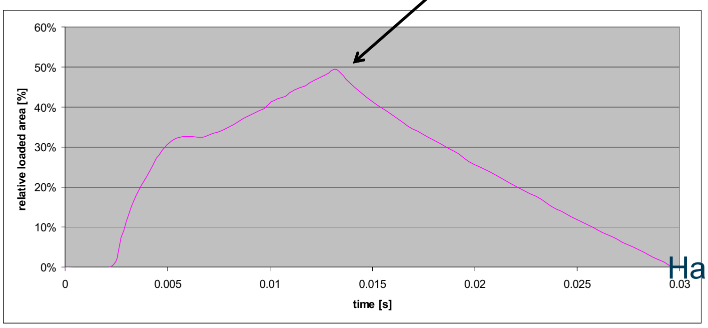
Relative loaded Area

$$A = \frac{F_{sum\ of\ loads}}{P_0}$$

50%



Half model

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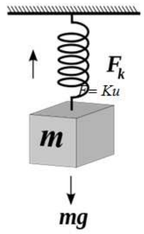
Solution methods: Static - Dynamic

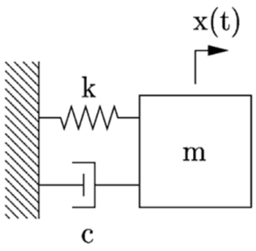
Static

$$F = Ku$$



Dynamic

$$M\ddot{u} + C\dot{u} + Ku = F(t)$$



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Rayleigh Damping

$$C = aM + bK$$

$$a = 2\omega_1\omega_2 \frac{\omega_1\xi_2 - \omega_2\xi_1}{\xi_2^2 - \xi_1^2}$$

$$b = 2\frac{\omega_1\xi_1 - \omega_2\xi_2}{\xi_2^2 - \xi_1^2}$$

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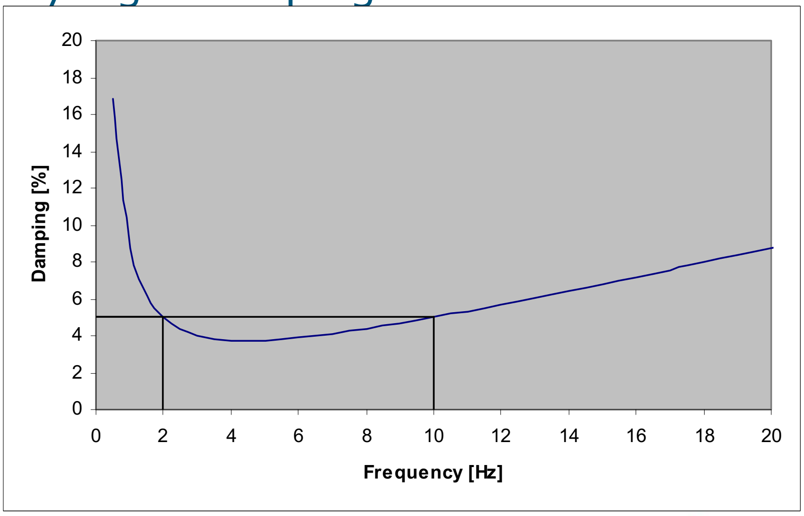
Rayleigh Damping



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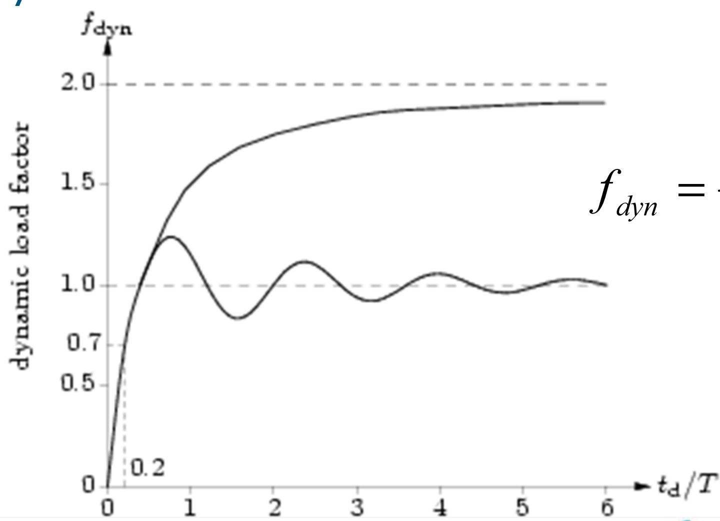
Dynamic Load Factor



$$f_{dyn} = \frac{u_{\max,d}}{u_{\max,s}}$$

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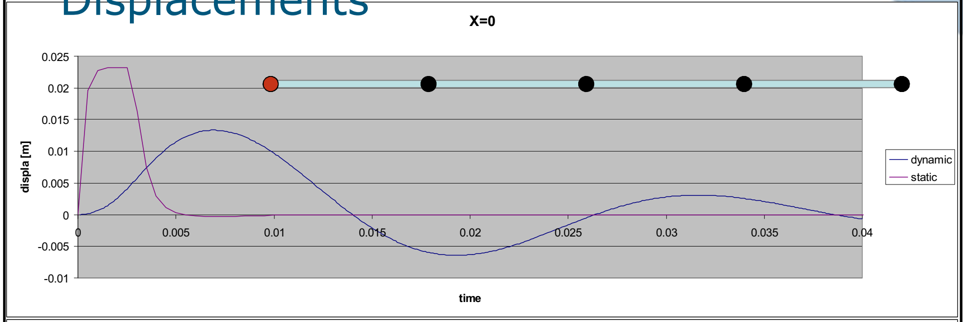
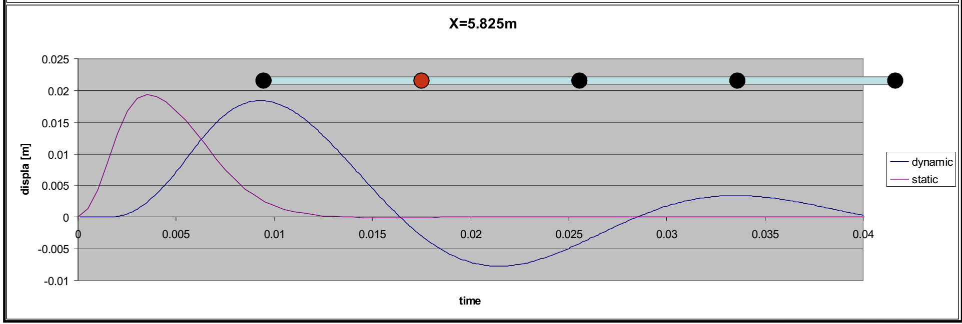
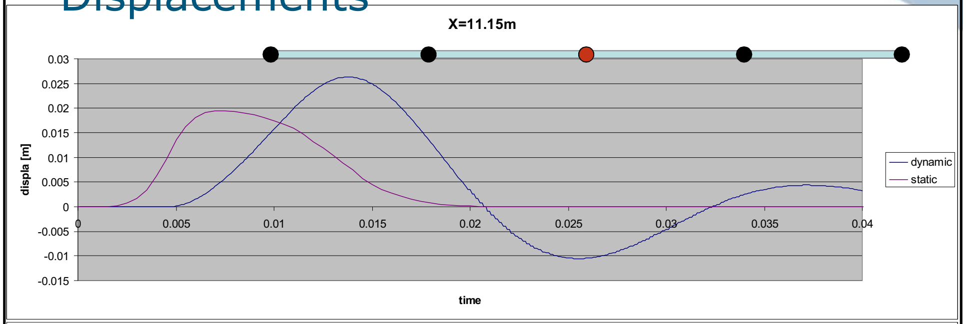
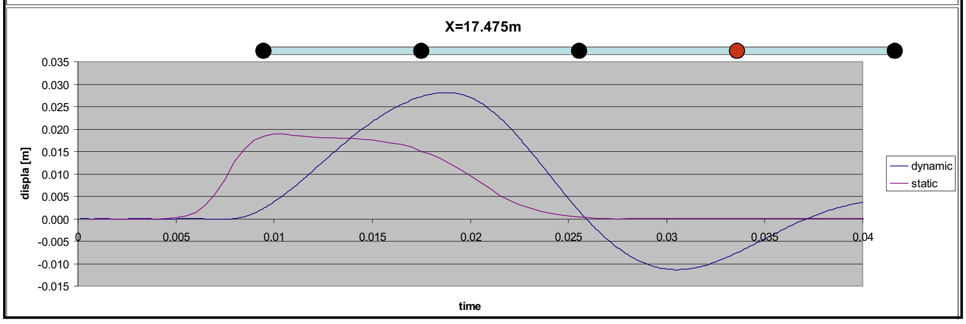
Displacements





Displacements





Dynamic Load Factor

Point	DLF
1	0.57
2	0.95
3	1.35
4	1.49
5	1.29

Conclusion

If the load of an detonation has to be applied on the tunnel, large areas need to be loaded with 2000MPa x DLF, which will result in a failure of structure in the Ultimate Limit State. Significant strengthening of the structure is needed to resist this load

Conclusion

You do not want a tunnel if you want to resist this load

↓

3 recommendations left:

- No tunnel
- Heavier tunnel
- Exclude this load using a probabilistic approach

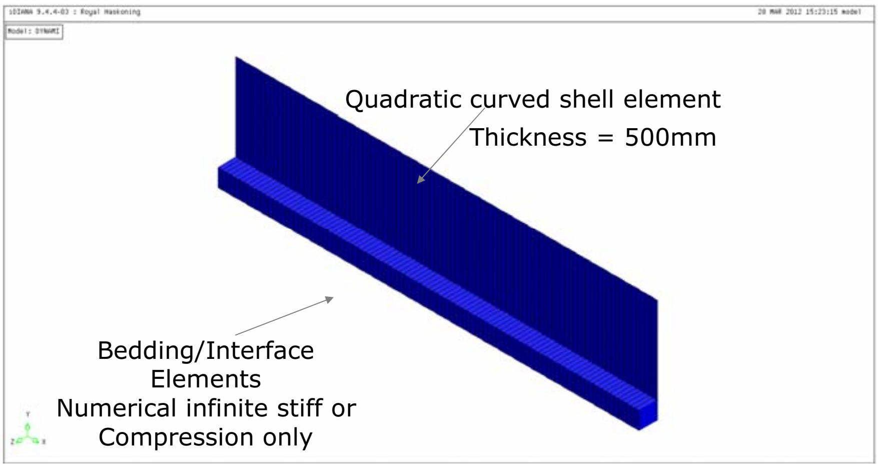
Be more smart

Use DIANA non-linear

Starting points

- Nonlinear dynamic approach
- Concrete nonlinear
- Reinforcement nonlinear
- Damage may occur, but must be repairable
- Draw a conclusion

Model



Reinforcement

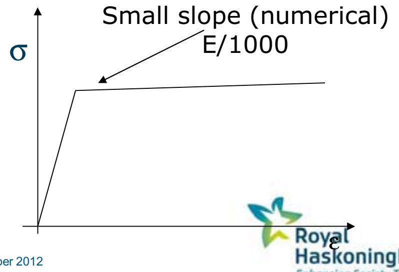
Vertical

Configuration	Area	Length over height
ϕ25-200 + ϕ32-200	6476mm²/m	1.5m
ϕ25-200 + ϕ20-200	4025mm²/m	1.9m
ϕ25-100	4909mm²/m	1.4m

f_{yd}= 500 MPa
E=210000MPa
ρ=7850 kg/m³

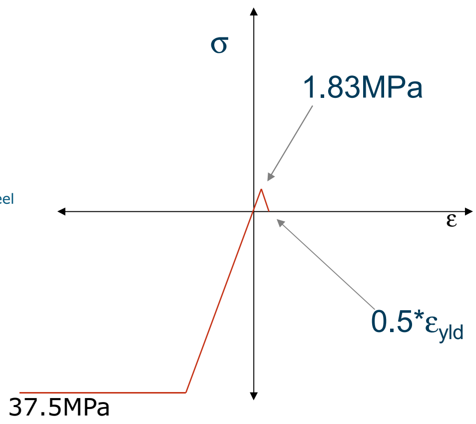
Horizontal

Configuratio n	Area	Length over height
ϕ16-150	1340mm²/m	2.0m
Φ16-225	894mm²/m	3.8m

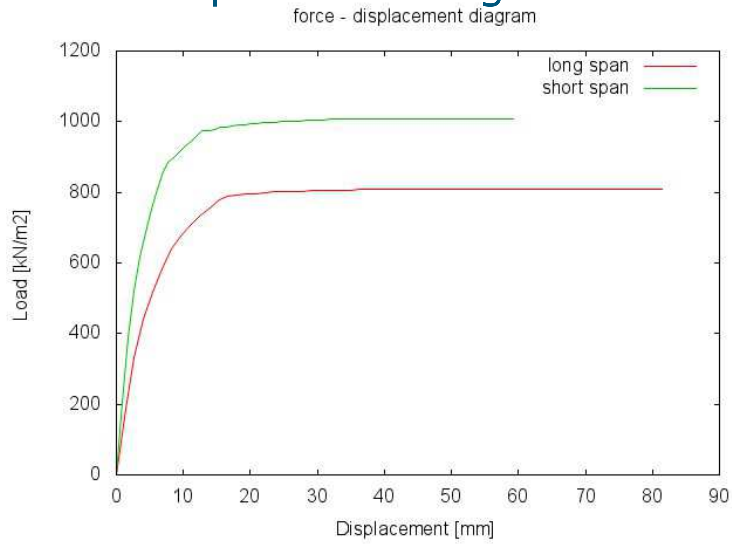


Concrete

- E = 34000MPa
- Smeared rotating crack model
- Tensile strength= 1.83MPa
- Compressive strength = 37.5 MPa
- Max. tensile strain = 0.5* $\varepsilon_{yldsteel}$
- Constant shear retention β=0.01
- ρ=2500 kg/m3



Influence op the bedding



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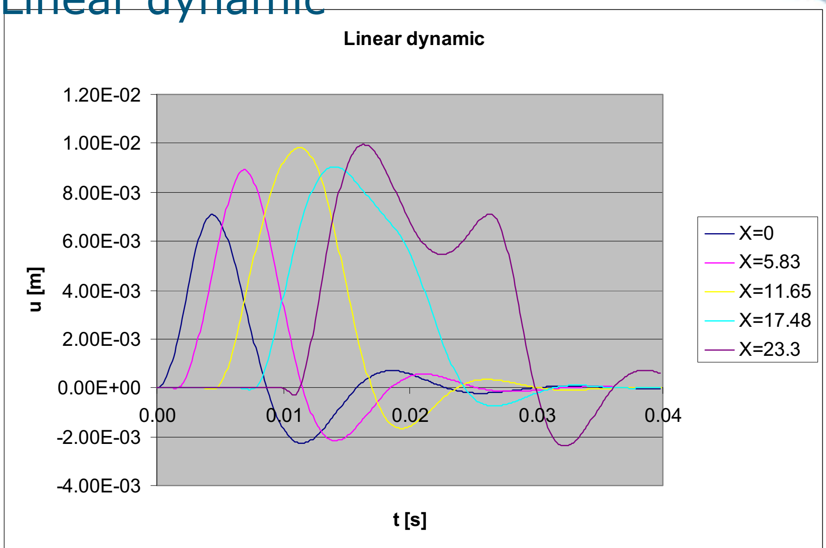
Linear dynamic



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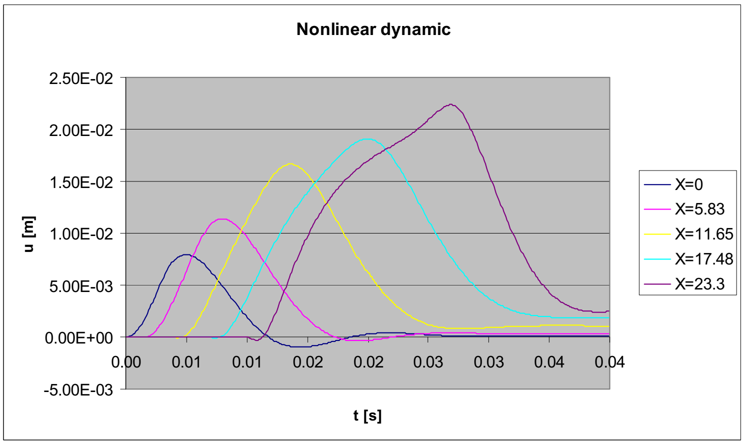
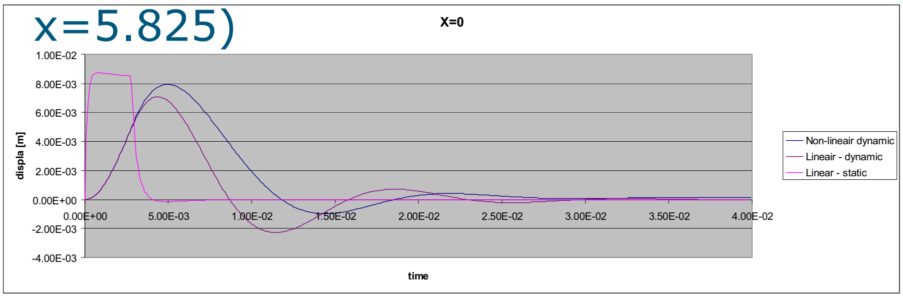
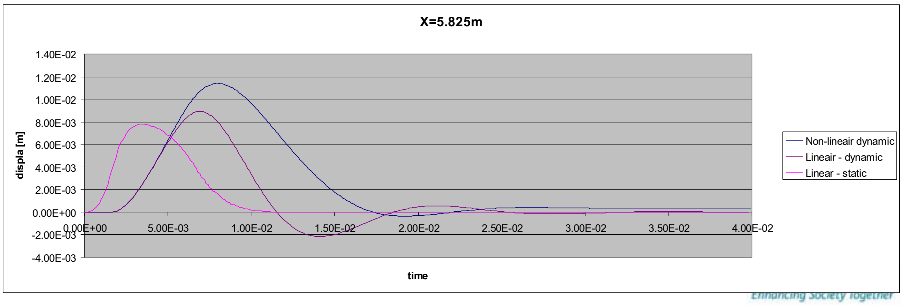
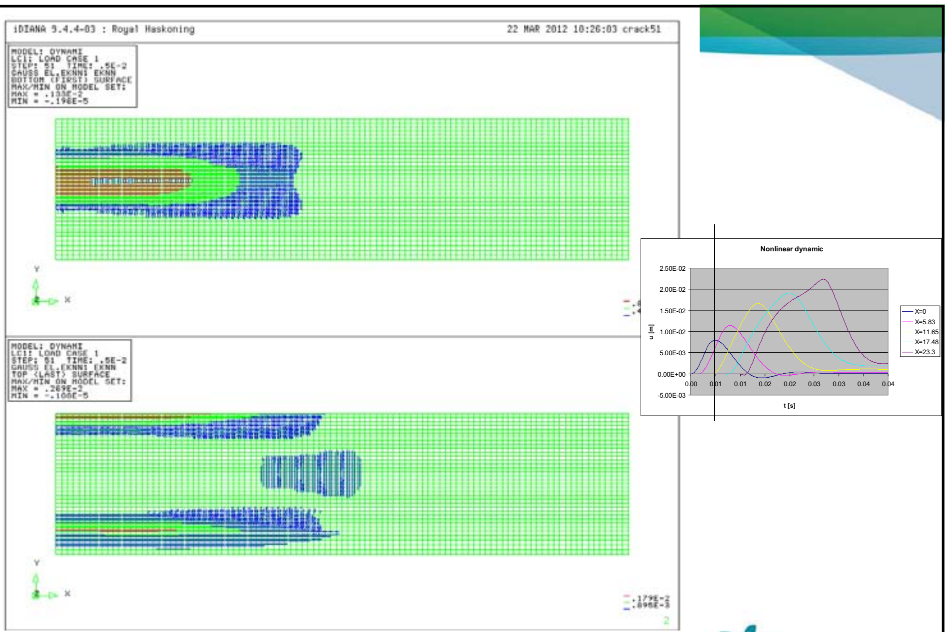
Nonlinear dynamic



Displacements in time (x=0; x=5.825)







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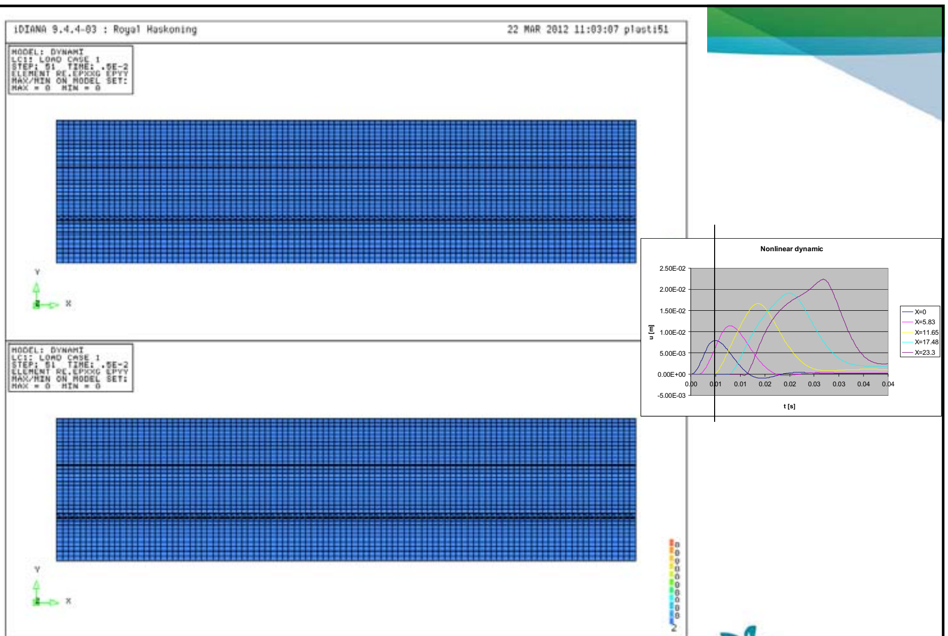

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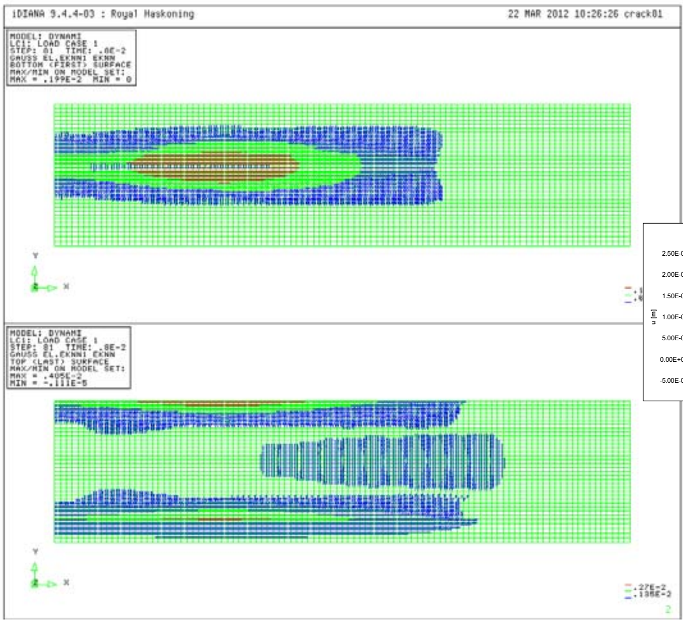

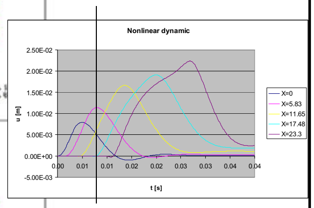

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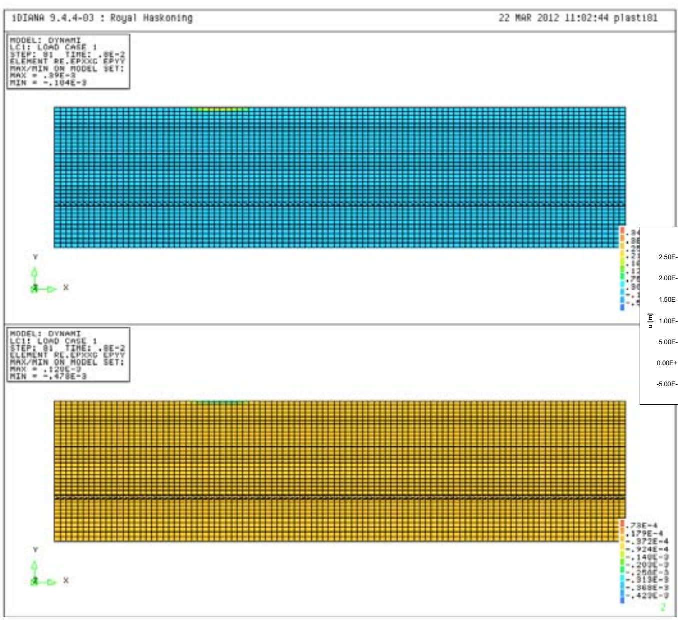

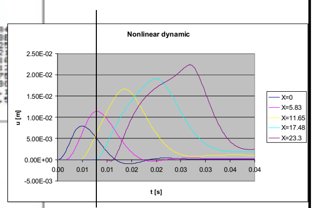

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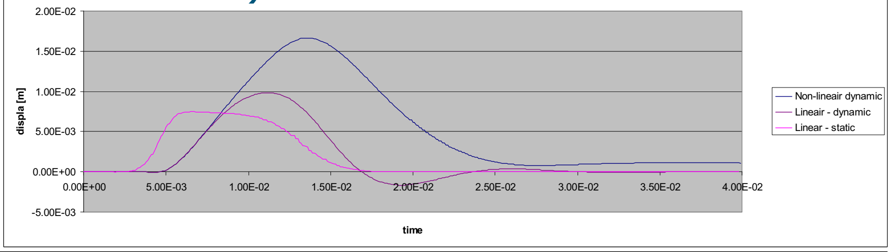
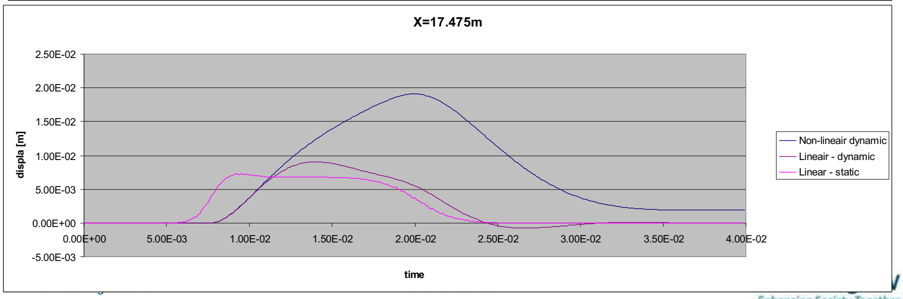
Displacements in time (x=11.65; x=17.475)





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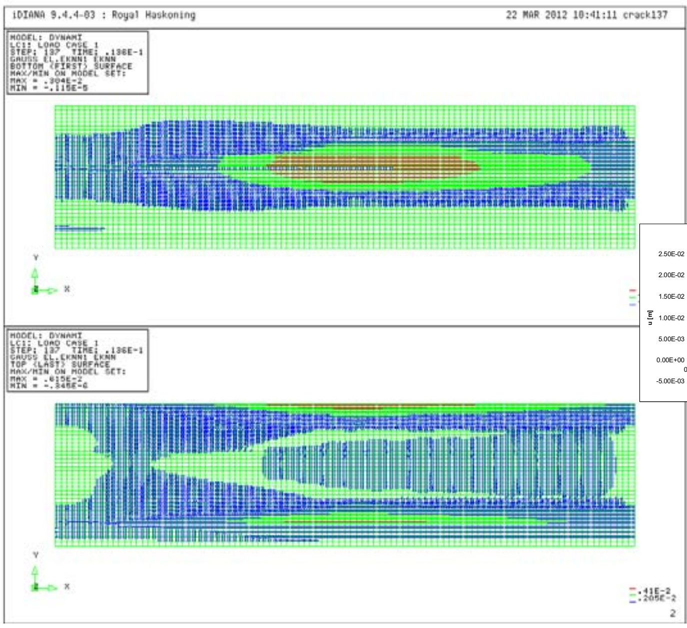

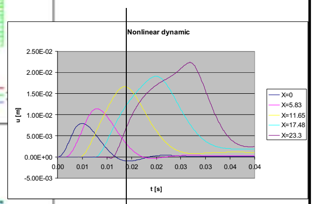

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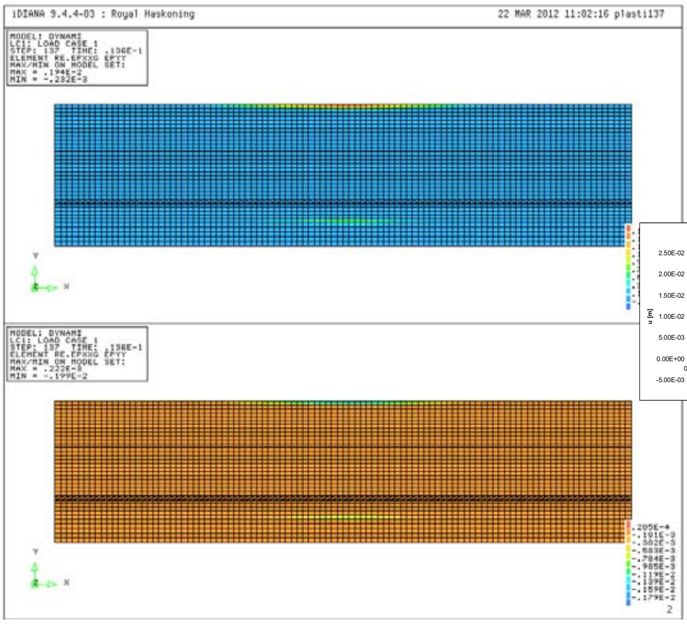

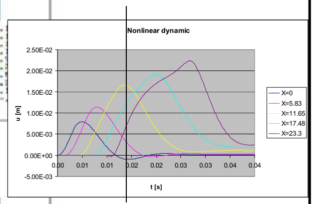

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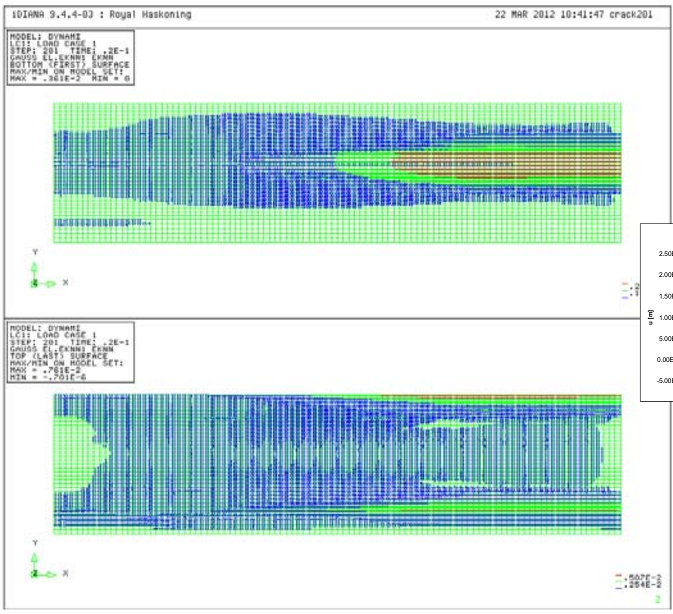

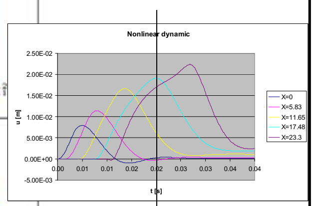

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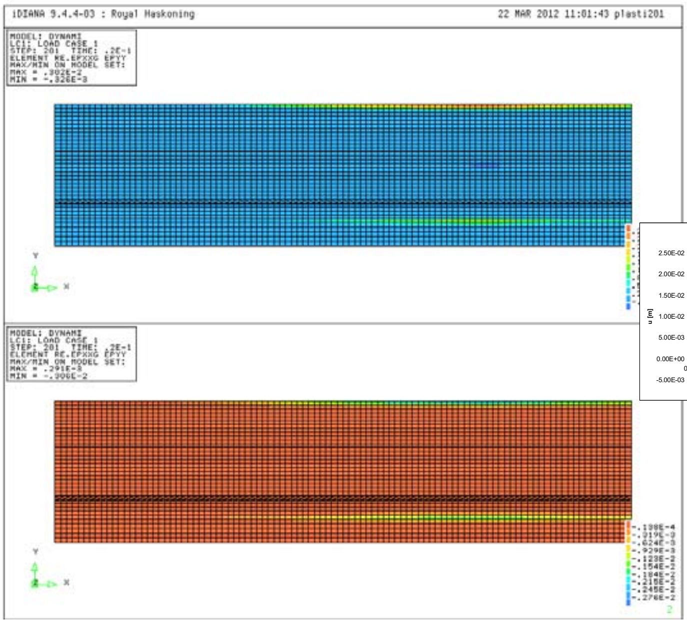

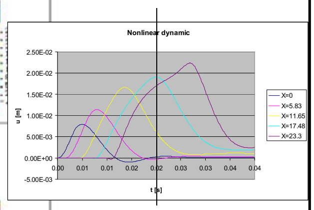

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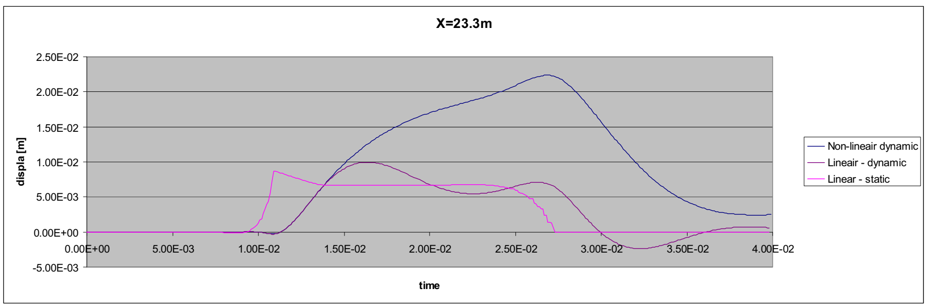
Displacements in time (x=23.3)



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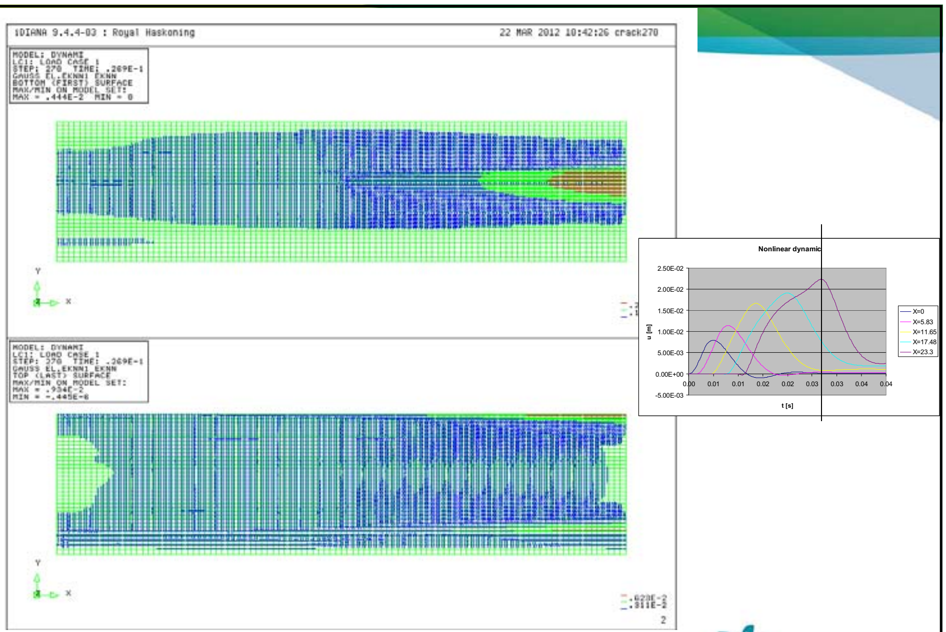

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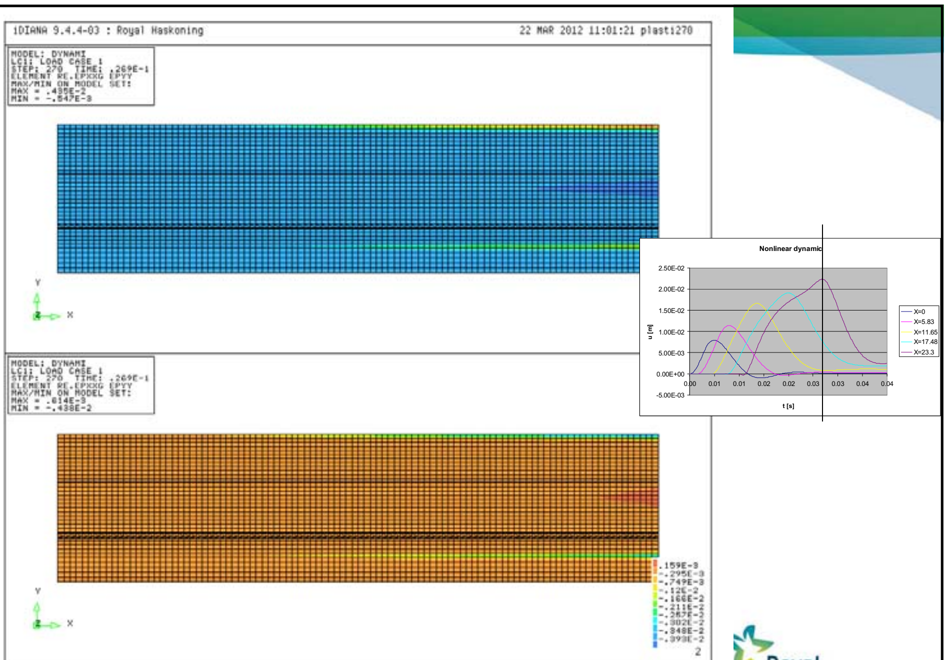

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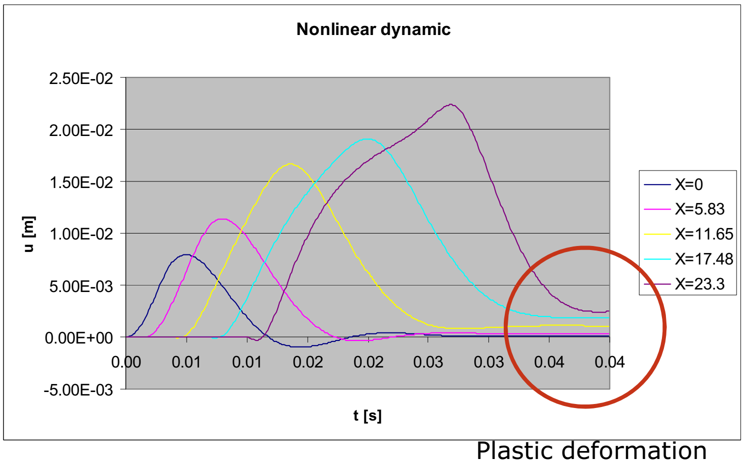
Nonlinear dynamic



Plastic deformation

Conclusions

- Wall can handle the dynamic load
- Only minor plastic deformations
- Substantial damage, but repairable