Påldag 09
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Analyser av en pålsko

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NTNU, Arne Aalberg

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Project description

- In the Norwegian Roads Administration's projects the pile shoes for point-bearing piles are mainly hollow with a steel dowel installed.
- standardization of this type of pile shoes
- reduce procurement cost
- reduce the risk of failures and rejected piles.
- **Participants in this research project:** NTNU, Aas-Jakobsen, Geovita, Ruukki, Statens vegvesen,

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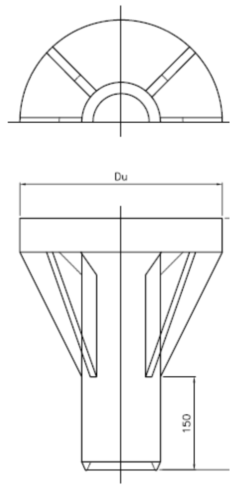
Planned working process

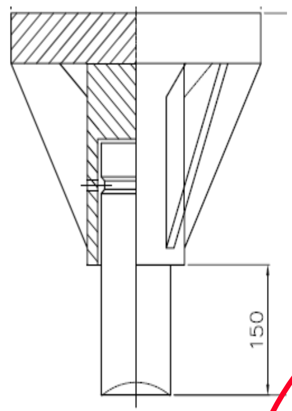
1. Pile shoe dimensions based on experience
2. Static FEM-analysis
3. Dynamic FEM-analysis
4. Laboratory test
5. Full scale test

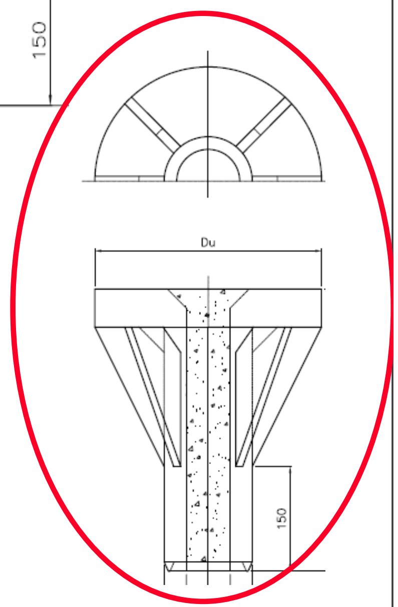
- Step 1 – 2 are performed, and step 3 is in progress.
- After step 1 and 2 we had the following question:
  Why the experience and analysis shows large differences in weld size?
  - Ruukki practical experience:
    Welding ribs to dowel a_{min} = 7 mm
  - Static FEM-analysis result:
    Welding ribs to dowel: a = 15 mm

Three different types of rock shoes

- Rock shoe with structural steel dowel
- Rock shoe with hardened steel dowel
- Rock shoe with structural steel dowel with hole







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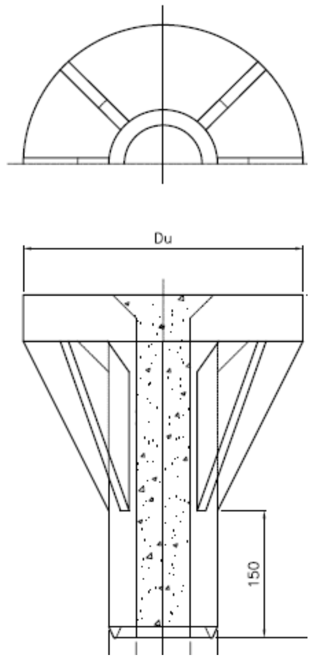
Calculated for the present pile type:

- Pile pipe dimension:
  Ø 813mm t = 14,3 mm
- Hollow dowel
- Pile shoe dimensions based on experience and Static FEM-analysis Ansys:
  - Design load $F_{c;d}$ = 5000 kN
  - Characteristic capacity:
    $R_{c;k} = F_{c;d} \times \gamma_t = 5000 \times 1{,}6 = 8000$ kN
- Dynamic FEM-analysis Abaqus:
  - $R_{c;k}$ = 10 000 kN



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Materials and stress

- Steel grade and quality: S355J2
- Minimum yield strength $f_{s;y}$ (R_{eH}) depends on thickness (t) (ref. NS-EN 10025 / 10210):
- t<16 mm: $f_{s;y}$ = 355 MPa
- 16< t $\leq$ 40 mm : $f_{s;y}$ = 345 MPa
- 40< t $\leq$ 63 mm : $f_{s;y}$ = 335 MPa
- 63< t $\leq$ 80 mm : $f_{s;y}$ = 325 MPa

The permitted stress level during driving is exceeding $f_{s;y}$ with 25 % (Peleveiledningen:1991).

The permitted stress after installation is less than or equal to $f_{s;y}$.

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Dowel area dimensions based on experience

- Norwegian pile handbook (Peleveiledningen:2005) recommends pile shoe dimensions based on experience.
- We roughly calculated necessary steel area to estimate dowel area before FEM-analysis

$$R_{c;k} = 8000\ kN \leq 1{,}25 \cdot N_d$$

$$R_{c;k} \leq A_{spiss} \cdot \frac{f_{s;y}}{\gamma_m} \cdot 1{,}25$$

$$A_{spiss} \geq \frac{1}{1{,}25} \cdot R_{c;k} \cdot \frac{\gamma_m}{f_{s;y}} = \frac{1}{1{,}25} \cdot 8000 \cdot \frac{1{,}1}{335} \cdot 10^3 = \underline{21\,015\ mm^2}$$

- Outer diameter dowel: D = 203 mm
  Inner diameter dowel: d = 113 mm
  Dowel Area: **A_{dowel} = 22 337 mm^2**
- Ruukki's recommendation: $Area_{dowel} = Area_{pipe}$ = 35 617 mm^2

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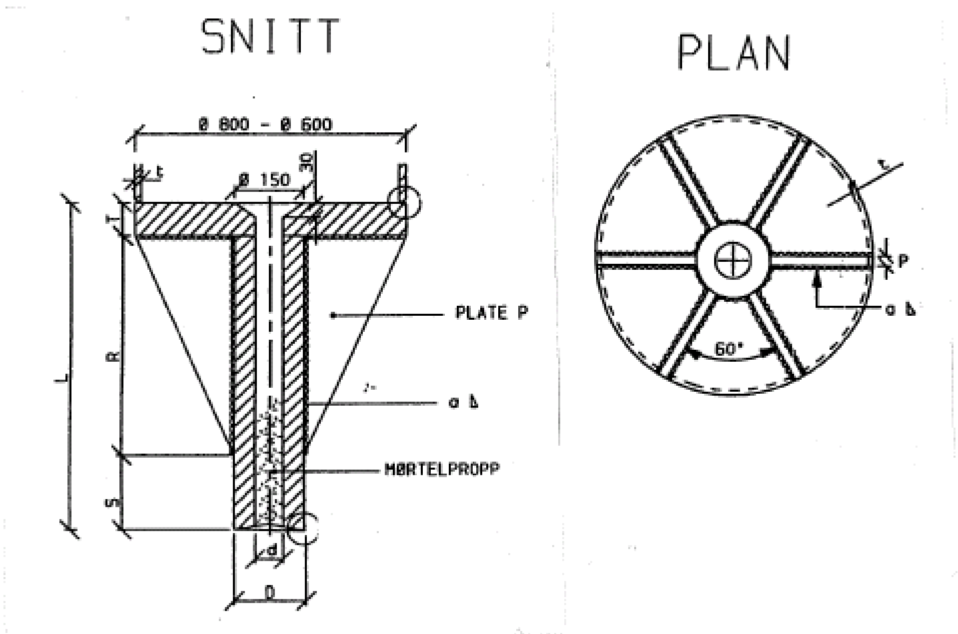
Pile shoe dimensions based on experience



Peleveiledningen2005: Norwegian Piling handbook

Dimension during installation:

Steel pipe:

Ø= 813 mm, t = 14,3 mm

Pile shoe:

Outer diameter:	D= 203 mm
Inner diameter:	d = 113 mm
Thickness bottom plate	T = 80 mm
Height reinforcing rib	R = 600 mm
Length pipe	S = 300 mm
Total length pile shoe	L = 980 mm
Thickness reinforcing rib	P = 30 mm

Dimension after installation:

- corrosion rate 0,025 mm/year per exposed side
- pile life 100 years

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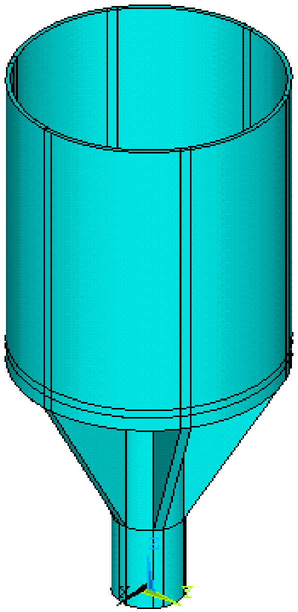
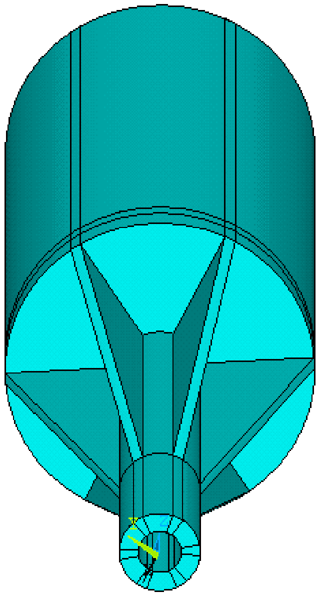
Static FEM-Calculation Geometric model





- FEM-analysis calculated by the program ANSYS
- Element type SOLID92
- Welds are not included in the model
- 1 m steel pipe

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5 different analysis

Analysis	Condition	Load	Analysis type
1	Pile driving Centric point bearing	8000 KN	Elastic
2	Pile driving Eccentric point bearing	8000 kN (exceeds break load)	Elastic
3	Permanent Centric point bearing	5000 KN	Elastic
4	Pile driving Centric point bearing	8000 kN	Elastoplastic
5	Pile driving Eccentric point bearing	4460 kN (2 mm vertical compression)	Elastoplastic

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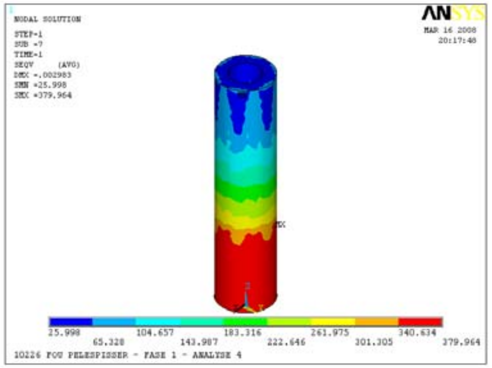
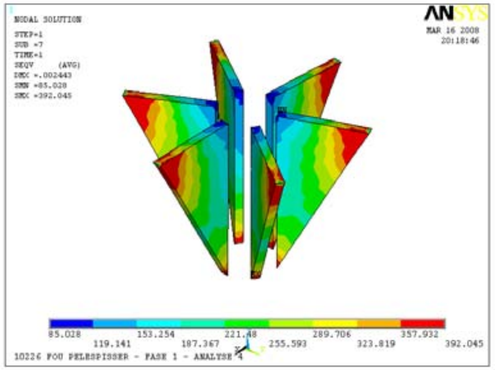
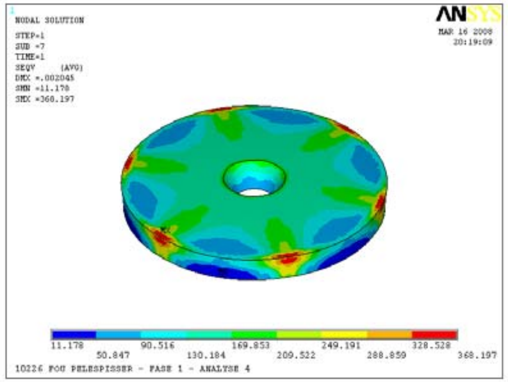
Analysis 4 –driving pile – load 8000 kN elastoplastic analysis


Average stress dowel


Average stress reinforcing ribs


Average stress bottom plate

	Dowel	Reinforcing ribs	Bottom plate
Maximal stress (σ_j)	381MPa	392 MPa	368 MPa
Utilization factor (σ_j/fd)	1,0	1,0	1,0
Maximum equivalent strain	0,285 %	0,338 %	0,308 %

- Vertical deformation 2,98 mm

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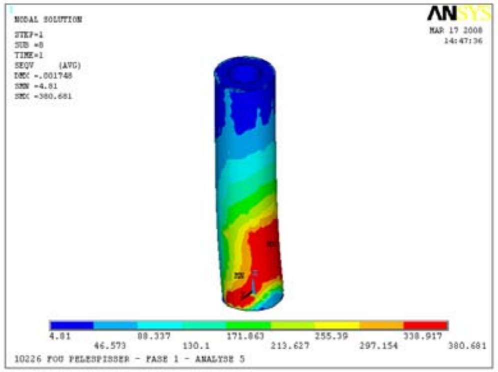
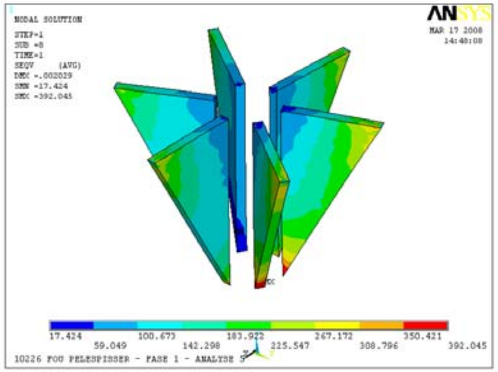
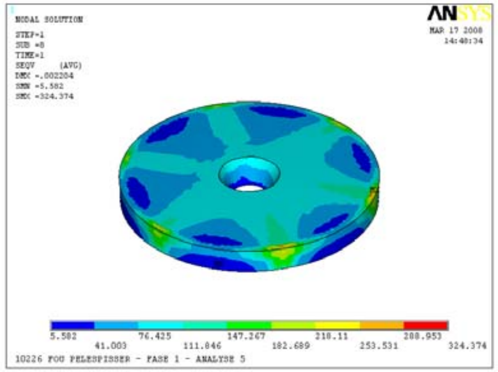
Analysis 5 –driving pile with eccentric load 4460 kN – elastoplastic analysis







	Dowel	Reinforcing ribs	Bottom plate
Maximal stress (σ_j)	381MPa	392 MPa	368 MPa
Utiliziation factor (σ_j/fd)	1,0	1,0	1,0
Maximal equivalent strain	3,13 %	0,366 %	0,163 %

- Load as a vertical displacement in the top of the pile pipe
- Vertical deformation 2,0 mm
- Breaking load = 4460 kN

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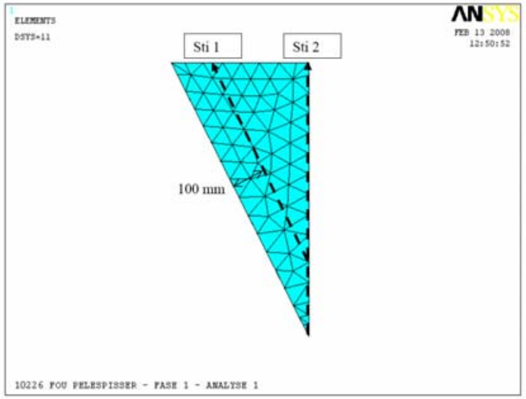
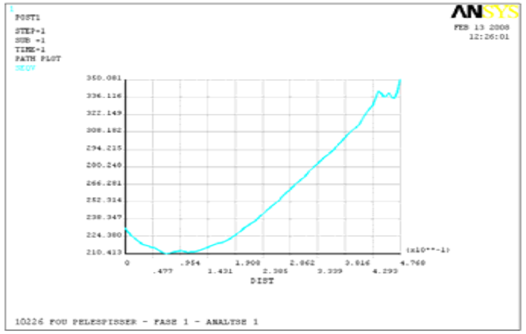
Weld design

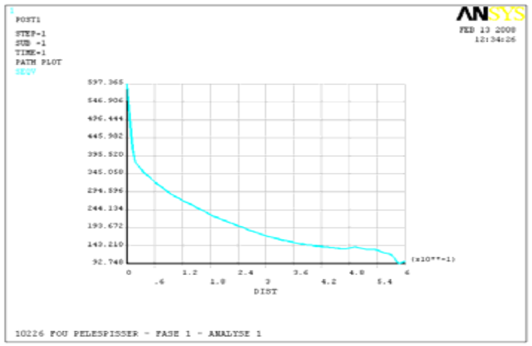
NS3472:2001 pnkt 12.6.2 og 12.6.3



Sti 1



Sti 2



- Average stress in the weld from strain path 2.
- Welding ribs to dowel:
  a = 15 mm
- Welding ribs to bottom plate:
  Butt weld
- Ruukki practical experience:
  Welding ribs to dowel
  a_{min} = 7 mm
- Weld with a = 15 mm costs 6 times more to produce than weld with a = 6 mm
- Why the different results?
  - Different dowel dimension
  - Correct design and calculation connection in ANSYS?

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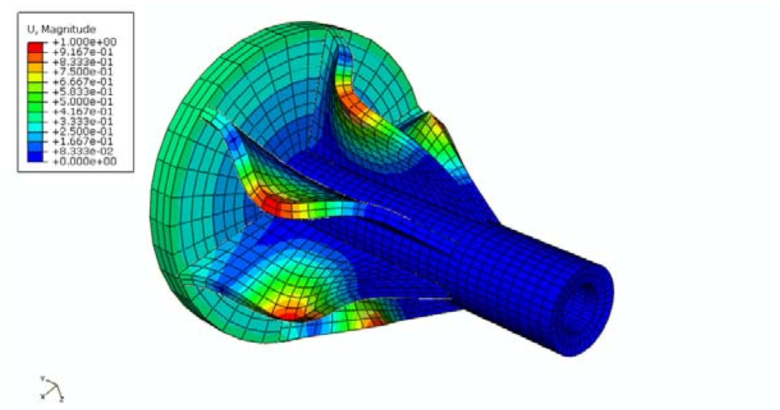
Buckling reinforcing ribs
(NS3472:2001 pnkt 12.3.2.1)



Static analysis

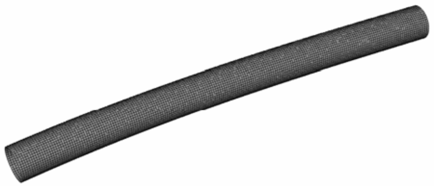
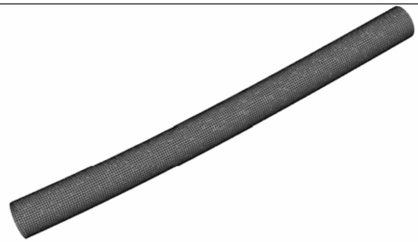
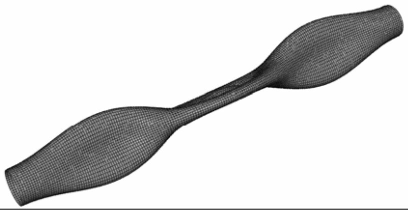
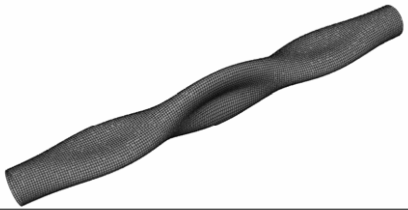
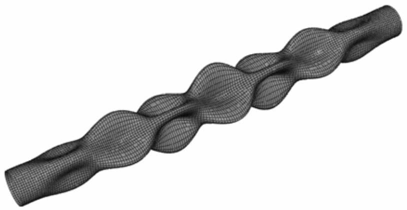
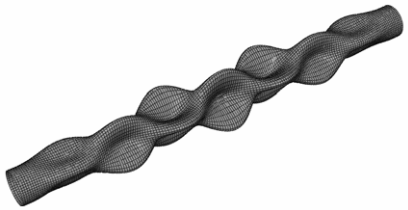
- $F_{buckling}$ = 8000 kN
- Reinforcing rib's thickness
  P = 30 mm
- Buckling stress
  f_{kd} = 280 MPa
- Reinforcing rib's stress
  f_{pl} = 275 MPa
- Utilization factor:
  μ = 0,98

Dynamic analysis

Axial load:

- $F_{buckling}$ = 155 000 kN>> Fy
- Buckling caused by bending load

Dynamic analysis
Buckling of the pile pipe

	
#1 Global knekking – Skalering: 1000	#2 Global knekking – Skalering: 1000
Knekklast: 14.565kN	Knekklast: 14.565kN
	
#3 Lokal knekking – Skalering: 400	#4 Lokal knekking – Skalering: 400
Knekklast: 115.459kN	Knekklast: 115.459kN
	
#9 Lokal knekking – Skalering: 400	#10 Lokal knekking – Skalering: 400
Knekklast: 136.219kN	Knekklast: 136.219kN

- Pile pipe dimensions:
  - Length: 10 m
  - Diameter: 813 mm
  - Thickness: 14,3 mm
- The dynamic analysis result in some samples of buckling forms on the pile pipe before the detail analysis of the pile shoe.

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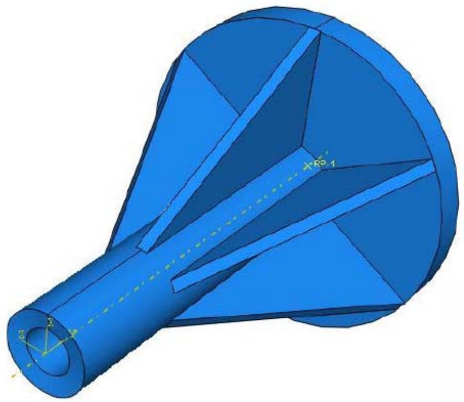
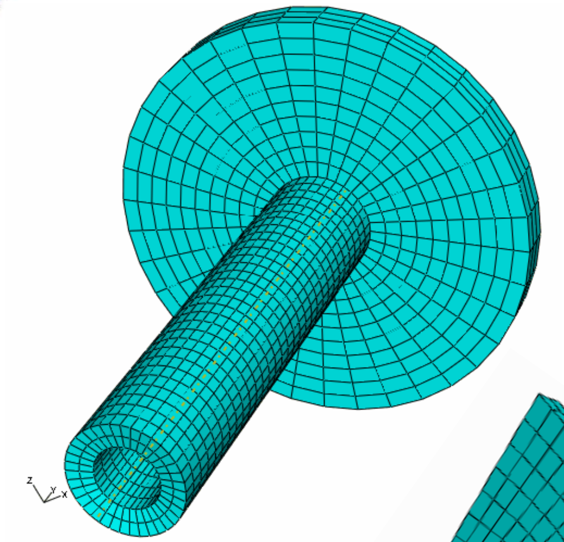
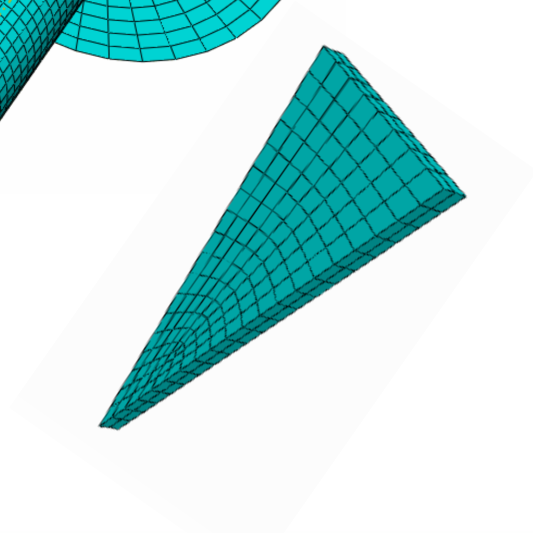
Dynamic FEM-Calculation Geometric model of detail analysis pile shoe







- NTNU, currently working on a master thesis.
- FEM-analysis calculated by the program Abaqus
- 8 nodes brick element C3D8R with
- 10 m steel pipe
- Behavior of a steel pipe and detail analysis of pile shoe

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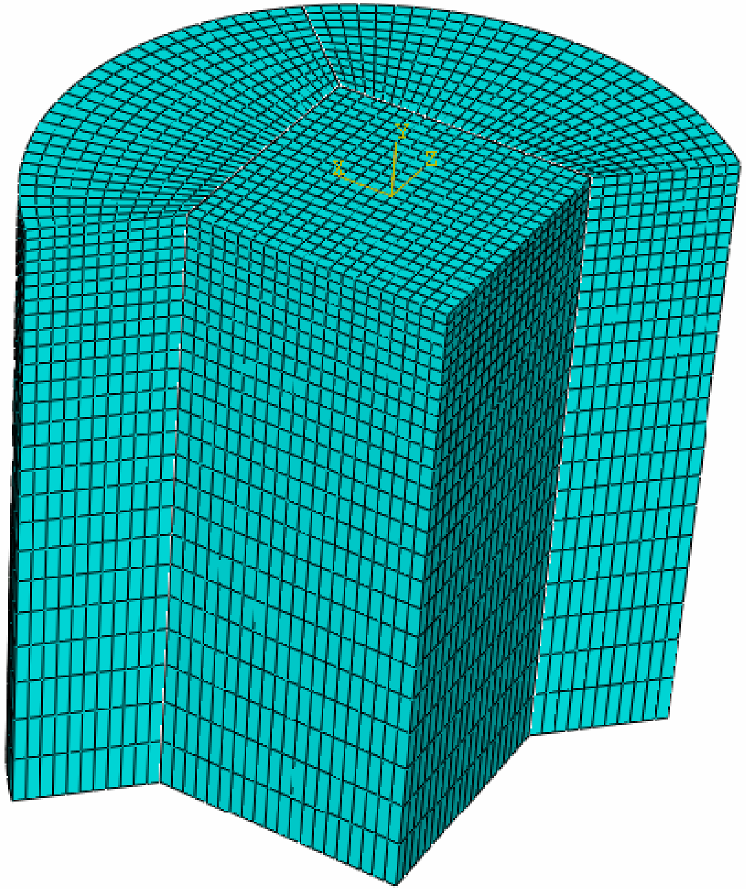
Dynamic FEM-Calculation – Geometric model of the rock



- Rock mass is modeled as a elastic-plastic material in Abaqus
- 1 m high and 1m diameter rock model
- Small-meshed elements close to the rock surface: 20 x 20 mm.

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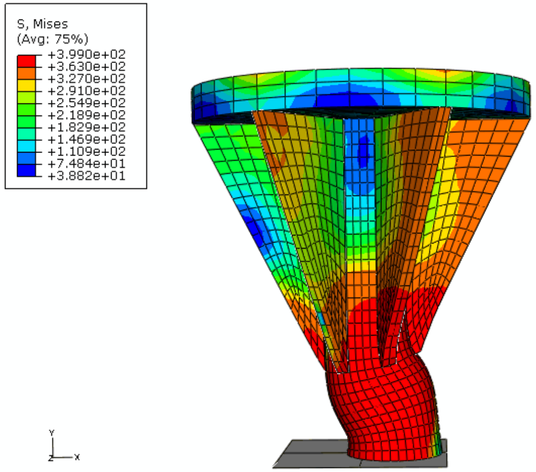
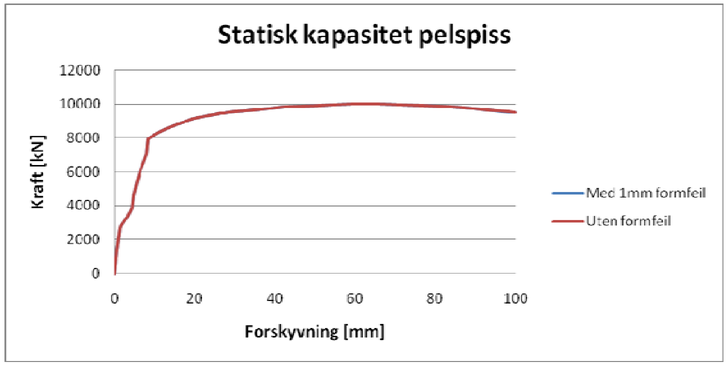
Dynamic FEM-Calculation
Preliminary results of the analysis

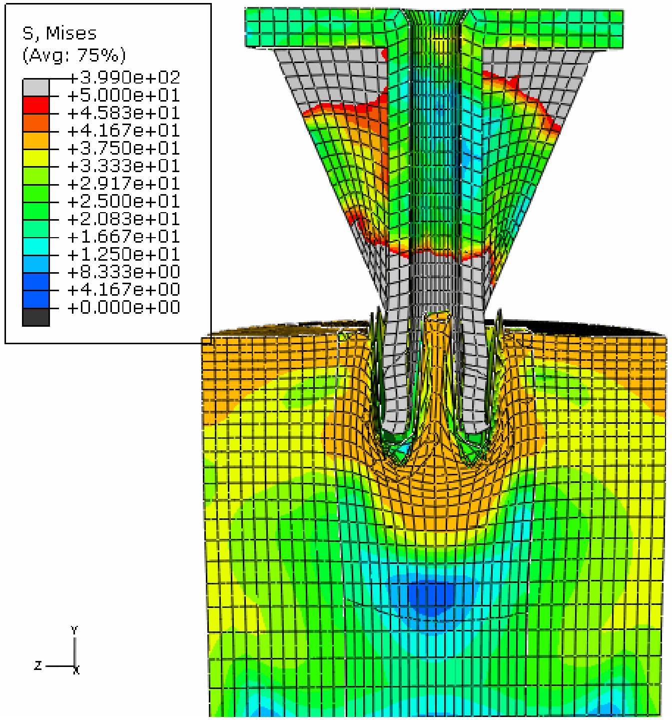




- Deformation of pile shoe
- Static load abaqus: $R_{c;k}$ = 10 000 kN
- Tensile stress increase with strain rate

Dynamic FEM-Calculation

Preliminary results of the analysis in colour plot



Further work:

- Effects of different rock qualities
- Effects of drilling hole before penetration
- Evaluate load of steel parts

Thanks to NTNU, Arne Aalberg and Andreas Kildal Forseth for the use of preliminary results.

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