Geosynthetics for soil reinforcement

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Content

- Background
- Principles and design
- Design
- Applications

Purpose:

To give a brief introduction to the topic, some ideas for possible uses of geosynthetics and some motivation for the rest of the seminar

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History-materials

- Historically a looooooong tradition for utilizing the beneficial effects of “geosynthetics”

- Natural materials for reinforcement, swampy areas

  -weed

  -bamboo

  -tree trunks, bushes

  -cotton textiles

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Zigurat - Ur - Babylon (Iraq)
1500 BC Height 60 m

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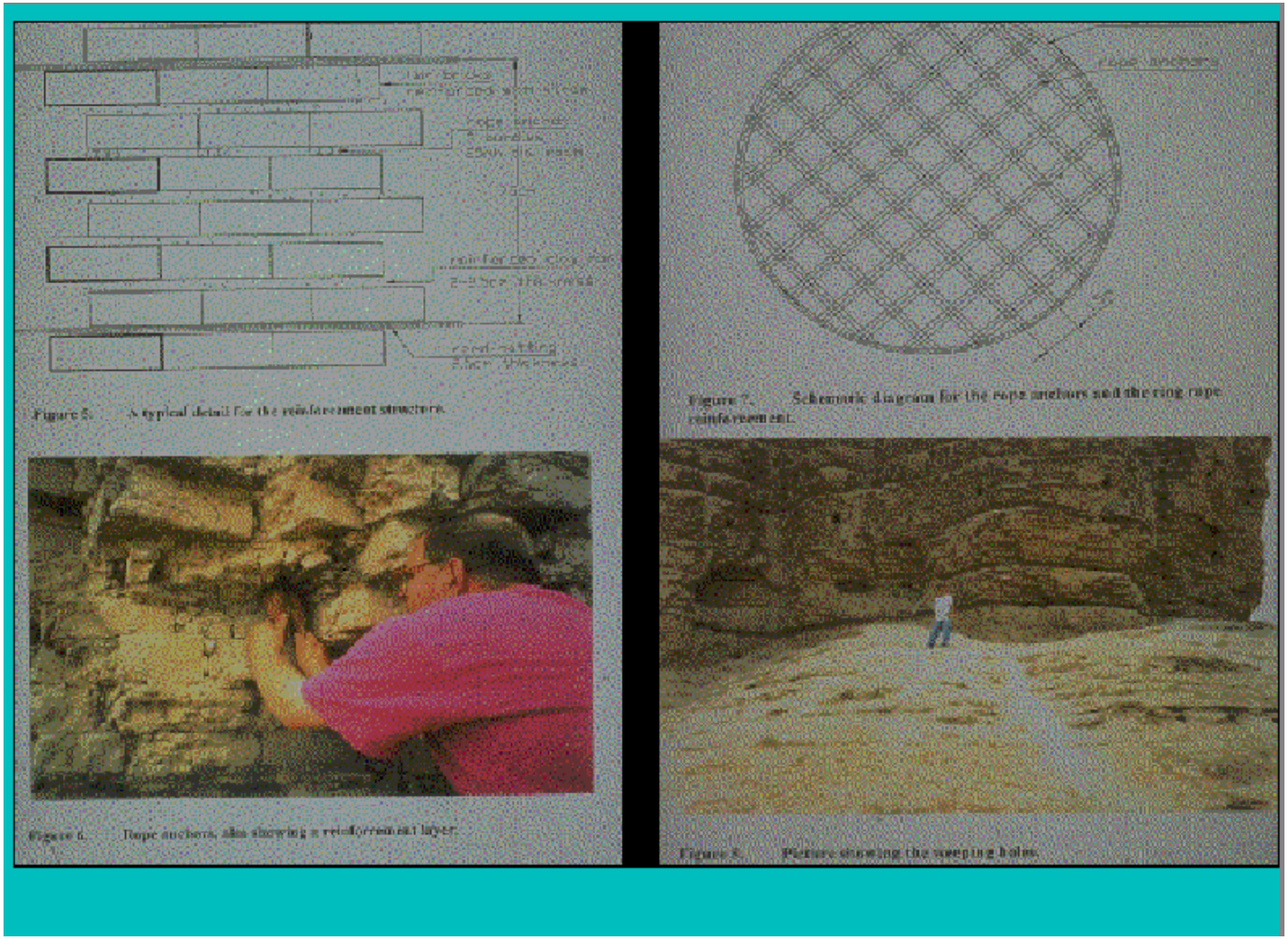
Straw reinforcement, cross laid, incrasing spacing with height!



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History - road applications

- Roads on peat bugs with timbers lashed together
  -UK 3000 B.C

- Roads on soft clay with bush vegetation
  -Vikings in the Nordic countries, 800 A.C

- Roads on heavy cotton fabric
  -South Carolina Highway dept, (1926, report from 1935!)
  -access road for Bidim, producer of curtains (1936)

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Installation on soft subsoil - Caen

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Functions

- Reinforcement
- Separation
- Filtration
- Drainage
- Barrier
- Protection

- Erosion control (coast and waterways)
- Slope erosion control
- Geotubes

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Applications - reinforcement

- Geotechnical applications
  -Retaining structures
  -Steep slopes
  -Embankments on soft subsoil
  -Embankments with support (piles)

- Road reinforcement
  -In granular layers (deformations/bearing capacity)
  -Asphalt (cracking reduction)

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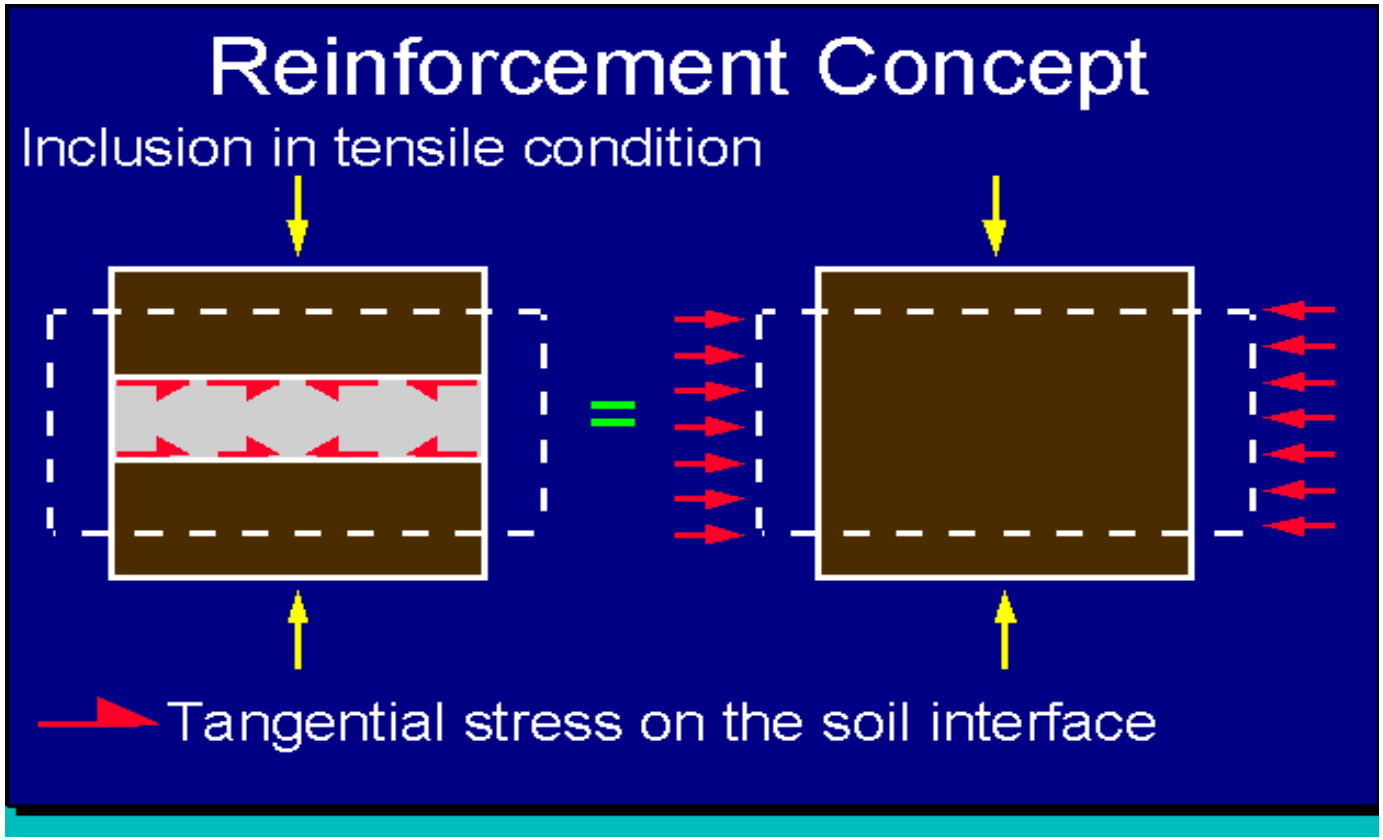
Reinforced soil-principle



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Reinforcement properties

- Tensile strength
- Tensile strain at failure
- Stress-strain properties with time
- Interaction properties with surrounding soil
- Durability

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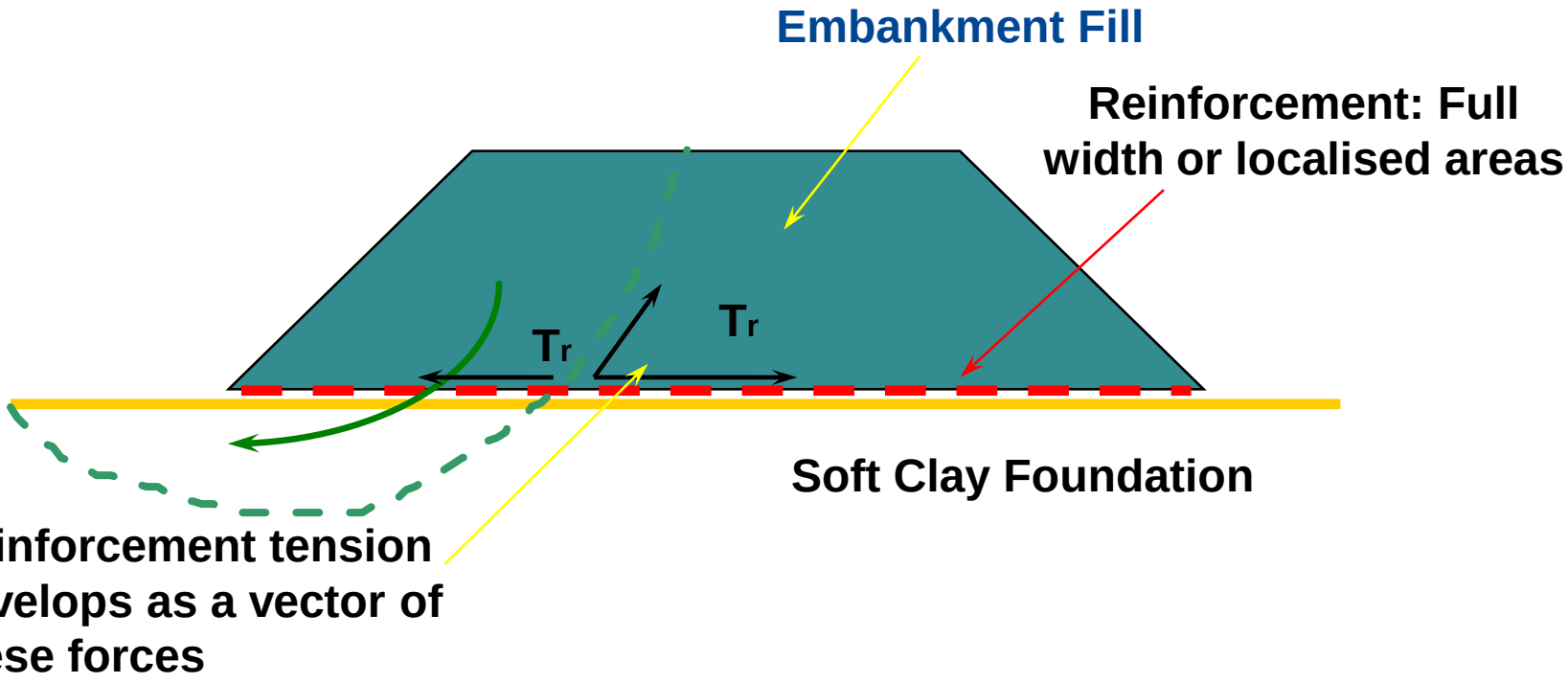
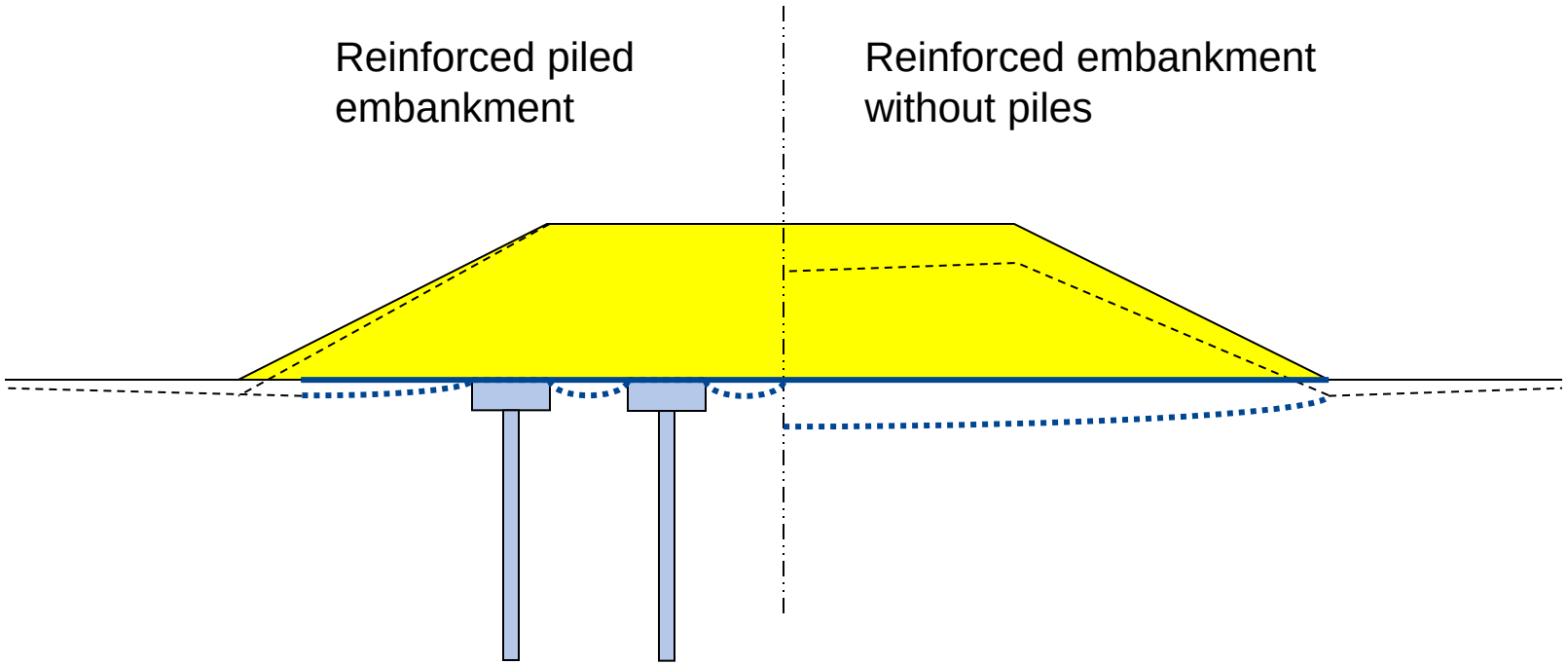
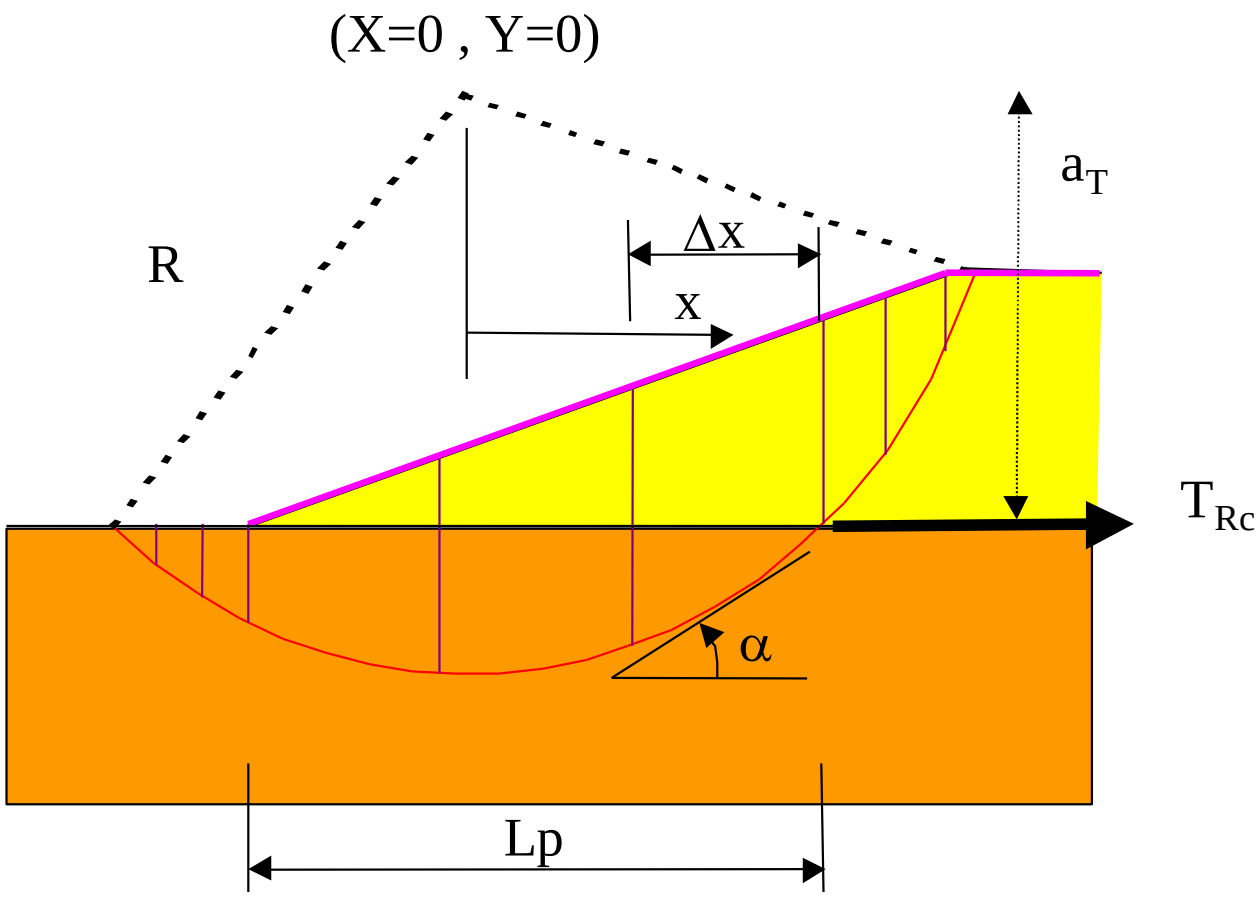
Reinforced embankments



Embankment on soft foundation



Rotational stability



Soft can be very soft!!

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Geotextile + bark

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Bearing capacity ok, Settlements?

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Geotextile sand columns- Botniabanan

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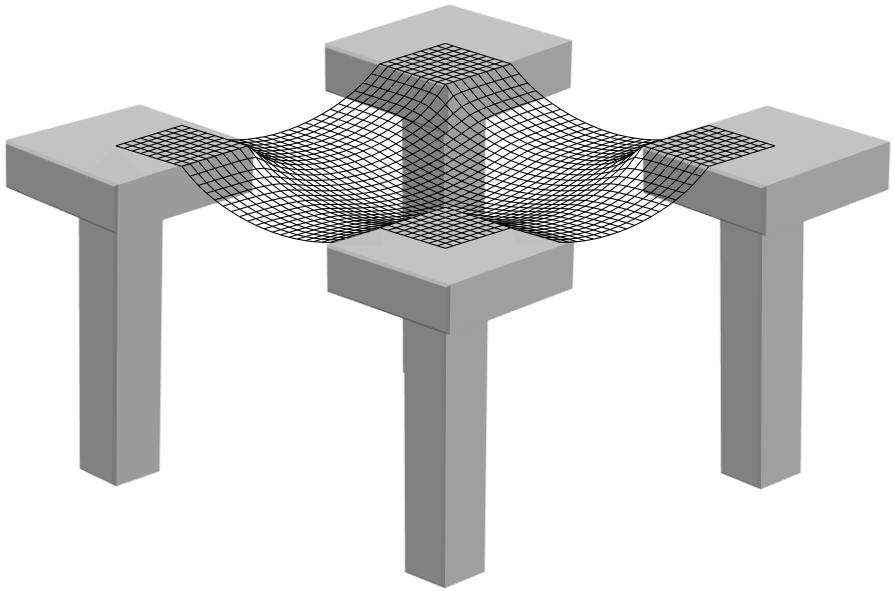
Alternative calculation principle for design of piled embankments with base reinforcement



SINTEF

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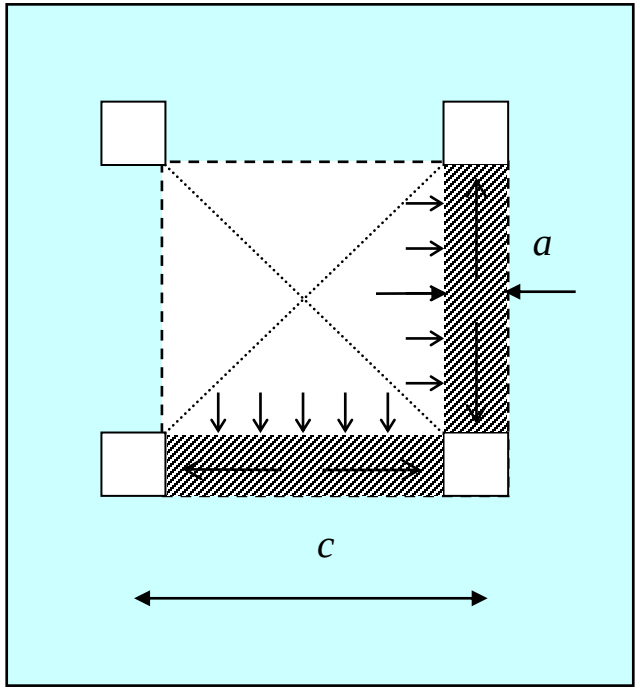
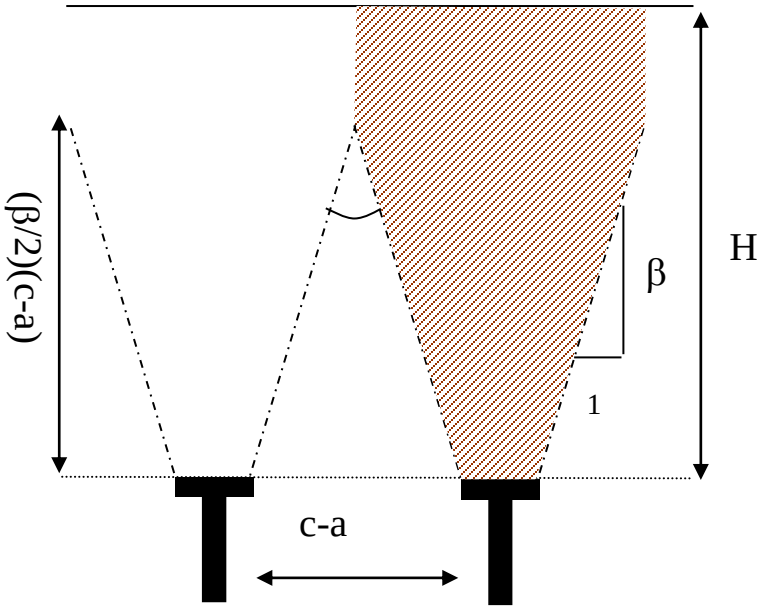
Basic design assumptions

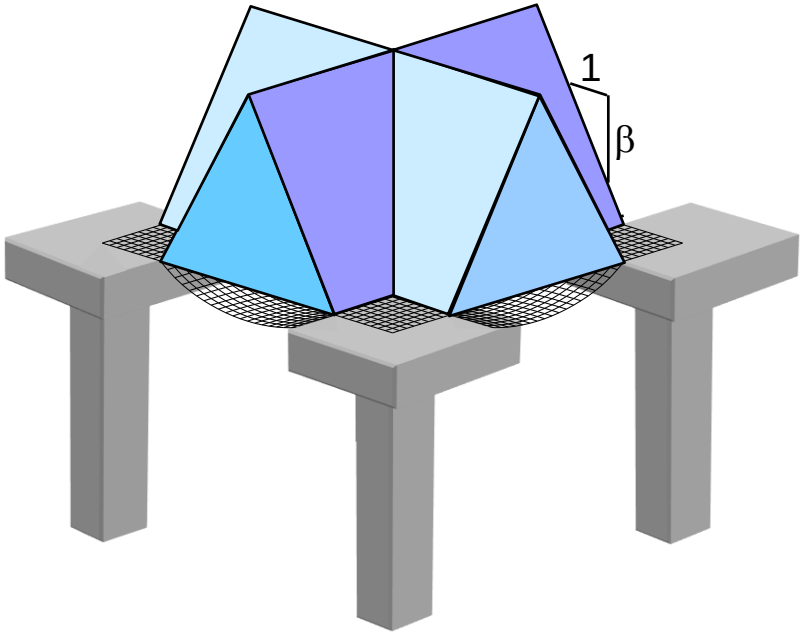
- Part of the fill weight is carried by the pile caps
- The remaining load is carried by the reinforcement
- No load on the soil below
- Two load carrying directions
- The load on the reinforcement carried by bands between the piles



Method proposed by SINTEF

- The weight of the hatched volume is carried by the pile cap
- The remaining fill material is carried by the reinforcement
- The slope β : 1 needs calibration





Conclusions

- The SINTEF method gives plausible tension in the reinforcement for a wide range of fill height and a/c - ratios
- The FEM calibration suggests β ranging from 3.4 to 4.7
- Further calibration including staged construction is required

Armering for vegbygging på bløt grunn

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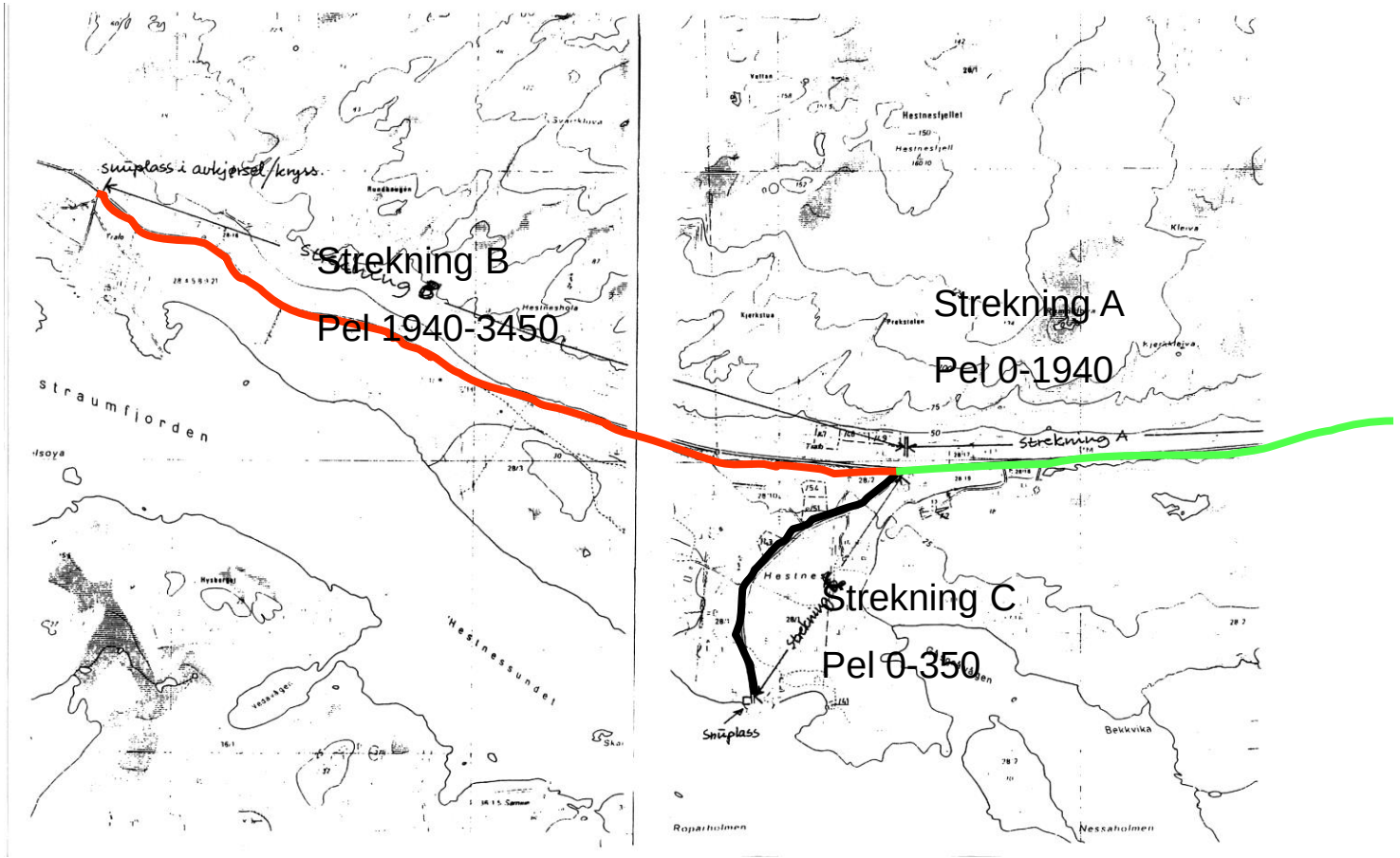
Bæreevne i teleløsning

Hestnes, Hitra



REHABILITERING AV FYLKESVEG, HITRA

Veilengde: 3900 m

Undergrunn: Myr
Finstoffholdig overbygning
Lav bæreevne: 50-60 kN

Kraftig spordannelse i teleløsning

Målsettinger

- Øke bæreevnen til 100 kN (10 tonn)
- Redusere spordannelse
- Asfalt dekke-krever begrensede deformasjoner
- Opphevelse av telerestriksjoner

Prosjektert løsning-
Hitra kommune + VV Sør Trøndelag

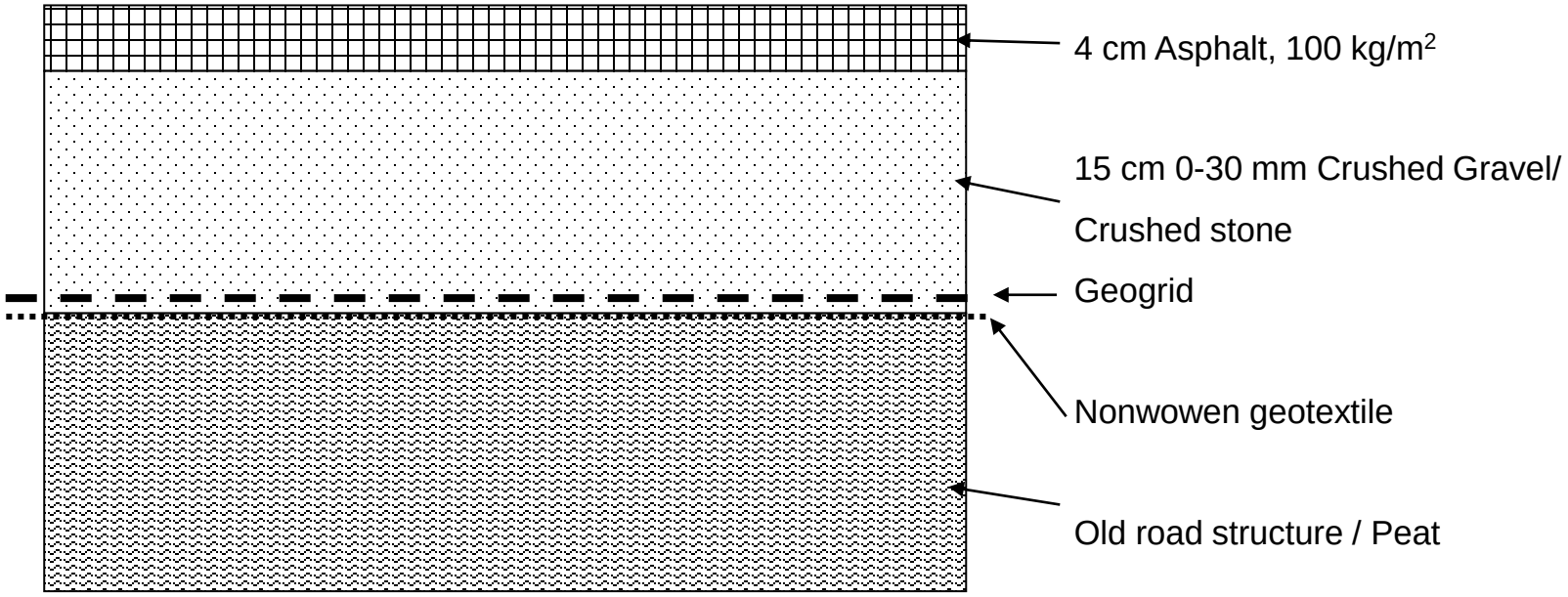
- Oppbygging tilpasset innledende undersøkelser
- Ulike løsninger mht:

  -separasjonsduk

  -armeringsnett (2 ekstruderte, 1 vevd)

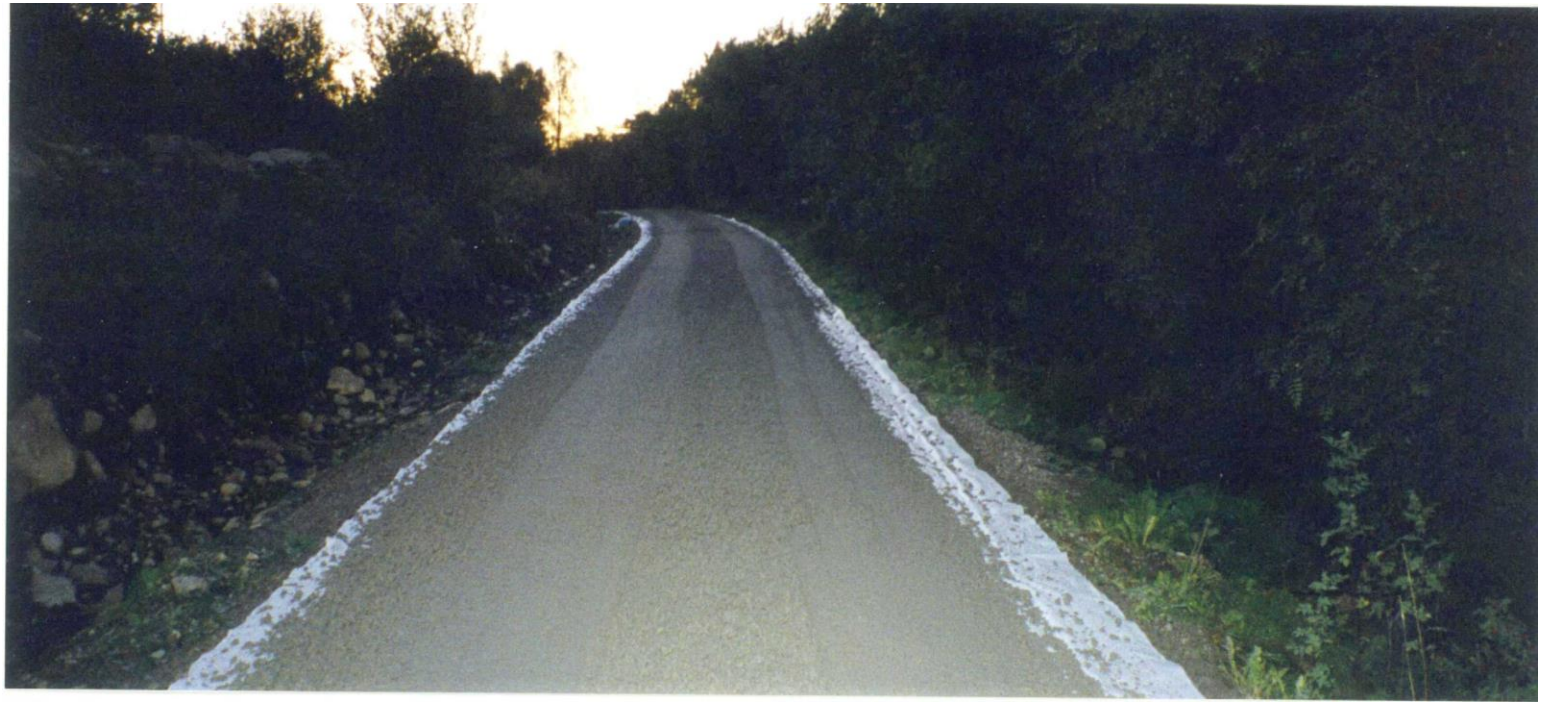
  -bærelag varierende tykkelse(grus og pukk)

  -asfalttype
- Løsning med armering benyttet på områder med dårligst initiell bæreevne


4 cm Asphalt, 100 kg/m2
15 cm 0-30 mm Crushed Gravel/
Crushed stone
Geogrid
Nonwowen geotextile
Old road structure / Peat

Utlegging av separasjonsduk og armeringsnett

Utlagt veggrus



Etterundersøkelser-SINTEF

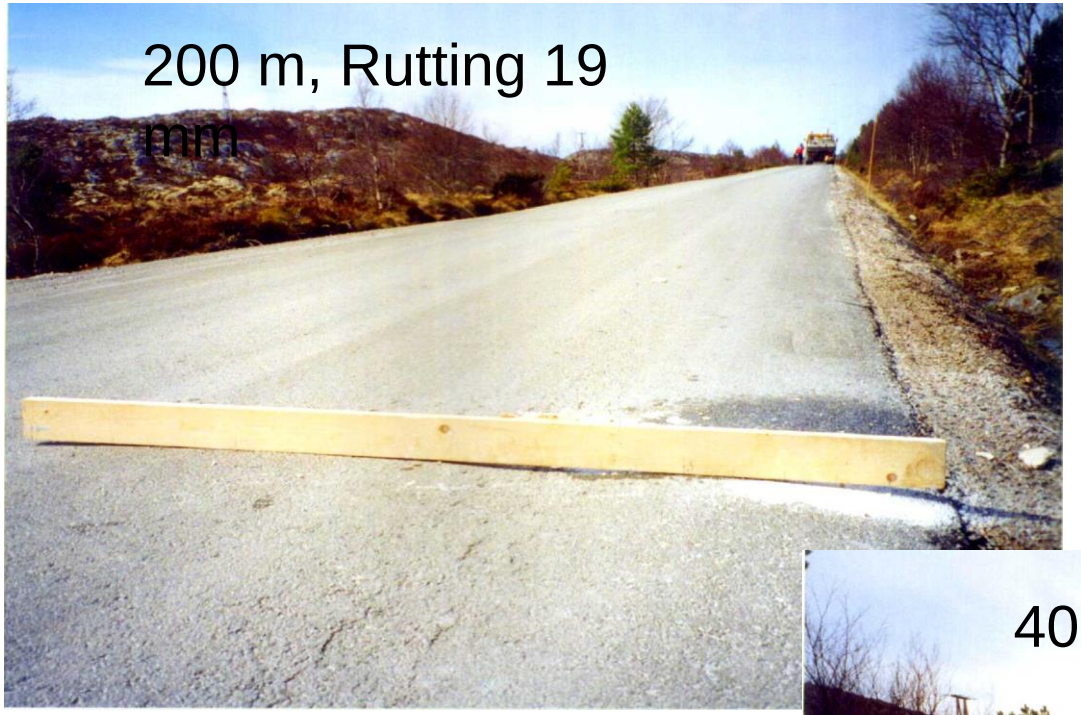
- Vurdere oppnåelse av målsetting
- Vurdere ulike evalueringsmetoder
- Vurdere resultat av ulike løsninger

Undersøkelser

- Forhåndsundersøkelser (VV-Sør-Trøndelag)
  -falloddsmålinger, vår 96

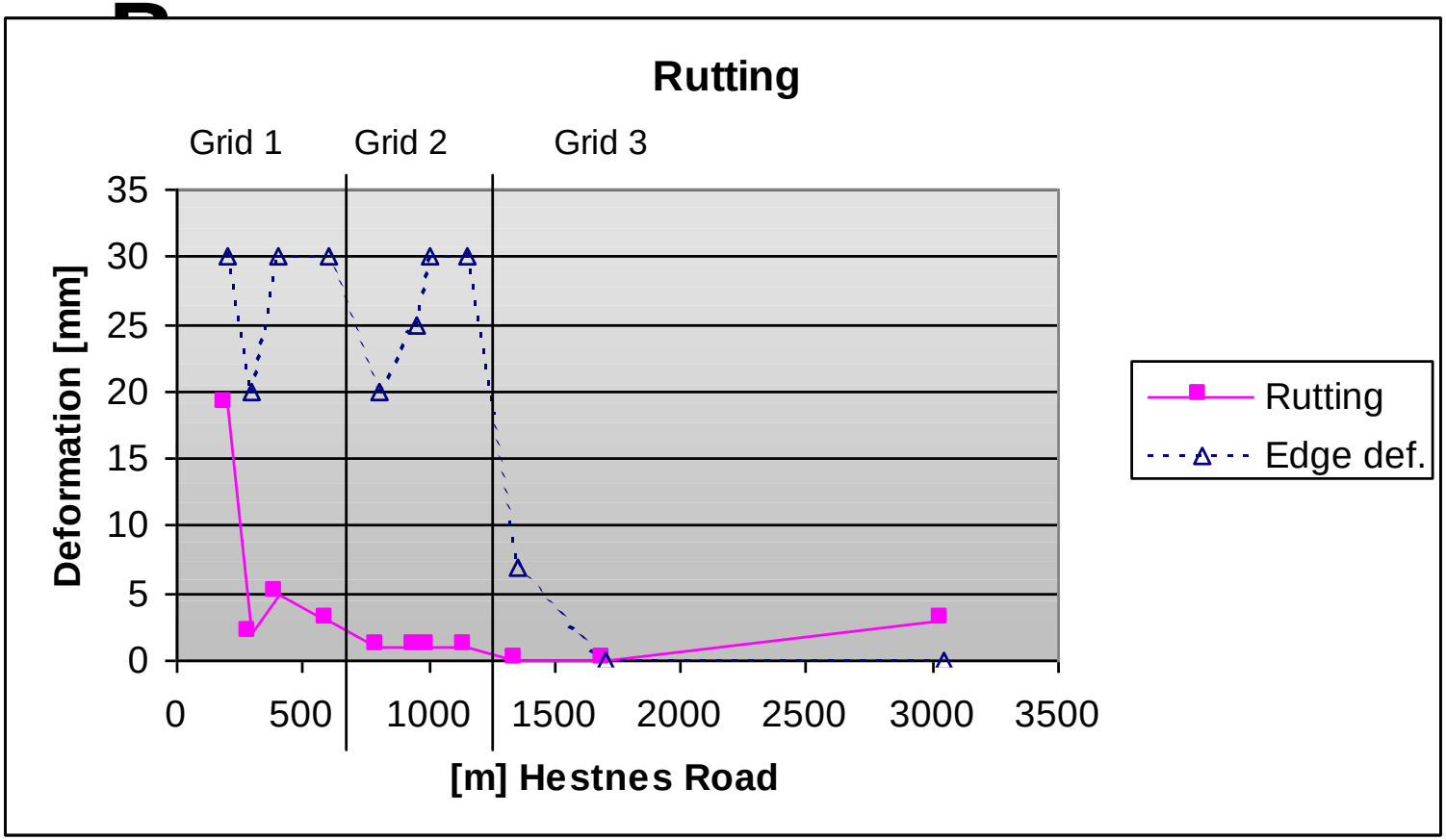
- Etterundersøkelser
  -falloddsundersøkelser, vår 99/vår2000
  -platebelastning, vår 99/vår 2000
  -spormålinger, vår 2000

Plate Load Test



GRID 1

Spordannelse-seksjon A og



Rehabiliteringskostnader NB 1999

Kostnader pr meter veg: (bredde 3.7m)

- Separasjonsduk: 30 kr/m (4%)
- Armeringsnett: 125 kr/m (16%)
- Bærelag (0-30): 110 kr/m (15%)
- Veggrus: 60 kr/m (8%)
- Transport: 75 kr/m (10%)
- Avretting/komprimering: 60 kr/m (8%)
- Asfalt dekke: 300 kr/m (40%)
- Totalt: 760 kr/m

Konklusjoner

- Armering med nett ved plastiske deformasjoner
- Kantdeformasjoner er kritisk
- Effekt av armeringsnett øker med økende deformasjoner
- Falloddsmålinger usikkert grunnlag for vurdering av effekt av armering
- Platebelastningsforsøk kan gi indikasjon på effekt
- Langtids spordannelse gir best grunnlag for vurdering
- Ingen av løsningene har oppnådd målsetting om bærevne (basert på fallodd)!
- Alle løsningene ser ut til å gi god funksjon (spordannelse)!
- Undersøkelsen kan ikke påvise forskjeller mellom funksjon av ulike oppbygginger pga varisjoner i grunnforhold, ulik oppbygging og ulik trafikk

Access road Lofast


CAT
320C L

Lofast access road – in use

Access road and new road

Lofast access road-excavation

Construction phase related to service lifetime

Installation is critical related to mechanical impact

Geotextiles may have severe damage during installation and consequently is not able to fulfill the function in the structure

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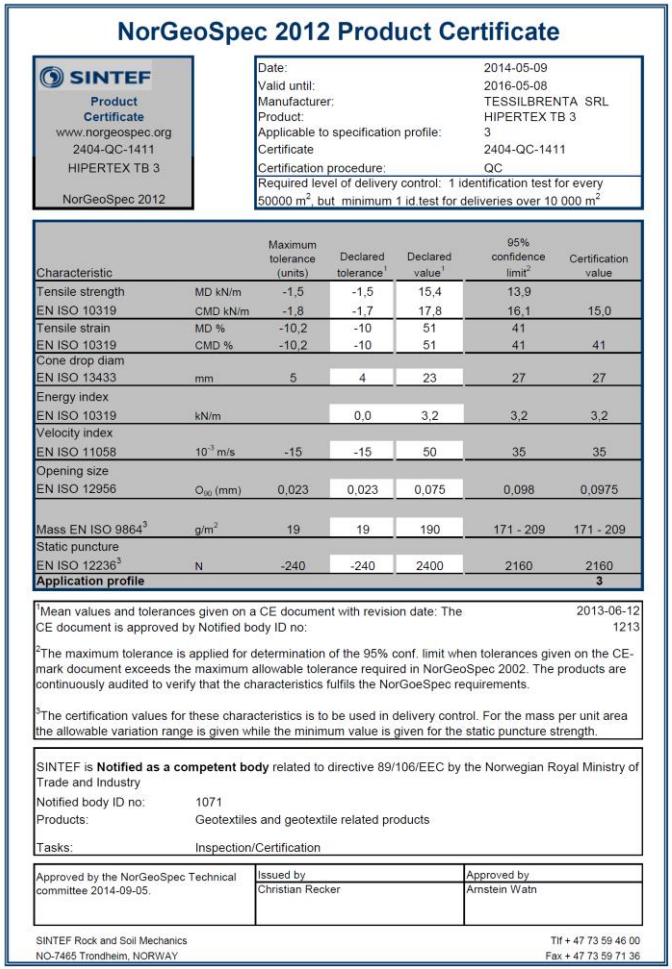
NorGeoSpec – Separation

- Main properties: Mechanical strength, permeability, pore size
- System for certification and specification: NorGeoSpec
- Gives specification for a set of characteristic parameters for 5 different related to intended use



NorGeoSpec 2012 Product Certificate

SINTEF
Product Certificate
www.norgeospec.org
2404-QC-1411
HIPERTEX TB 3
NorGeoSpec 2012

Date:	2014-05-09
Valid until:	2016-05-08
Manufacturer:	TESSILBRENTA SRL
Product:	HIPERTEX TB 3
Applicable to specification profile:	3
Certificate	2404-QC-1411
Certification procedure:	QC
Required level of delivery control: 1 identification test for every 50000 m^2, but minimum 1 id.test for deliveries over 10 000 m^2	

Characteristic		Maximum tolerance (units)	Declared tolerance[1]	Declared value[1]	95% confidence limit[2]	Certification value
Tensile strength	MD kN/m	-1,5	-1,5	15,4	13,9	
EN ISO 10319	CMD kN/m	-1,8	-1,7	17,8	16,1	15,0
Tensile strain	MD %	-10,2	-10	51	41	
EN ISO 10319	CMD %	-10,2	-10	51	41	41
Cone drop diam						
EN ISO 13433	mm	5	4	23	27	27
Energy index						
EN ISO 10319	kN/m		0,0	3,2	3,2	3,2
Velocity index						
EN ISO 11058	10^{-3} m/s	-15	-15	50	35	35
Opening size						
EN ISO 12956	O_{90} (mm)	0,023	0,023	0,075	0,098	0,0975
Mass EN ISO 9864[3]	g/m^2	19	19	190	171 - 209	171 - 209
Static puncture						
EN ISO 12236[3]	N	-240	-240	2400	2160	2160
Application profile						**3**

[1]Mean values and tolerances given on a CE document with revision date: The 2013-06-12
CE document is approved by Notified body ID no: 1213

[2]The maximum tolerance is applied for determination of the 95% conf. limit when tolerances given on the CE-mark document exceeds the maximum allowable tolerance required in NorGeoSpec 2002. The products are continuously audited to verify that the characteristics fulfils the NorGoeSpec requirements.

[3]The certification values for these characteristics is to be used in delivery control. For the mass per unit area the allowable variation range is given while the minimum value is given for the static puncture strength.

SINTEF is **Notified as a competent body** related to directive 89/106/EEC by the Norwegian Royal Ministry of Trade and Industry

Notified body ID no:	1071
Products:	Geotextiles and geotextile related products
Tasks:	Inspection/Certification

Approved by the NorGeoSpec Technical committee 2014-09-05.	Issued by	Approved by
	Christian Recker	Amstein Watn

SINTEF Rock and Soil Mechanics
NO-7465 Trondheim, NORWAY

Tlf + 47 73 59 46 00
Fax + 47 73 59 71 36

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NorGeoSpec - Reinforcement

NorGeoSpec
2012 Product Certificate

Quality Product Certification
Reinforcement

This product has been found to be fit for use in accordance with NorGeoSpec 2012 System for the above given function.

Certificate no.:	NGS-50262
Date:	08.05.2021
Valid until:	09.05.2023
Manufacturer:	Huesker Synthetic GmbH
Product:	FORTRAC ® 35T
Product Type:	GGR
Raw material:	PET
Function:	Reinforcement

Issued by

Christian Recker, SINTEF project manager

Approved by

Arnstein Watn, Head of the Technical committee

The products are regularly audited and tested to verify that the characteristics fulfil the NorGeoSpec 2012 Rev: 01/14.12.2016 requirements.
Approved by the NorGeoSpec Technical committee: 01.12.2021

NorGeoSpec Certification body: SINTEF Building and Infrastructure - Forskningsveien 3B - 0373 Oslo
SINTEF is appointed Notified Body by the Norwegian Building Authority, related to Regulation (EU) No. 305/2011 – Construction Products.
Notified Body No. 1071.

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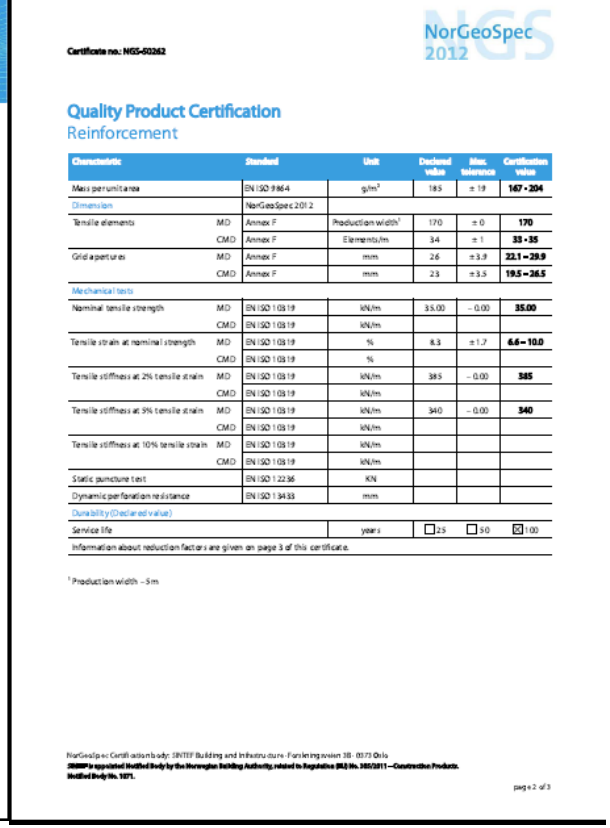

Certificate no.: NGS-50262

NorGeoSpec 2012

Quality Product Certification
Reinforcement

Characteristic		Standard	Unit	Declared value	Max. tolerance	Certification value
Mass per unit area		EN ISO 9864	g/m²	185	± 19	**167 - 204**
Dimension		NorGeoSpec 2012				
Tensile elements	MD	Annex F	Production width[1]	170	± 0	**170**
	CMD	Annex F	Elements/m	34	± 1	**33 - 35**
Grid apertures	MD	Annex F	mm	26	± 3.9	**22.1 – 29.9**
	CMD	Annex F	mm	23	± 3.5	**19.5 – 26.5**
Mechanical tests						
Nominal tensile strength	MD	EN ISO 10319	kN/m	35.00	- 0.00	**35.00**
	CMD	EN ISO 10319	kN/m			
Tensile strain at nominal strength	MD	EN ISO 10319	%	8.3	± 1.7	**6.6 – 10.0**
	CMD	EN ISO 10319	%			
Tensile stiffness at 2% tensile strain	MD	EN ISO 10319	kN/m	385	- 0.00	**385**
	CMD	EN ISO 10319	kN/m			
Tensile stiffness at 5% tensile strain	MD	EN ISO 10319	kN/m	340	- 0.00	**340**
	CMD	EN ISO 10319	kN/m			
Tensile stiffness at 10% tensile strain	MD	EN ISO 10319	kN/m			
	CMD	EN ISO 10319	kN/m			
Static puncture test		EN ISO 12236	KN			
Dynamic perforation resistance		EN ISO 13433	mm			
Durability (Declared value)						
Service life			years	☐ 25	☐ 50	☒ 100

Information about reduction factors are given on page 3 of this certificate.

[1] Production width – Sim

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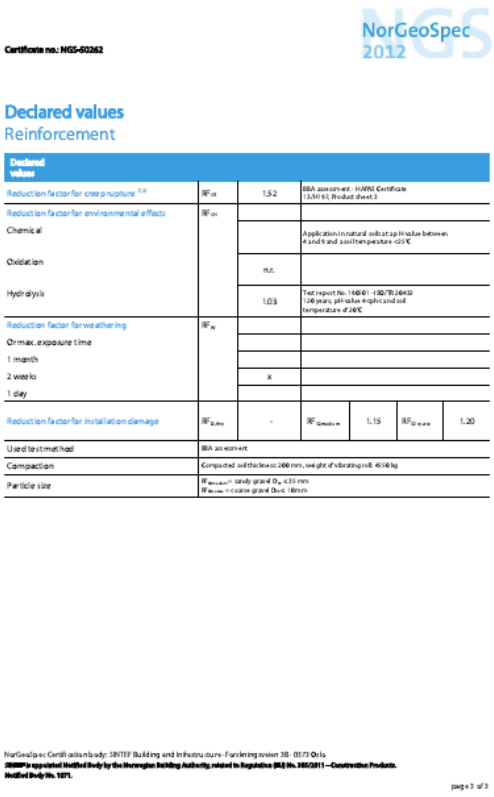

Certificate no.: NGS-50262

NorGeoSpec 2012

Declared values
Reinforcement

Declared values						
Reduction factor for creep rupture [1,2]	RF_{CR}	1.52	BBA assessment - HAPAS Certificate 13/H190, Product sheet 3			
Reduction factor for environmental effects	RF_{CH}					
Chemical			Application in natural soils at ph-Value between 4 and 9 and soil temperature <25°C			
Oxidation		n.r.				
Hydrolysis		1.03	Test report No. 146101 - ISO/TR 20432 120 years, ph-value 4 ph/9 and soil temperature of 20°C			
Reduction factor for weathering	RF_W					
Or max. exposure time						
1 month						
2 weeks		x				
1 day						
Reduction factor for installation damage	$RF_{ID,Min}$	-	$RF_{Gmedium}$	1.15	$RF_{Gcoarse}$	1.20
Used test method	BBA assessment					
Compaction	Compacted soil thickness: 200 mm, weight of vibrating roll: 4500 kg					
Particle size	$RF_{Gmedium}$: sandy gravel D_{max} ≤ 35 mm $RF_{Gcoarse}$: coarse gravel D_{max} ≤ 100 mm					

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NTNU

Standards and guidelines

- New standards are being developed (CEN)
  -product standards
  -test methods
- Construction standards reinforced soil
- Guidelines for design
- Guidelines for durability (CEN)

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Durability

What can we expect as service lifetime?

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The Zigurat
3500 years later!

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Supplementary information

- The nordic handbook reinforced soil:

http://www.norskgeotekniskforening.no/

- Geosyntetguiden:

https://igsnorge.no/geosyntetguiden

- Statens Vegvesen: Normaler og veiledninger

  -N200 Vegbygging

  -V220 Geoteknikk i vegbygging

  -Håndbok V221 Grunnforsterkning, fyllinger og skråninger

- NorGeoSpec:

https://www.norgeospec.org/acms/

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