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Structural strap connections for bamboo and wooden shelter frames

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Structural strap connections for bamboo and wooden shelter frames

IFRC-SRU Cladding & Fixing Conference
Luxembourg 03-09-2014

Dr. ir. Roel Gijsbers
ir. Mark Cox

TU/e Technische Universiteit Eindhoven University of Technology

Where innovation starts

Contents

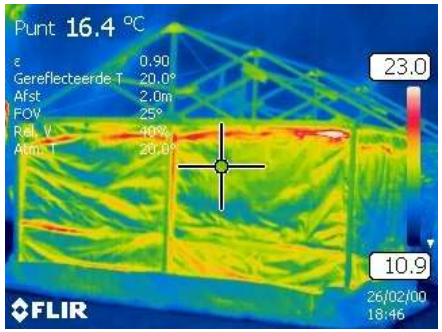
1. Introduction

Faculty of the Built Environment

- **Chair of Building Technology / Product development**

- **Actively involved in humanitarian sector since 2007**
  - Official partnership with Netherlands Red Cross
- **Cooperations with a variety of NGO's and organizations**

- **Currently involved in S(P)EEDKITS project**
  - Modular mobile 120m2 unit (MMU120)
  - Indoor climate experiments and material development
  - Water tower kit
  - Debris recycling kit



SPEEDKITS
rapid deployable kits as seeds for self-recovery

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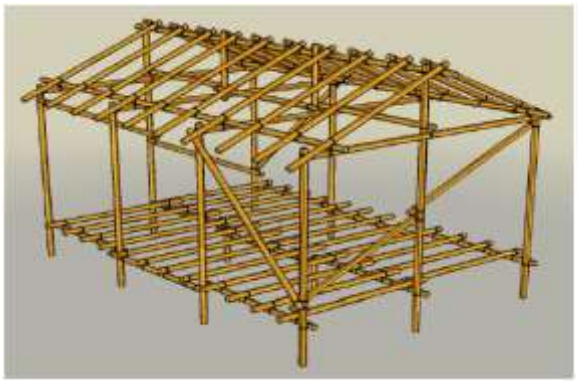
2. Objective

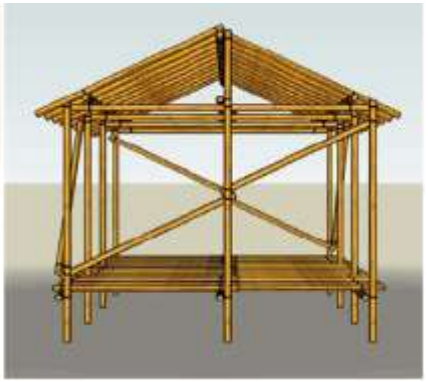
Problem:

Many potential beneficiaries live in areas where sufficient bamboo or round wood is available for (re)building shelters/houses. However, regular bamboo or (round)wood connections are structurally sensitive to climatic conditions and depending on (traditional) craftsmanship

Question (raised by Red Cross):

Tie wraps are often included in shelter kits. Is it possible to easily and rapidly erect safe basic shelters/houses with these, using locally available bamboo or wood?

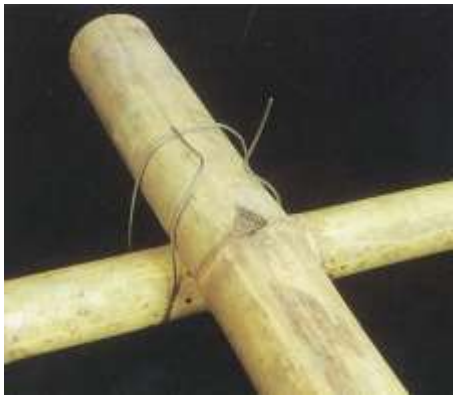




3. State of the art

Bamboo connection techniques

- Ropes
- Lashing
- Nails
- Strips
- Wire



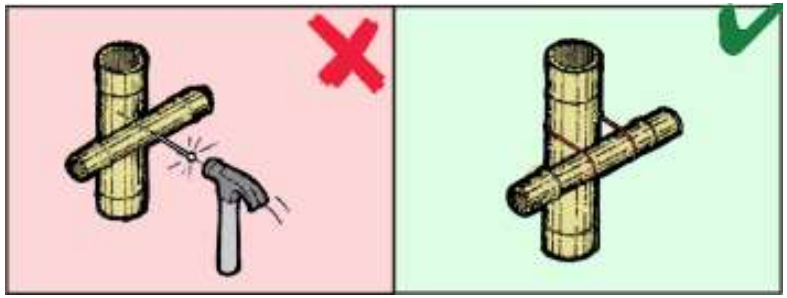
3. State of the art

Strap connection materials

- Organic: Rope, Lashings
- Polymer: Lashings, Tie-wraps, Linear straps
- Steel: Linear straps, Tie-wraps

Applications of straps in bamboo/wood building

- Traditional: Rope / Lashings (craftsmanship, UV, moisture)
- Scaffolding: Nylon lashings (much material use, moisture)



Applicability of tie-wraps? (cable fasteners!)

- Low cost
- Intuitive
- High strengths (>1 kN) possible?

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3. State of the art

Tie-wraps

Materials

Polymers: thermosets

Stainless steel

Properties / points of attention

- **Many sizes and qualities**
- **UV sensitivity**
- **Moisture absorption**
- **Creep**
- **Changing material properties under tension/temperature differences (elongation/necking)**

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3. State of the art

Experiments on basic mechanical properties

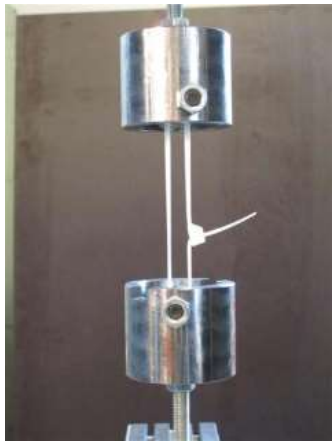
- Tensile strength
- Breaking strength
- Deformation

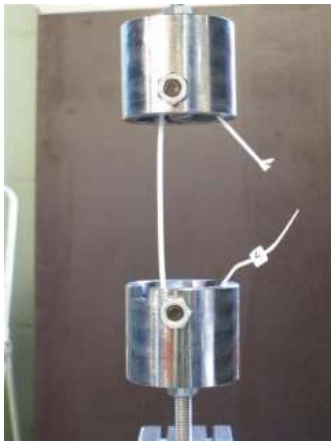
Nylon (PA66/UVR)

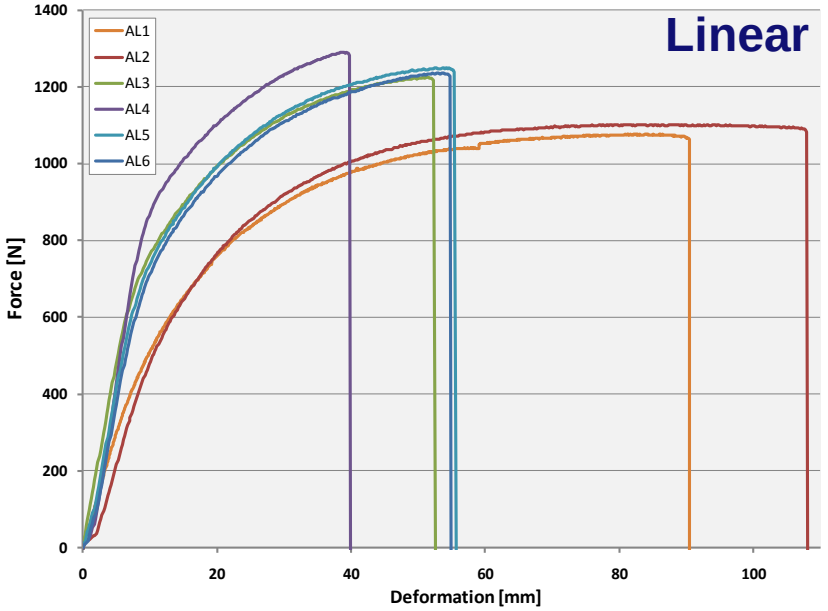
Breaking strength: 113 kg

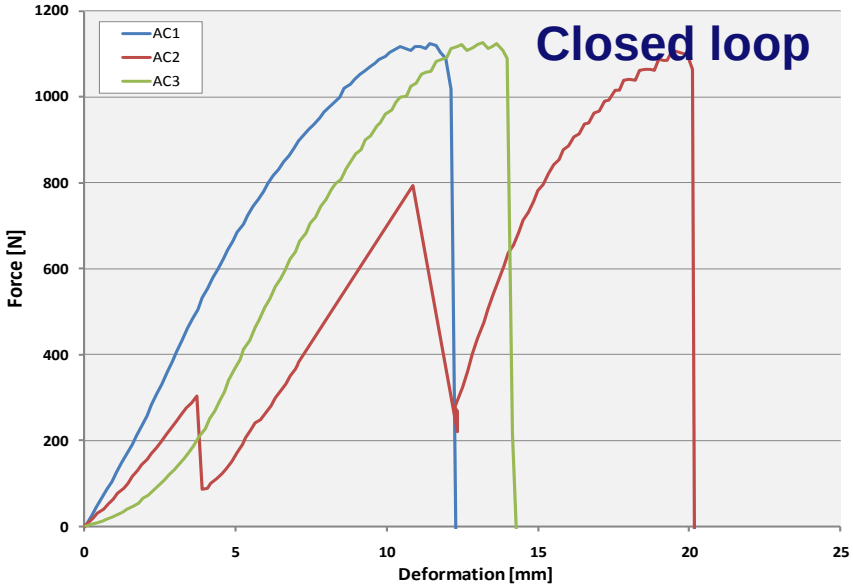
w=12,6 mm / th = 1,9 mm

UV resistant









3. State of the art

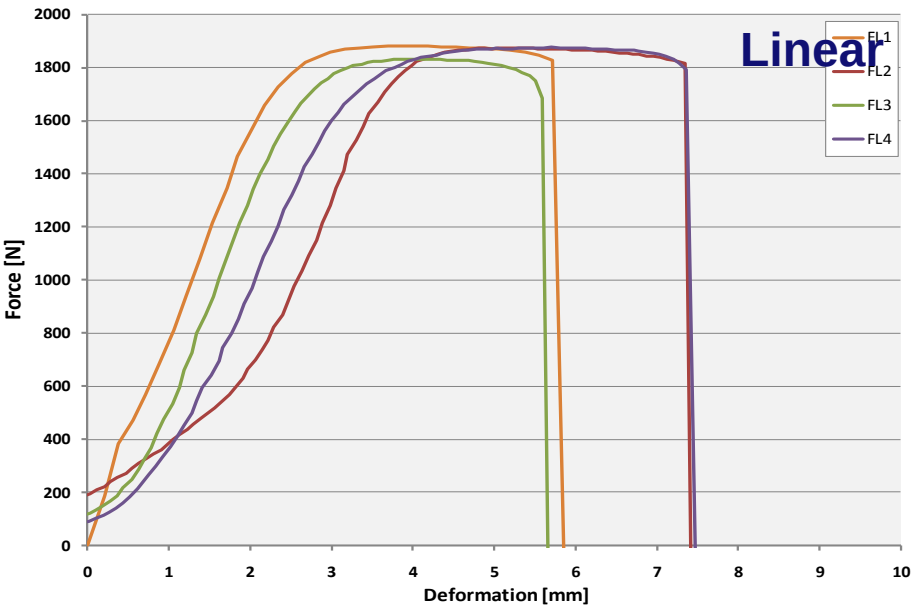
Experiments on basic mechanical properties

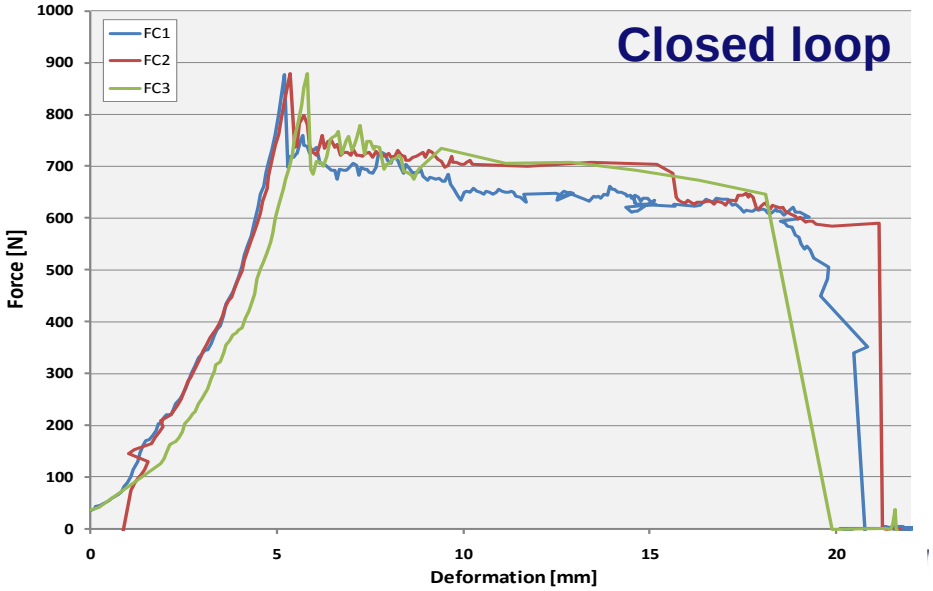
- Tensile strength
- Breaking strength
- Deformation

Stainless steel

Breaking strength: 113 kg

w=7,9 mm / th = 0,24 mm





3. State of the art

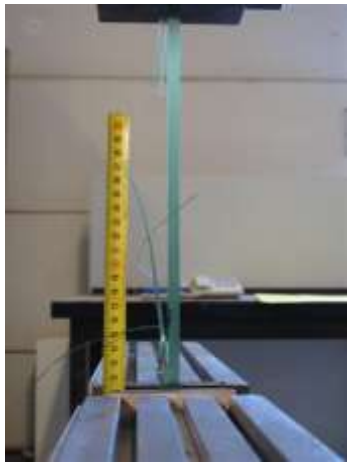
Experiments on basic mechanical properties

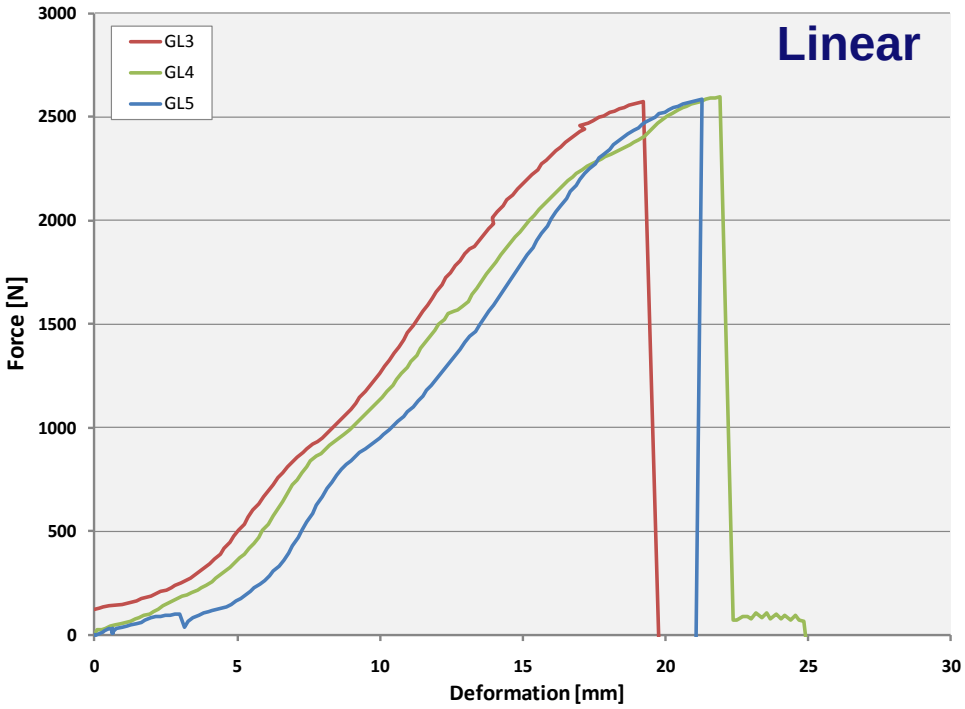
- Tensile strength
- Breaking strength
- Deformation

Reinforced Polyester straps

Breaking strength: unknown

w=12,0 mm / th = 0,6 mm





3. State of the art

Experiments on basic mechanical properties

Results:

- **Breaking strength seems sufficient**
- **Deformation of polymers under tension is much too large for stiff connections (especially under dynamic loading such as wind)**
- **Weak point: tie-wrap lock**
  - **Nylon: due to droplet shape, unfavorable force distribution**
  - **Stainless Steel: slippage of connection**

Commonly available tie-wraps are <u>not suitable nor safe</u> for structural application!

However, the product principle is very useful.

How to make it applicable for building purpose?

4. Boundary conditions

Structural Strap connection for sheltering

Cost effectiveness

- Minimize material use & costs (length, width, thickness)
- One strapping per connection

Applicability

- Intuitive closing mechanism
- Ability to be retightened (e.g. after storm, creep)
- Optimize shape (circular for optimal force distribution)
- Irregular shape of pole and size variations
- No tools or additional equipment

Material properties

- Tensile strength approx. 100-150 kg (1-1,5 kN), low deformation
- Lifespan of 5 years, 80% of original strength after 5 years
- UV resistant
- Moisture resistant

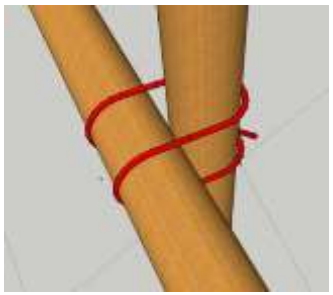
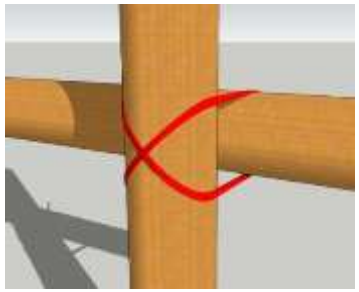
5. Connection optimization

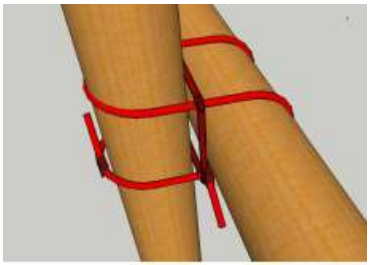
Experiments on optimal connection

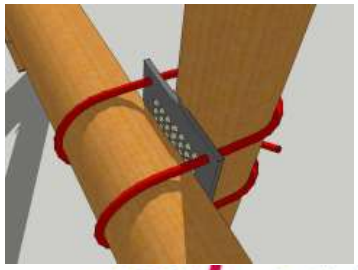
- **Impending friction (axial loading)**
- **Rotational stiffness (lateral loading)**

Variables

- **Type of winding**
  - **Straight**
  - **Crossed**
- **Tension**
  - **pre tension of 350N (normalized with tensioner tool)**
  - **extra tension (additional strap)**
- **Friction**
  - **no friction (teflon)**
  - **normal friction (no addition)**
  - **extra friction (rubber)**





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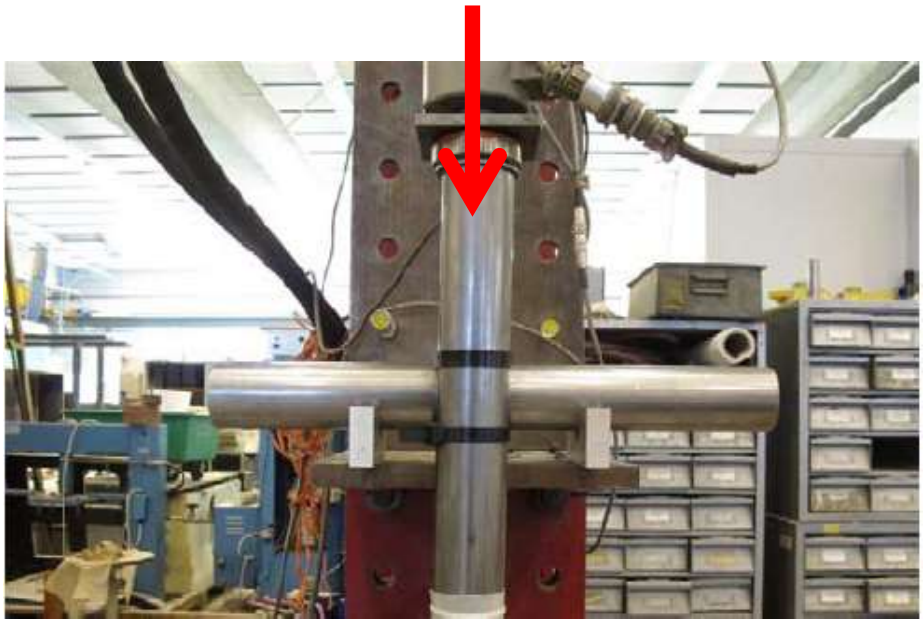
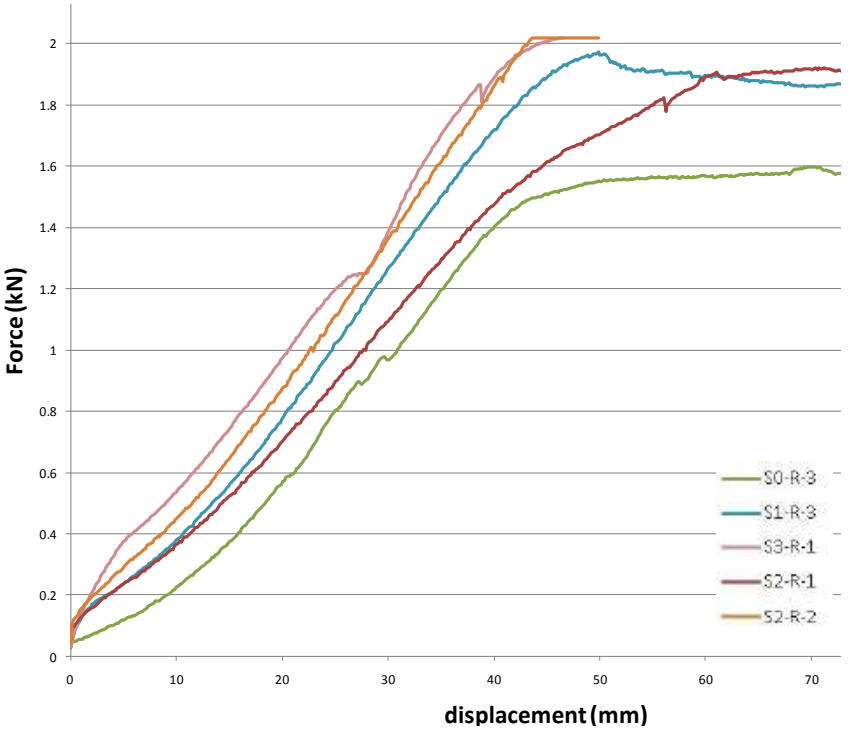
5. Connection optimization

Impending friction experiments (axial loading)






crossed


low friction


high friction


extra tension

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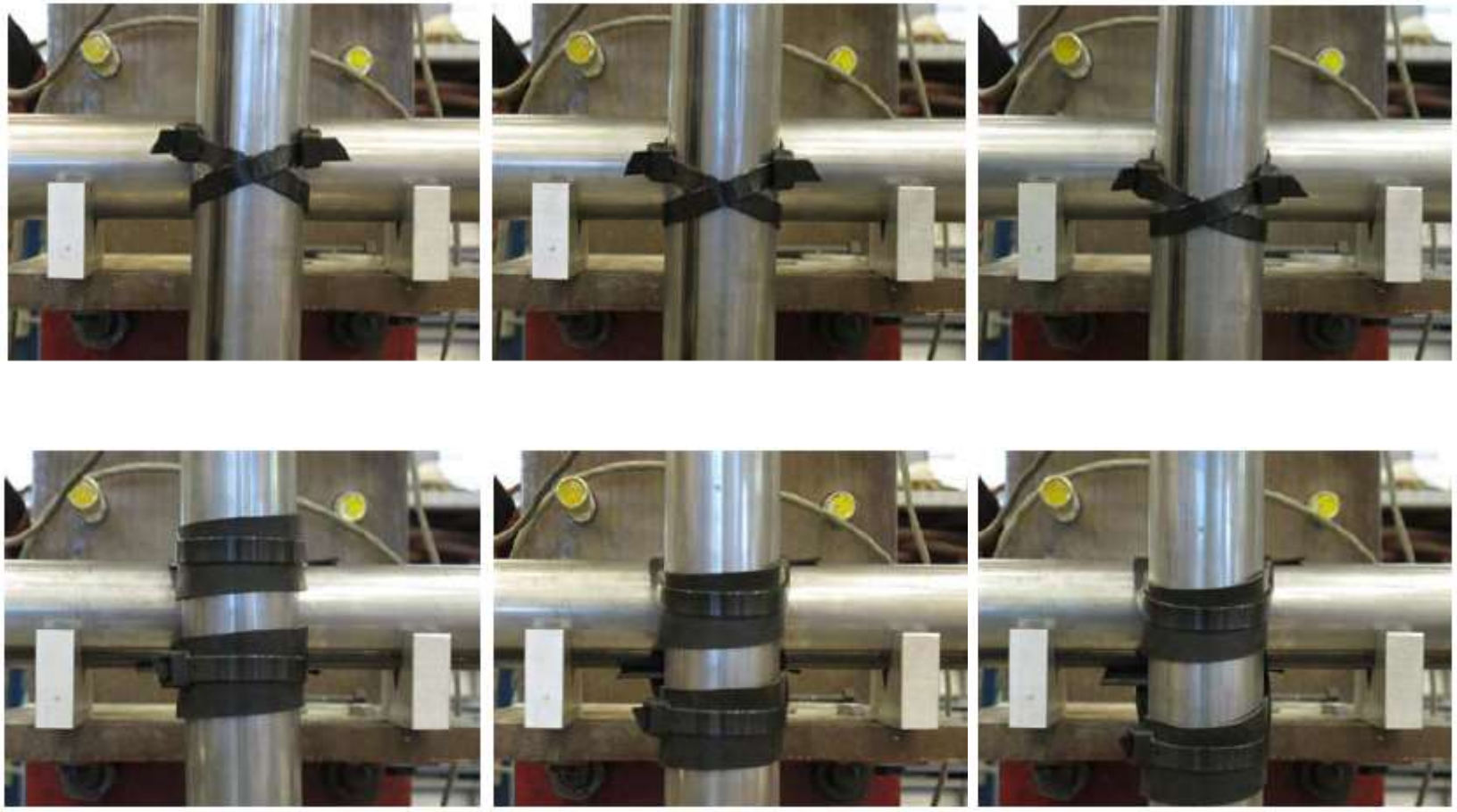
5. Connection optimization

Impending friction experiments (axial loading)

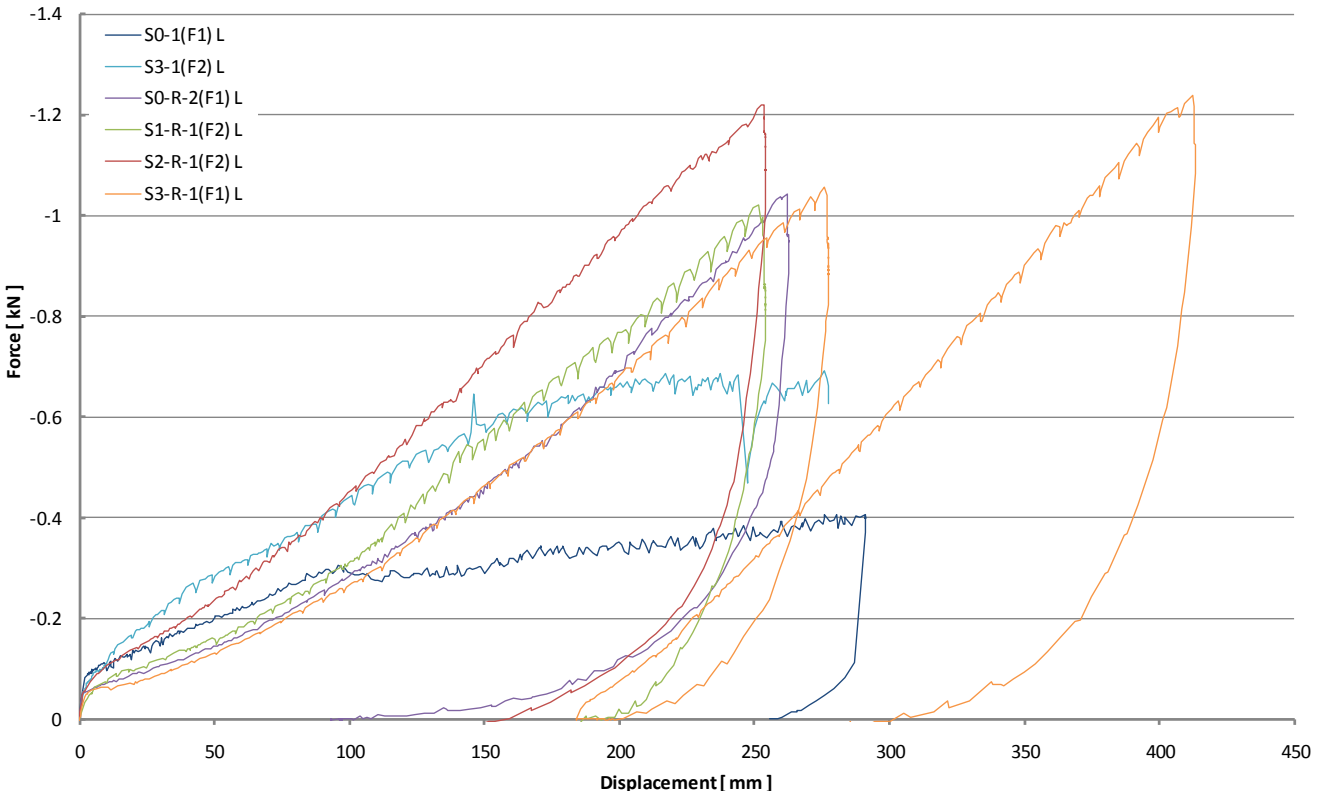


5. Connection optimization

Rotational stiffness experiments (lateral loading)

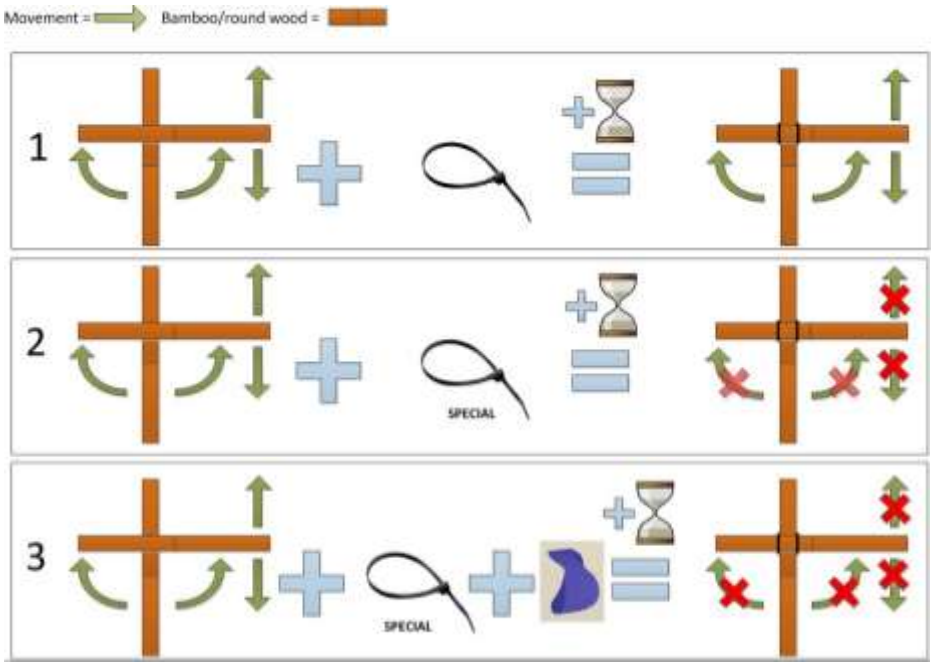
5. Connection optimization

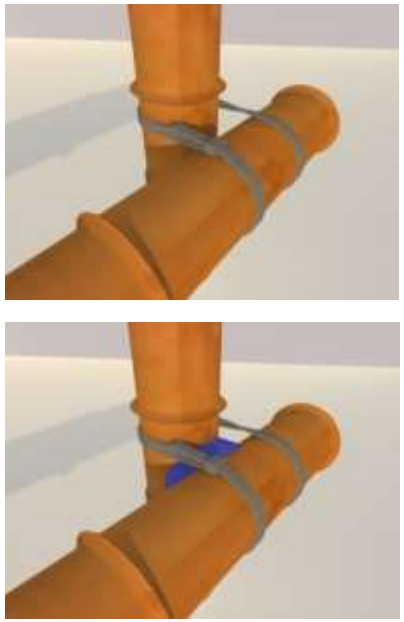
Rotational stiffness experiments (lateral loading)



6. Conclusions

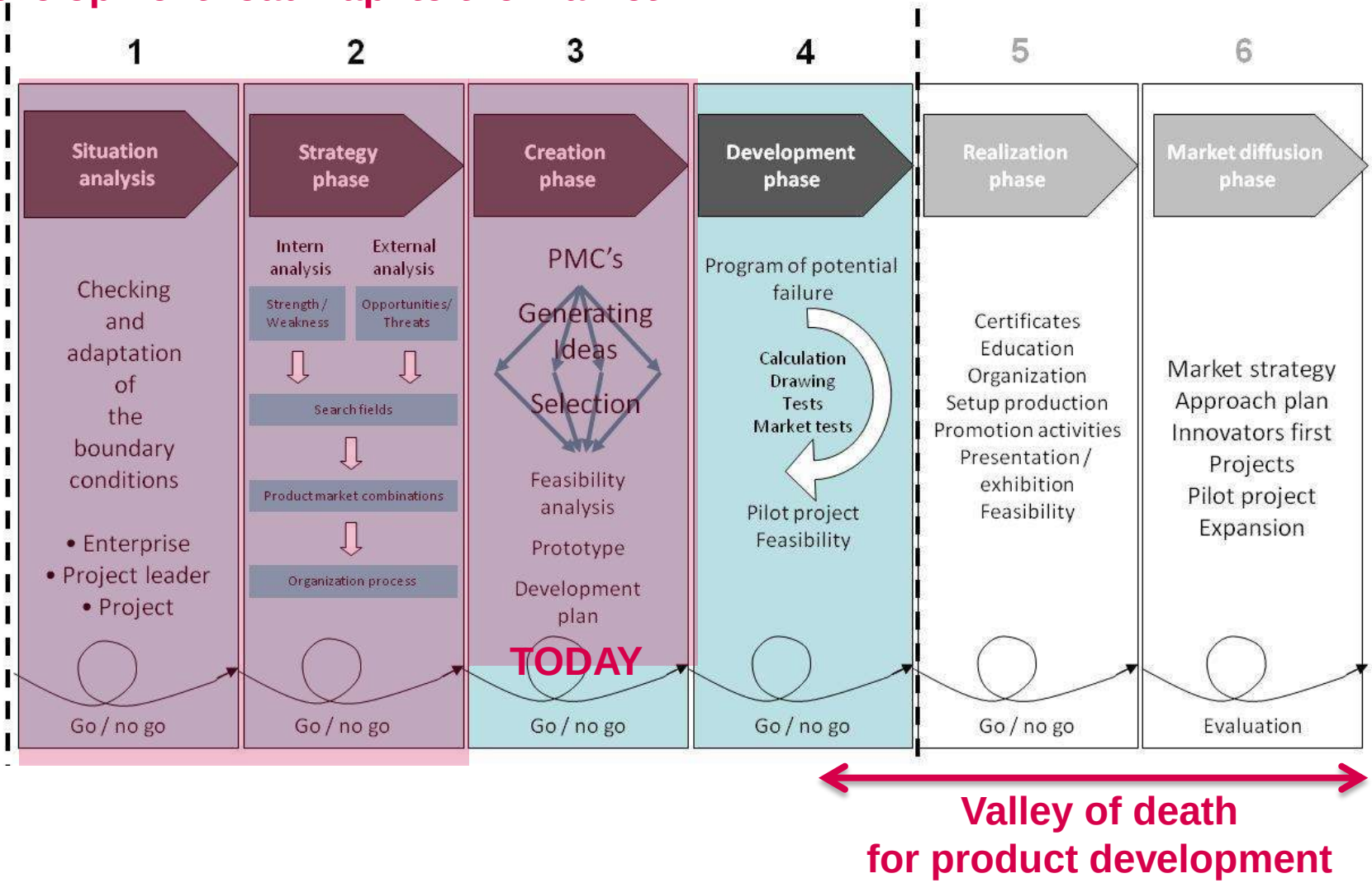
- **Conventional tie-wraps are versatile and intuitive in use, but NOT suitable for safe structural connections**
- **Friction between poles and straps under axial loading can be substantially increased by applying friction-increasing properties/component**
- **Rotational stiffness can be substantially increased by an additional connection element**





7. Next steps

Development roadmap to the market



7. Next Steps

Business case has been validated in Business Plan, further development is not a technical challenge anymore

1. Further product development

- **Industry partner?**

2. Production

- **Industry Partner?**

3. Lab tests

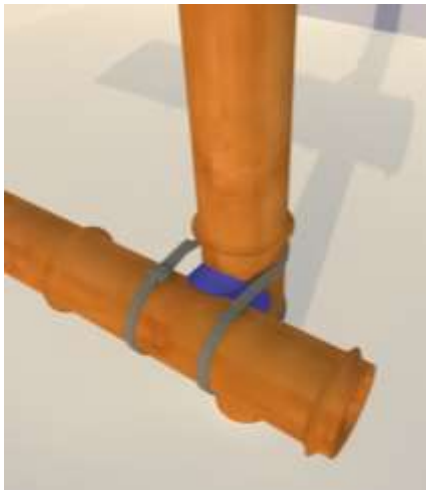
- **TU/e**

4. Field Testing + publication of results & experiences

- **NGO partnership(s)?**

5. Upscaling of production + market implementation

- **Industry partner?**
- **NGO partnerships?**



Additional SUPPORT NEEDED to bring this innovation to the beneficiaries!

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Thank you!

IFRC-SRU Luxembourg 10-04-2013

Dr. ir. Roel Gijsbers
r.gijsbers@tue.nl
ir. Mark Cox
m.g.d.m.cox@tue.nl

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