techtextil
symposium

messe frankfurt

Creative concrete constructions by the use of textiles as flexible formwork or as functional framework liner

www.bbri.be

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Outline

- Introduction & partners
- Goal of the project
- Overview of the state-of-the-art
- Potential benefits
- Textile requirements & selection
- Test platform: concrete slab
- Test platform: column
- Column+
- Textures
- Case study 1: Cone
- Case study 2: Hypar
- Conclusion & outlook
- Acknowledgements

Introduction

- Current trends in architecture
  - rounded, 'organic' shapes
  - textile tensile structures


Municipal funeral hall by Ito in Kagamihara, Japan


Millenium Dome by Rogers in London, UK


Guggenheim Museum by Gehry in Bilbao, Spain


Court of Law by Rogers in Antwerp, Belgium

BUT for such concrete constructions, classic formwork is very expensive!

⇒ Could textiles be used as formwork or formwork liner?

⇒ BBRI (Building), Centexbel (Textile) and VUB-ARCH (Architecture) set up a project
  - ⇒ with subsidies from the Flemish Community through IWT
  - ⇒ started in september 2006

BBRI - Belgian Building Research Institute

Status

Private research institute founded in 1960 by the National Federation of Belgian Building Contractors under the application of the « De Groote » act

Members

Statutory Members: more than 74.500 Belgian building contractors (general contractors, carpenters, plasterers, glaziers, plumbers, roofers, tilers, …)

Staff

220 high-school graduates and motivated collaborators from a wide range of educational disciplines, working in multidisciplinary teams (petrographs, surveyors, architects, engineers in construction, material science, mechanics, mining, …)

Belgian Building Research Institute

3 Missions

- Collective Research
- Information Transfer
- Development & Innovation

To the benefit of members and:

- Government
- Architects
- Experts
- Material Producers
- Financial partners

Centexbel: who we are & what we do

Textile research centre

- non-profit
- membership organisation
  - ~900 textile producers
  - ~100 associated members
  - collaboration with 3rd parties
- ~120 (of which ~50% scientists)
- 3 offices in Belgium's regions
  - Brussels - Ghent – Verviers

Markets

- Interior textiles
- Apparel & accessories
- Technical textiles
- Environment & Energy
- Safety, Security & Health

- **Research on textile products:**
  - Basic, applied, pre-standard
  - EU, national, regional, private
  - Domains:
    - Processes
    - Materials
    - Safety, security & health
    - Environment & energy

- **Testing, certification & labelling**

- **Services**
  - Patents,
  - Standardization,
  - Consultancy,
  - Training,…

Centexbel: what we have

Officially accredited laboratories

physical
(incl. electrostatic)

microbiological

ISO 17025
BELAC
056-TEST

chemical
(incl. permeation,
polymer rheology,…)

burning
behaviour

Semi-industrial & lab-scale platforms

knitting

coating

finishing
(incl. plasma)

extrusion
(incl. bico)

Vrije Universiteit Brussel

VUB

- Vrije Universiteit Brussel
  - ~9000 students, ~2500 staff
  - 8 faculties including Engineering and Sciences
  - Research budget 62M € in 2005

- ARCH: Department of Architectural Engineering
  - ~25 staff members
  - Head: Prof. Mollaert
  - æ-lab
    - Renovation & Re-use
    - Lightweight Structures =>Tensile Surface Structures
    - 4D Design

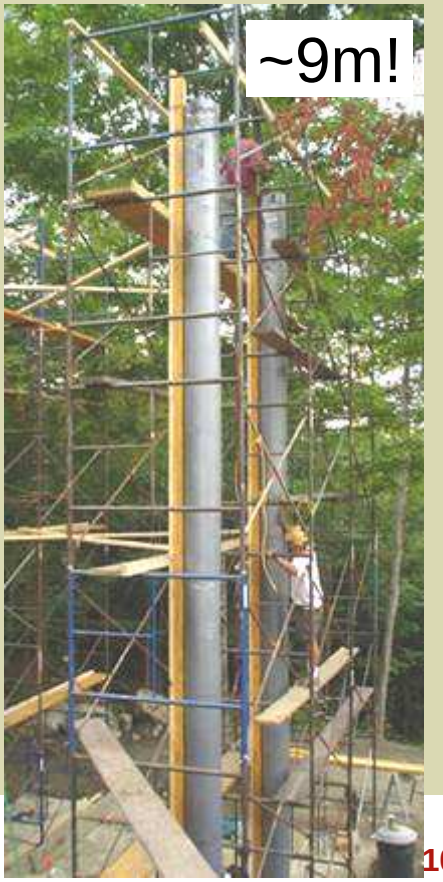
Goal of the project

- Gain knowledge on the use of textiles
  - as formwork for rounded, organic concrete structures
  - as formwork liner for functionalizing the concrete surface (i.e. texture and structure)

  by studying several materials and concepts
- Investigate the practical feasibility and limitations by modelling and developing prototypes

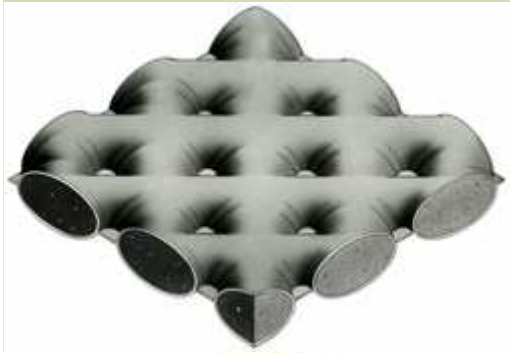
State-of-the-art (1)

- Simple products are commercially available
  - Fab-form Industries (www.fab-form.com)
    - Fastfoot®, Fastbag®,Fasttube™



State-of-the-art (2)

- Simple products are commercially available
  - Fab-form Industries (www.fab-form.com)
    - Fastfoot®, Fastbag®,Fasttube™
  - Hydrotex® (www.hydrotex.com)
  - Bonar TM Concrete Matrasses (www.bonartf.com)

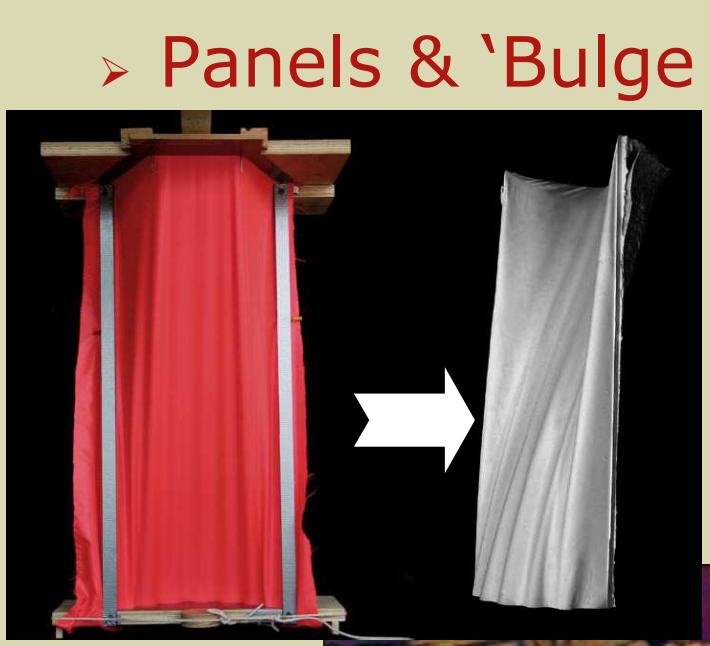


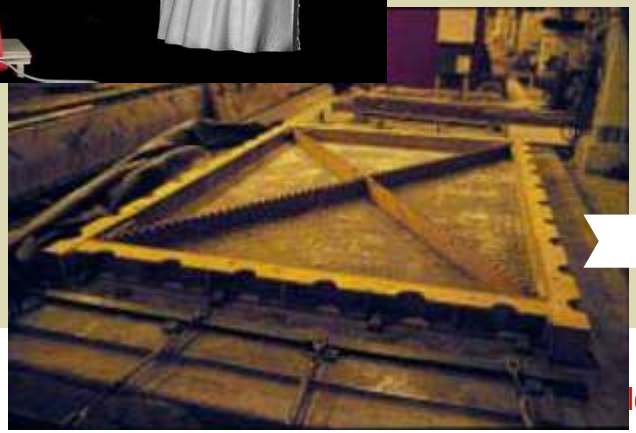
State-of-the-art (3)

- Prof. M. West (University of Manitoba, Canada)
  - Columns

State-of-the-art (4)

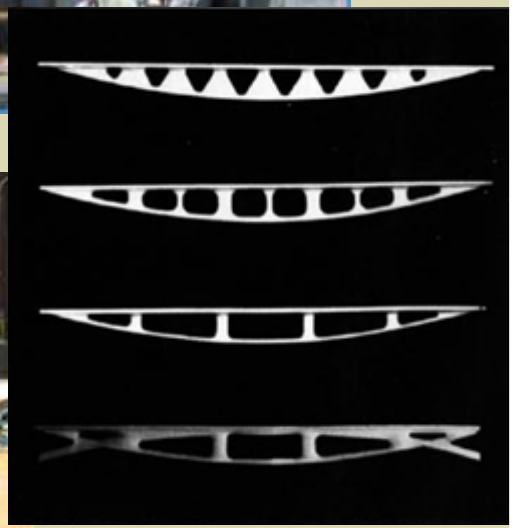
- Prof. M. West (University of Manitoba, Canada)
  - Panels & 'Bulge wall'





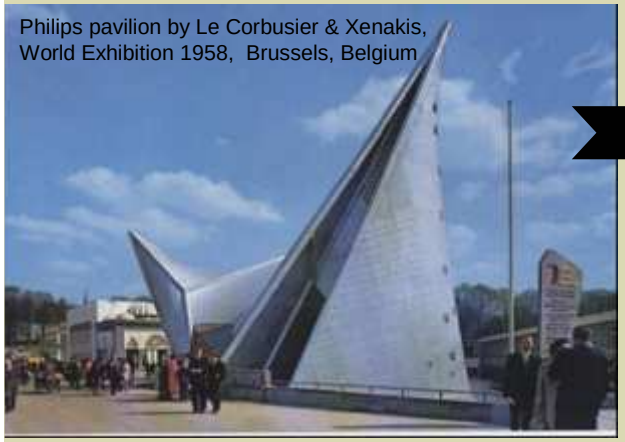
State-of-the-art (5)

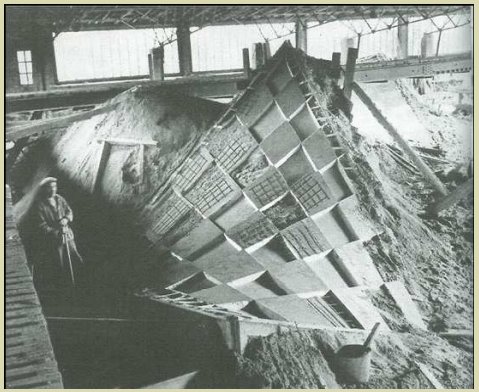
- Prof. M. West (University of Manitoba, Canada)
  - Beams & trusses



State-of-the-art (6)

- Ir. A. Pronk (TU Eindhoven, the Netherlands)





Potential benefits of fabric formwork

- No classic formwork required => cheap
- Less weather dependent (cfr. cardboard)
- Large structures feasible (e.g. columns)
- Easy to install
- Complex rounded structures feasible
- Easy storage (compact)

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- Texture
- Case study 1: Cone
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Textile requirements & selection

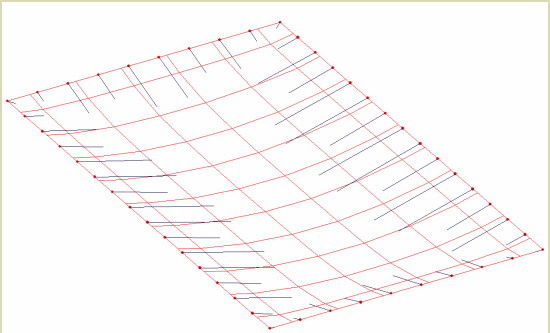
- Main requirements
  - High strength @ low elongation => knitted textiles not selected
  - Good demoulding & re-use
  - Low cost
  - Good alkali resistance (concrete has a pH ~11-13)
- Material selection & testing

	PP NW	PE(/twaron) woven	PVC coated woven
Mech. strength (kN/m) @ elongation	45 @ 40-65%	100(-600*) @ 10-20%	40-150 @ 20-35%
Bursting strength (GPa)	Not tested	Not tested**	>2 - 4.5***
Tearing strenght (N)	Not tested	225-25	1000-160
Permeable	Yes	Yes	No
Demoulding	Bad	Moderate	Good
Re-usability	Bad	Moderate	Good
Price (€/m²)	0.2	2(-6)	3-5
Alkali resistance	Good	Good	Good

* For MD; ** Materials too thick & rough to be tested; *** For light materials, heavy materials (>1kg/m²) could not be tested

Test platform: concrete slab

- Concept: horizontally suspended, unsupported textile
  to correlate deformation, load & textile properties
- Modelling & tests
  - 15cm concrete load, 100kN/m stiffness, 10N/m pretension
    => Model predicts sagging by 6cm
    => corresponded quite well with the experiments



- Conclusion:
  - In flat structures, high tension & deformation quickly occur
  - Material stiffness has a bigger impact than prestressing
    => Horizontal slab is not a good test platform

Test platform: column (1)

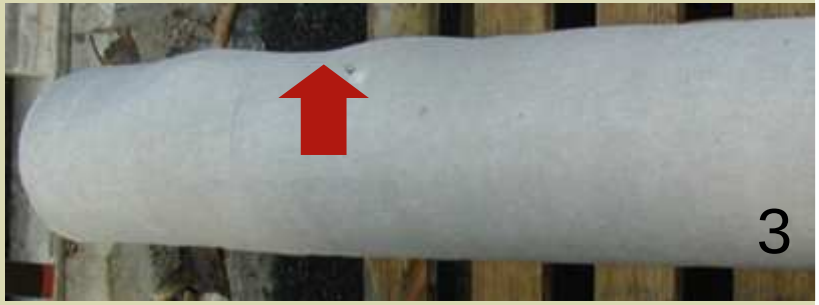
- Basic approach: clamp textile in wood frame

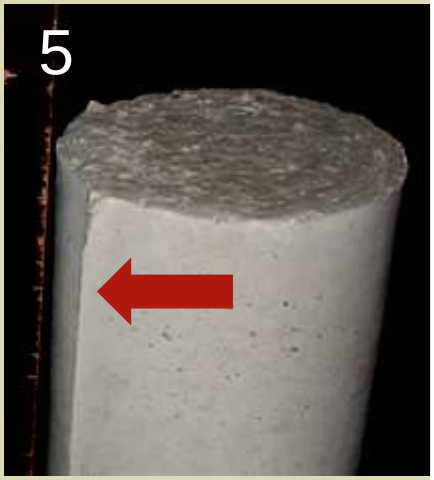
Test platform: column (2)

- Similar approach:

Test platform: column (2)

- Similar approach:

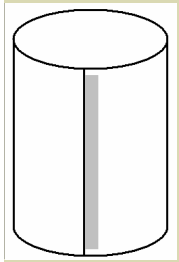




- Conclusions basic approaches:
  1. Light materials are strong enough
  2. Diameter can be easily adjusted
  3. More uniform tension required
  4. Wovens bleed cement grout => bad demoulding & re-use
  5. Edge remains at clamping site

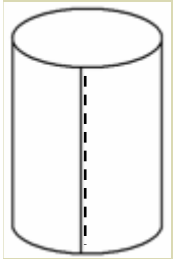
Test platform: column (3)

- ‘Advanced’ approach: ready-made columns



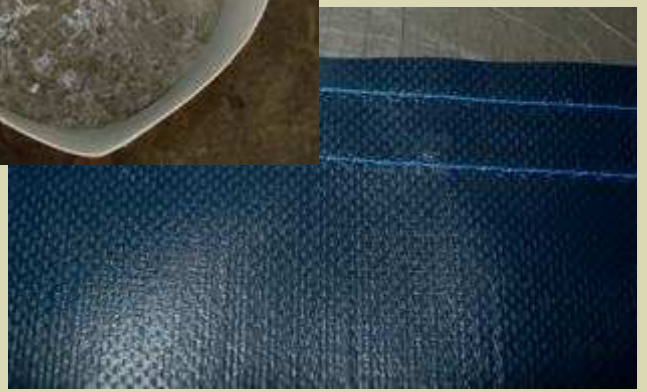
By welding:

- Strength ~ textile
- Only for coated materials
- Single use
- Cheap



By sewing:

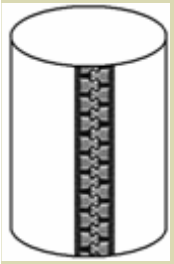
- Strength ~ ½ textile
- Single use
- Cheap



- Conclusion:
  - Works well but seam/edge remains visible in concrete

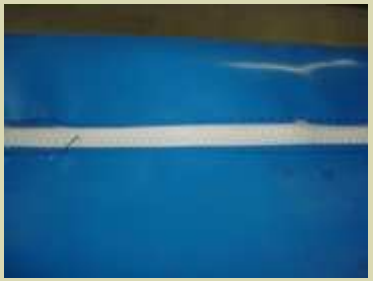
Test platform: column (4)

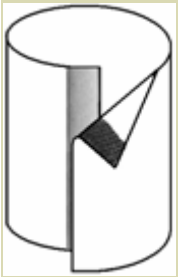
- ‘Advanced’ approach: ready-made columns



With (watertight) zip-fastener:

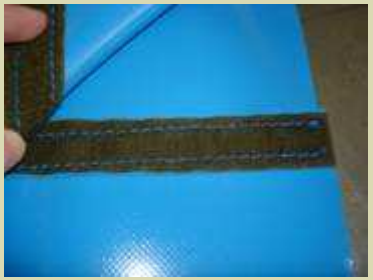
- up to 28kN/m (= column 10m x 0.2m Ø)
- Re-usable
- Expensive





With velcro:

- Re-usable
- Variable diameter
- Expensive
- up to 25N/cm²



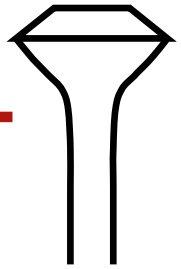
- Conclusion:
  - Zip: protective flap required
  - Velcro: stronger/wider velcro required

  => Further testing necessary

Column+

- Column with ‘chalice’-shaped head
  - Wood clamp: sagging

Column+

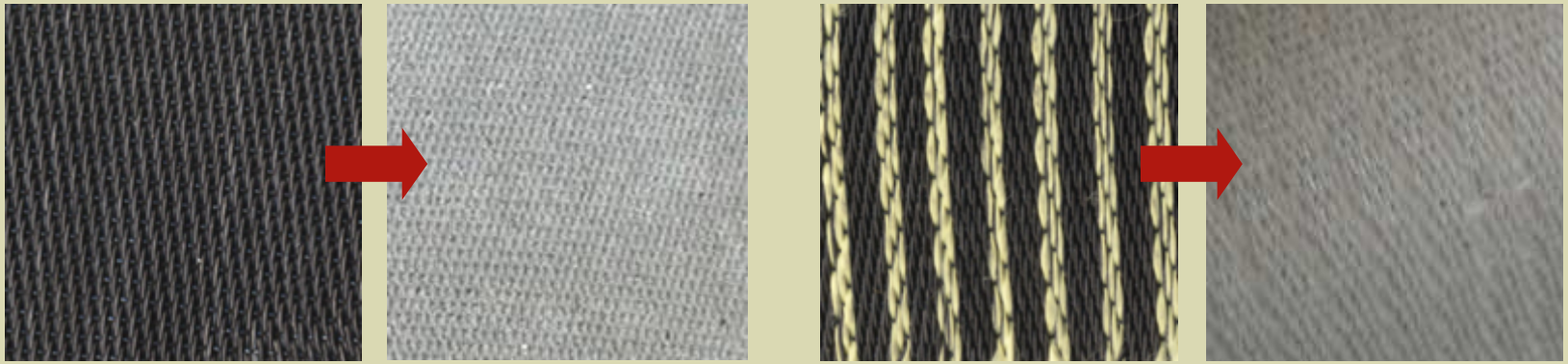


- Column with ‘chalice’-shaped head
  - Wood clamp: sagging
  - Ready-made formwork

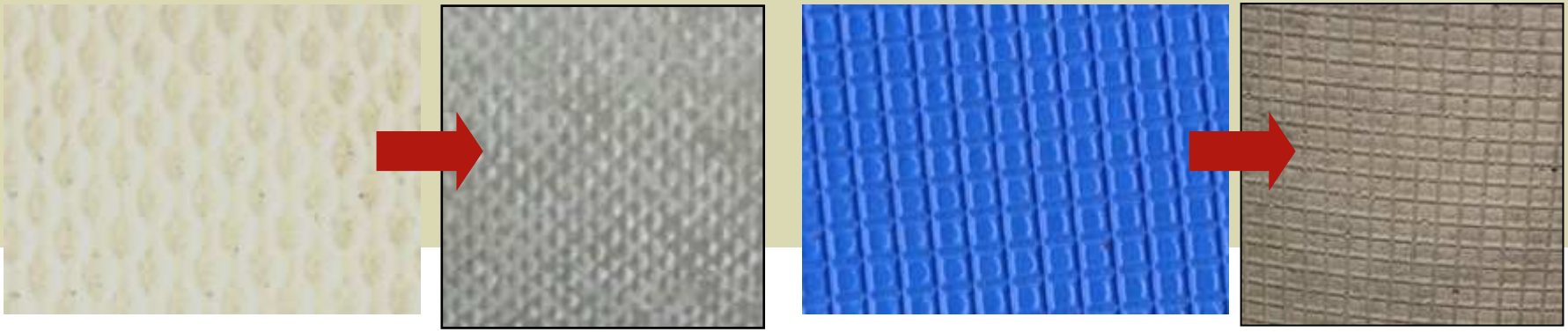
Textures (1)

- Non-wovens: Rough, fluffy finish

- Wovens: good surface finish, typical woven textures



- Coated fabrics: excellent finish, wide variety of (pronounced) textures available



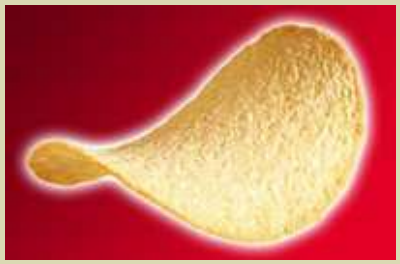
Textures (2)

- Wallpaper as liner

- Conclusions:
  - High quality transfer of texture
  - Many interesting and aesthetic textures available
  - Concrete surface porosity & durability to be assessed

Case studies

- Shapes based on input from the construction sector
- Concepts: cone & hypar



- BUT
  - Difficult to pour concrete directly onto textile because
    - Concrete flows
    - Bad adhesion, especially on coated fabrics

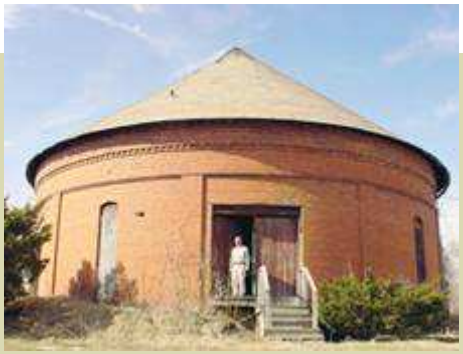
      => use wovens (or non-wovens) as liner, special additives, viscous concrete, shotcrete,…
  - Easy of use in situ? => to be checked
  - Classic reinforcement difficult to integrate

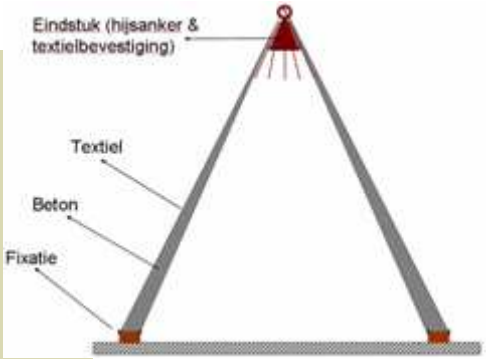
  => use small-scale prototypes

  => novel reinforcement concepts required

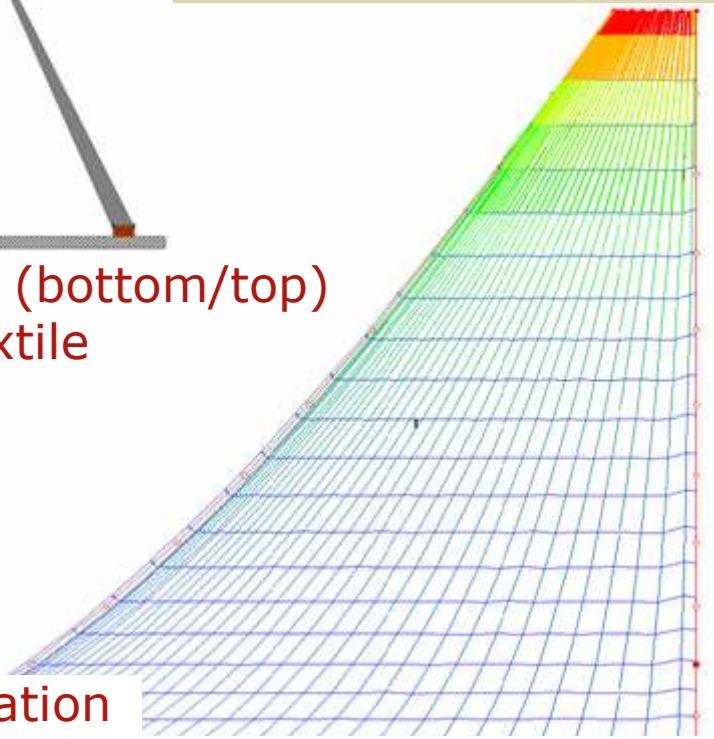
Case study 1a: cone

- Concept:





  - Cone: height 2.7m, radius 2.25m/0.225m (bottom/top)
  - Pour concrete directly on a cone-shape textile



- Modelling
  - Load: 5 cm concrete
  - Tension concentrates near top
  - Increasing prestress reduces deformation
  - Textiles with high stiffness reduce deformation

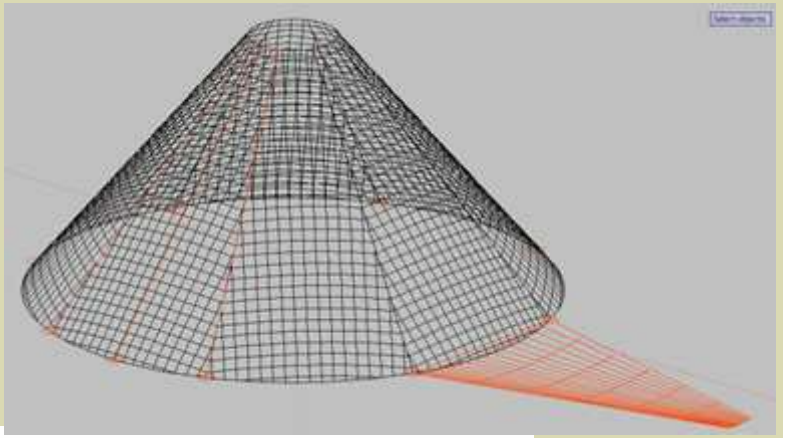
  =>3cm deformation for 1000kN/m stiffness & 0.4kN prestress

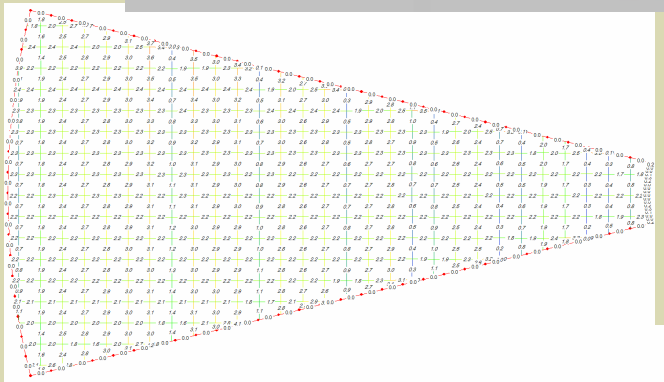
  =>Tension is in the order of maximum strength of the selected textiles!

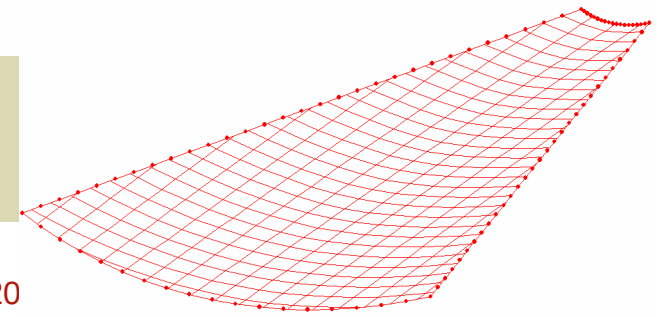
=> Use cone section (wedge) to reduce tension & deformation

Case study 1b: cone wedge

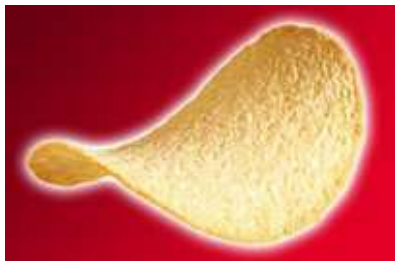
- Concept:
  - 1/8th of cone placed horizontally
- Modelling
  - Load: 5 cm concrete
  - Prestressing both directions
  - ⇒ Load increases tension slightly
  - ⇒ Only 1cm deformation
  - ⇒ Hardly double-curved
  - ⇒ High stiffness textile required
- Currently:
  - Building experimental setup
  - Manufacturing of the textile formwork



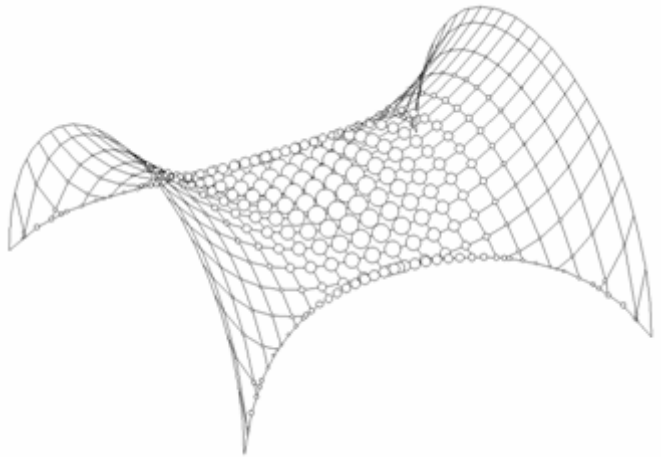




Case study 2: hypar/saddle



- Concept
  - 2 arch frames, 2x2m, height 1m
  - Strongly double-curved
- Modelling
  - Load 5cm concrete
  - Uniaxial pretensioning
  - ⇒ High stiffness textile required (~1000kN/m)
  - ⇒ 9cm deformation @ 1kN/m prestress, 1cm deformation @ 2kN/m prestress
- Currently:
  - Building experimental setup
  - Manufacturing of the textile formwork



Conclusion & outlook

- General conclusions on fabric formwork:
  - State-of-the-art is still primitive and mostly academic
  - Many potential advantages
  - Shown promising experiments & prototypes
  - Obtained interesting and unique textures
  - Investigated feasibility of 2 exemplary case studies

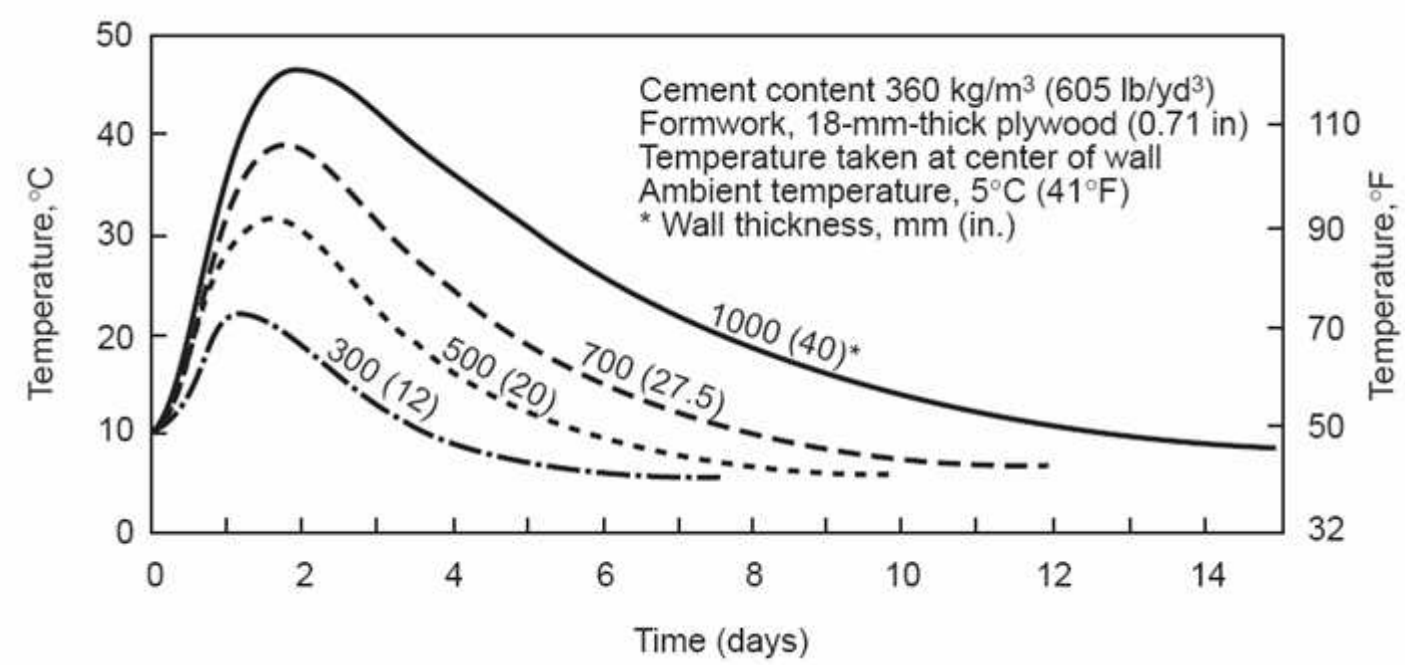
- Outlook
  - Textile testing: creep, biaxial mechanical strength,…
  - Manufacturing more ready-made formworks
    - Evaluate velcro/zip-fastening
    - Try more complex shapes
  - Experimental tests on the case studies

Acknowledgements

- Visit us in hall 4.1 at stand E52
- Other lectures by Centexbel
  - Dr. I. De Witte: lecture AX.4.2 "Sol-gel durable nano-metric coatingq for hydrophilic/hydrophobic surface modification" on Wed. 13/06 at 9h25
  - Ing. F. Pirotte: lecture AX.7.8 "OFSETH: Optical Fibre Sensors Embedded in Technical Textiles for Healthcare" on Thu. 14/06 at 12h15
- Acknowledgements
  - IWT for financial support
  - Sioen Industries NV (Hall 3.0 Stand D45)
  - Bonar Technical Fabrics NV (Hall 3.1 Stand G11)
  - Axel Troch bvba
  - The Nomad Concept bvba
  - You for your kind attention

Thermal influence

- Temperatures due to the heat of hydration of concrete are within the typical operational temperature range (-30° to +70°) of textiles



Harrison, T. A., Early-Age Thermal Control in Concrete, Report 91, Construction Industry Research and Information Association, London, 1981.