Structural strap connections for bamboo and wooden shelter frames

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

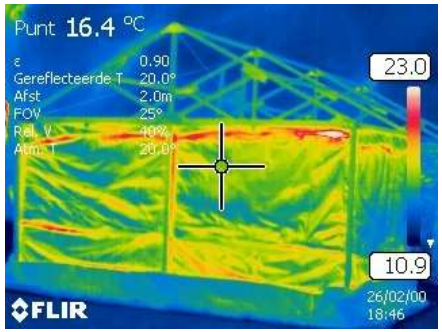
1. Introduction

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

Technische Universiteit Eindhoven University of Technology

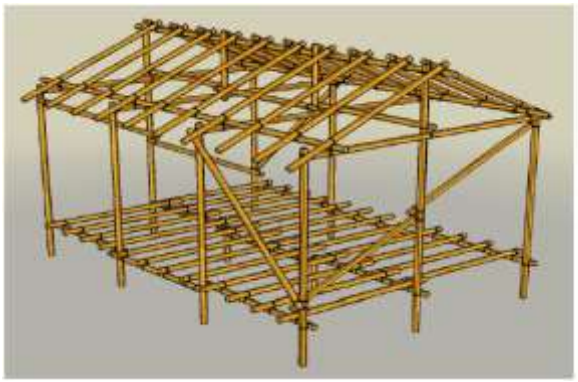
2. Objective

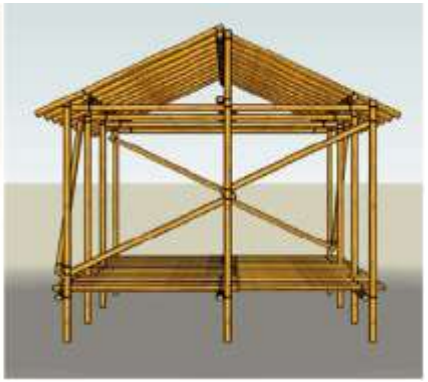
Problem:

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?

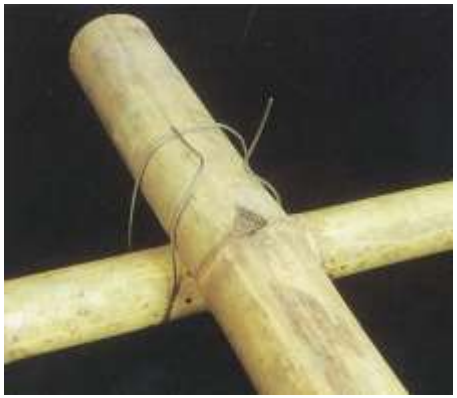




3. State of the art

Bamboo connection techniques

- Ropes
- Lashing
- Nails
- Strips
- Wire



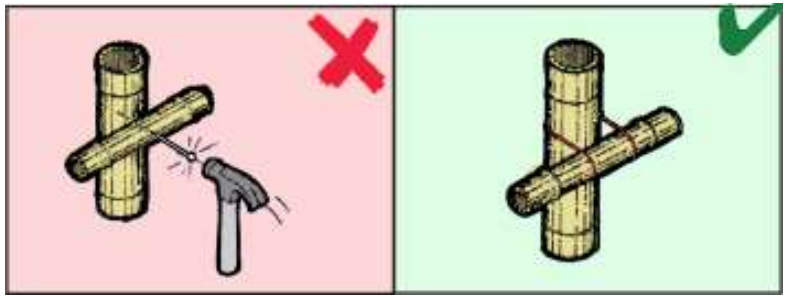
3. State of the art

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?

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)**

3. State of the art

Experiments on basic mechanical properties

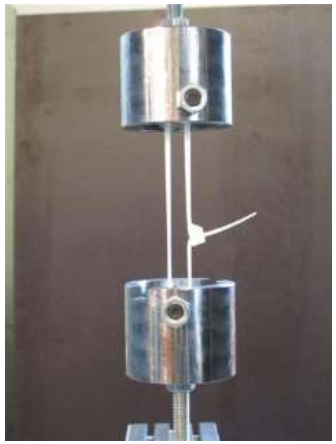
- Tensile strength
- Breaking strength
- Deformation

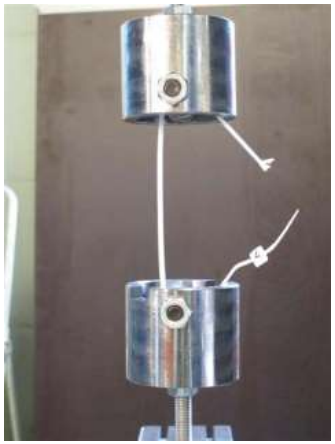
Nylon (PA66/UVR)

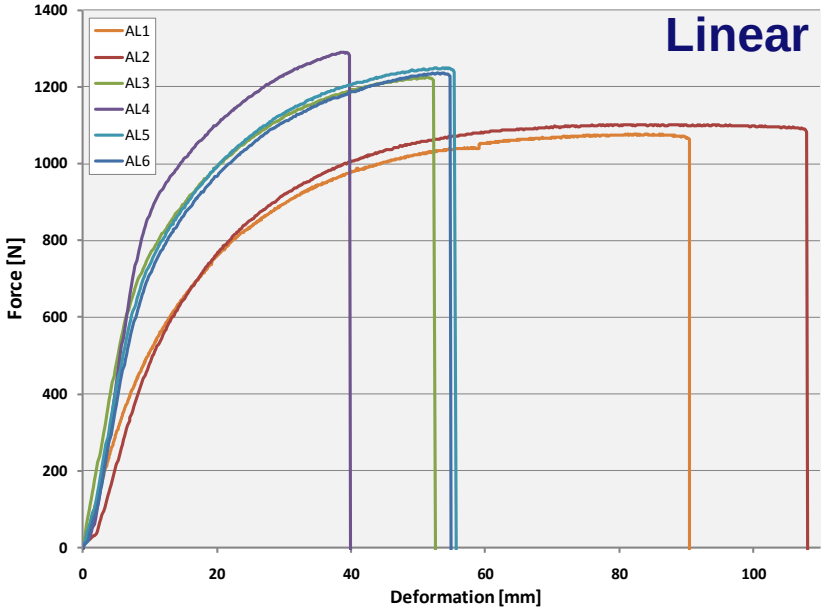
Breaking strength: 113 kg

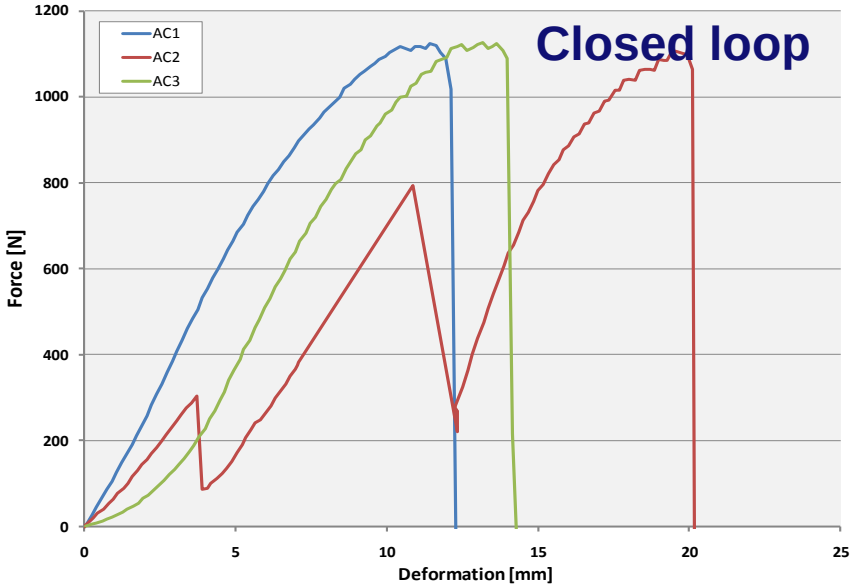
w=12,6 mm / th = 1,9 mm

UV resistant









3. State of the art

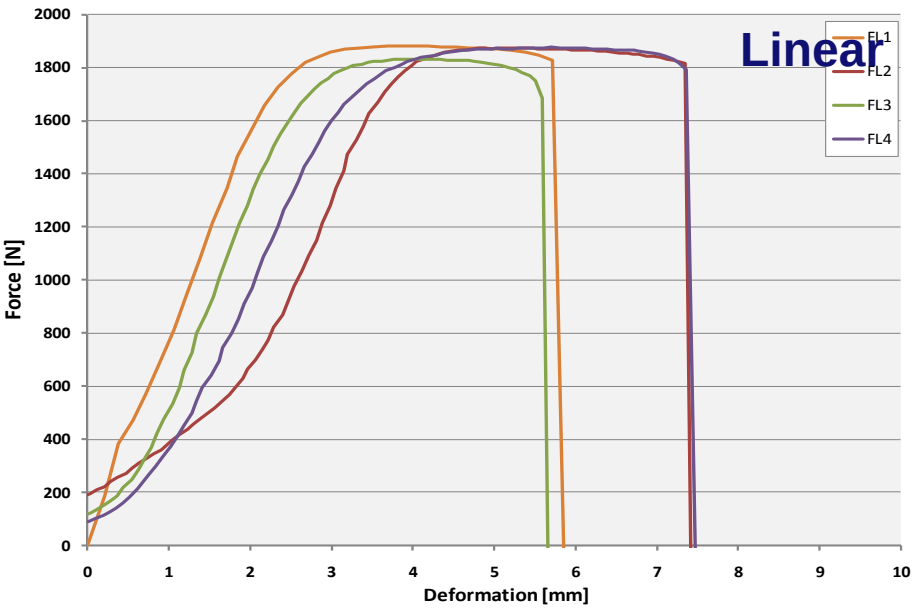
Experiments on basic mechanical properties

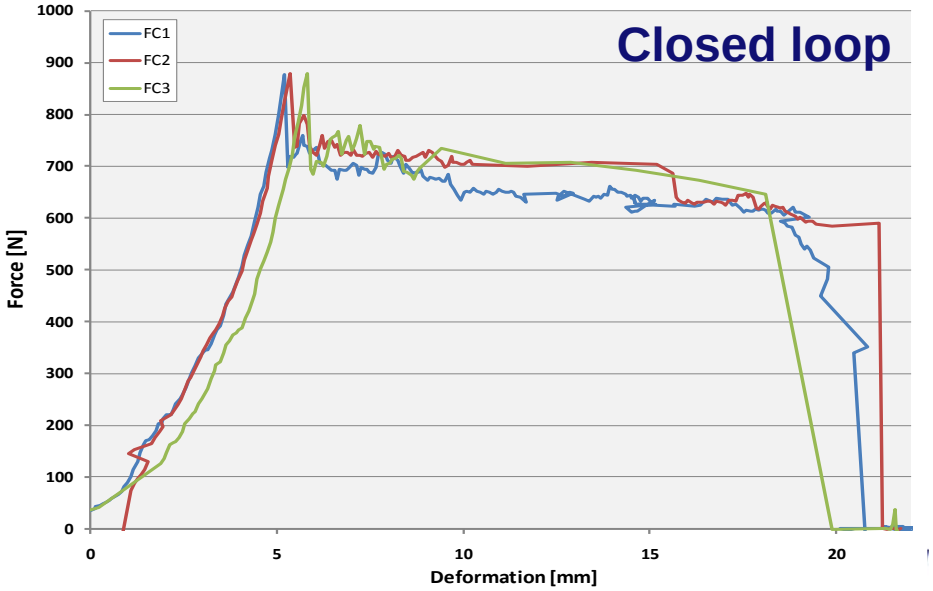
- Tensile strength
- Breaking strength
- Deformation

Stainless steel

Breaking strength: 113 kg

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





3. State of the art

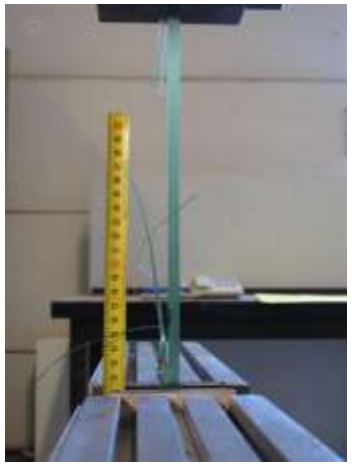
Experiments on basic mechanical properties

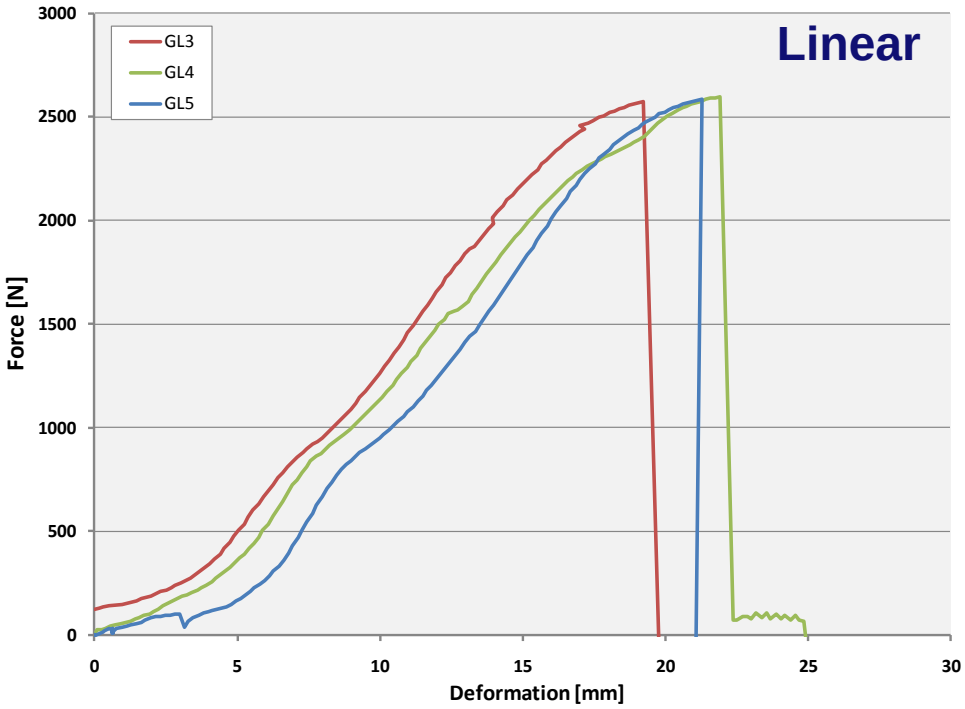
- Tensile strength
- Breaking strength
- Deformation

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

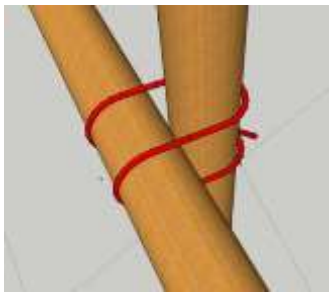
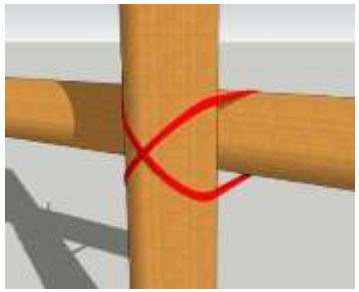
5. Connection optimization

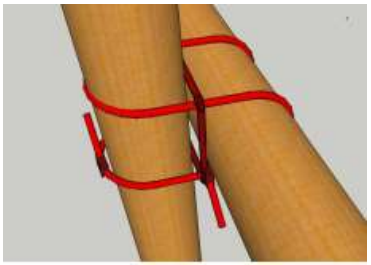
Experiments on optimal connection

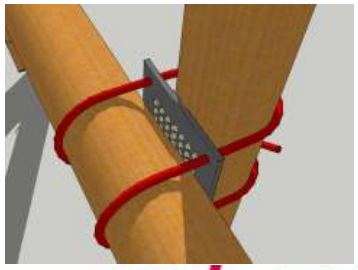
- **Impending friction (axial loading)**
- **Rotational stiffness (lateral loading)**

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)**

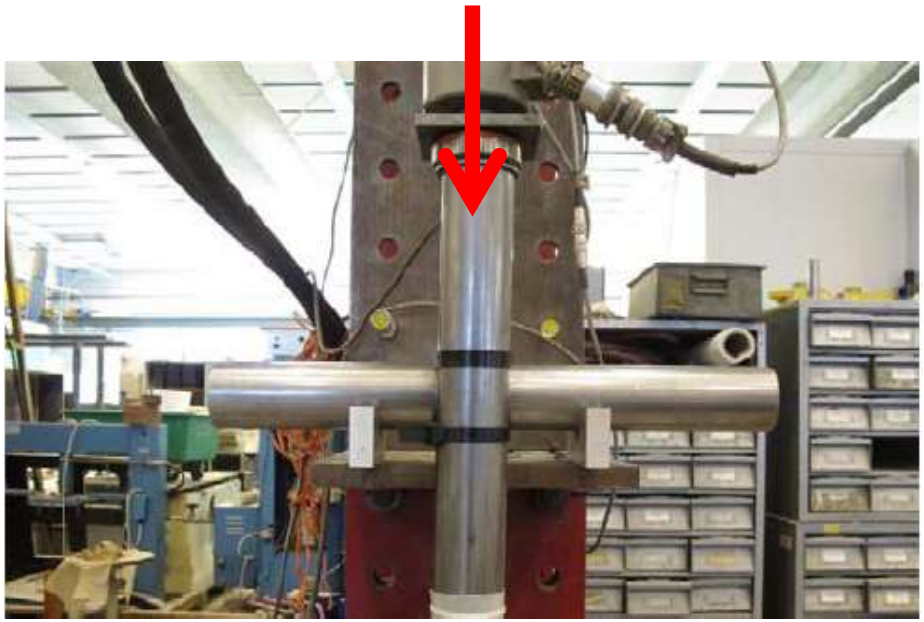



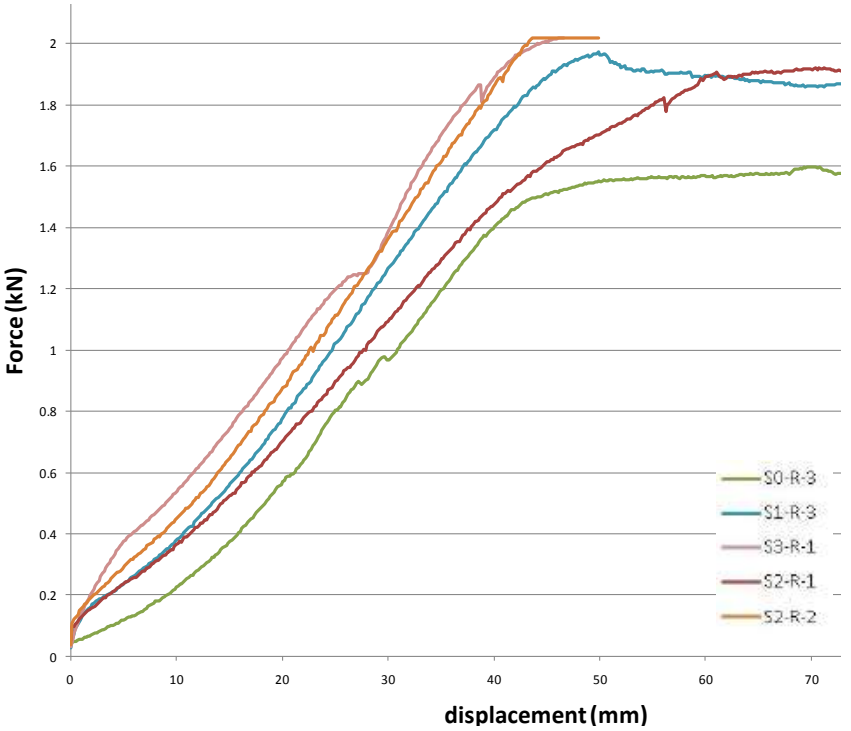




5. Connection optimization

Impending friction experiments (axial loading)






crossed

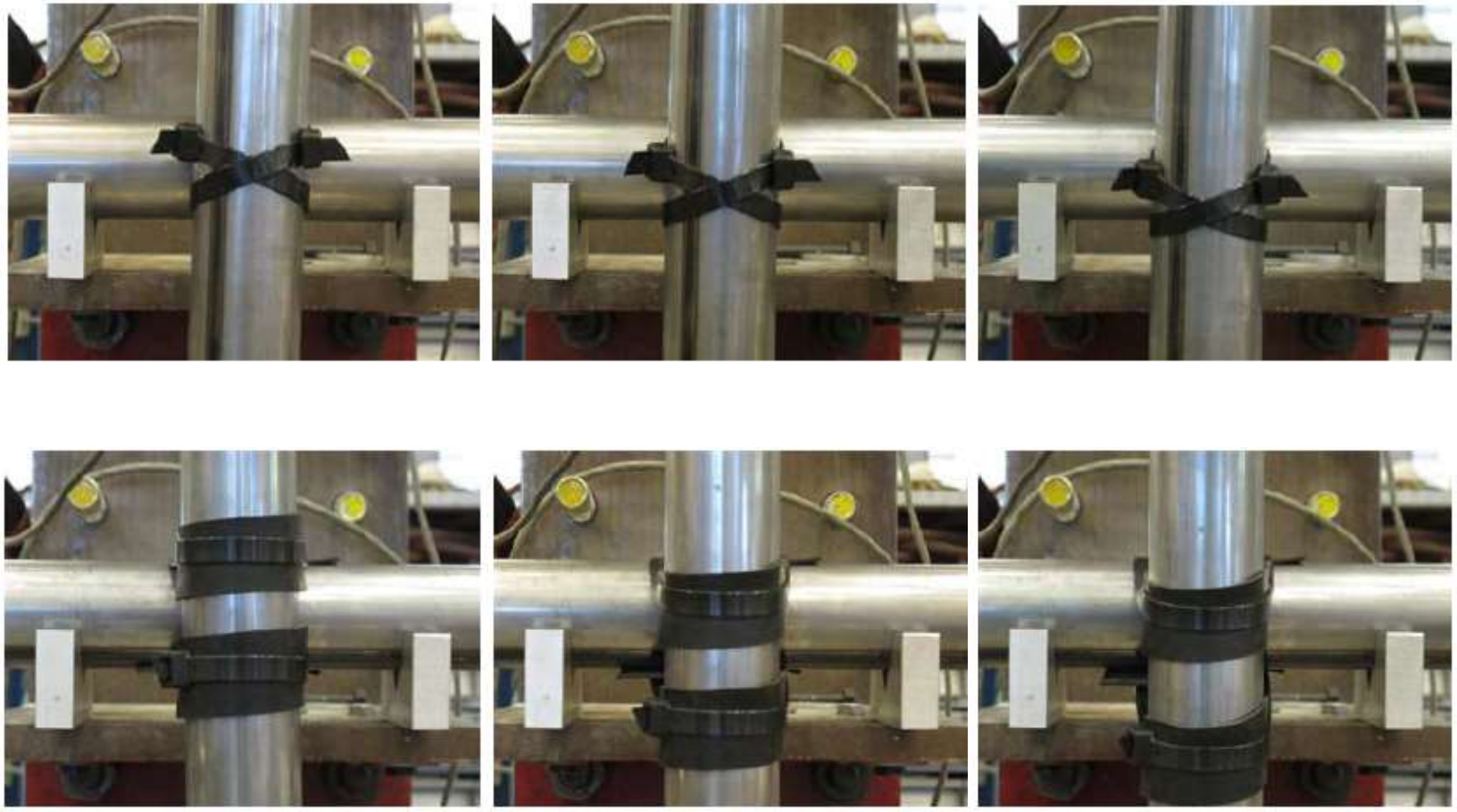

low friction


high friction


extra tension

5. Connection optimization

Impending friction experiments (axial loading)

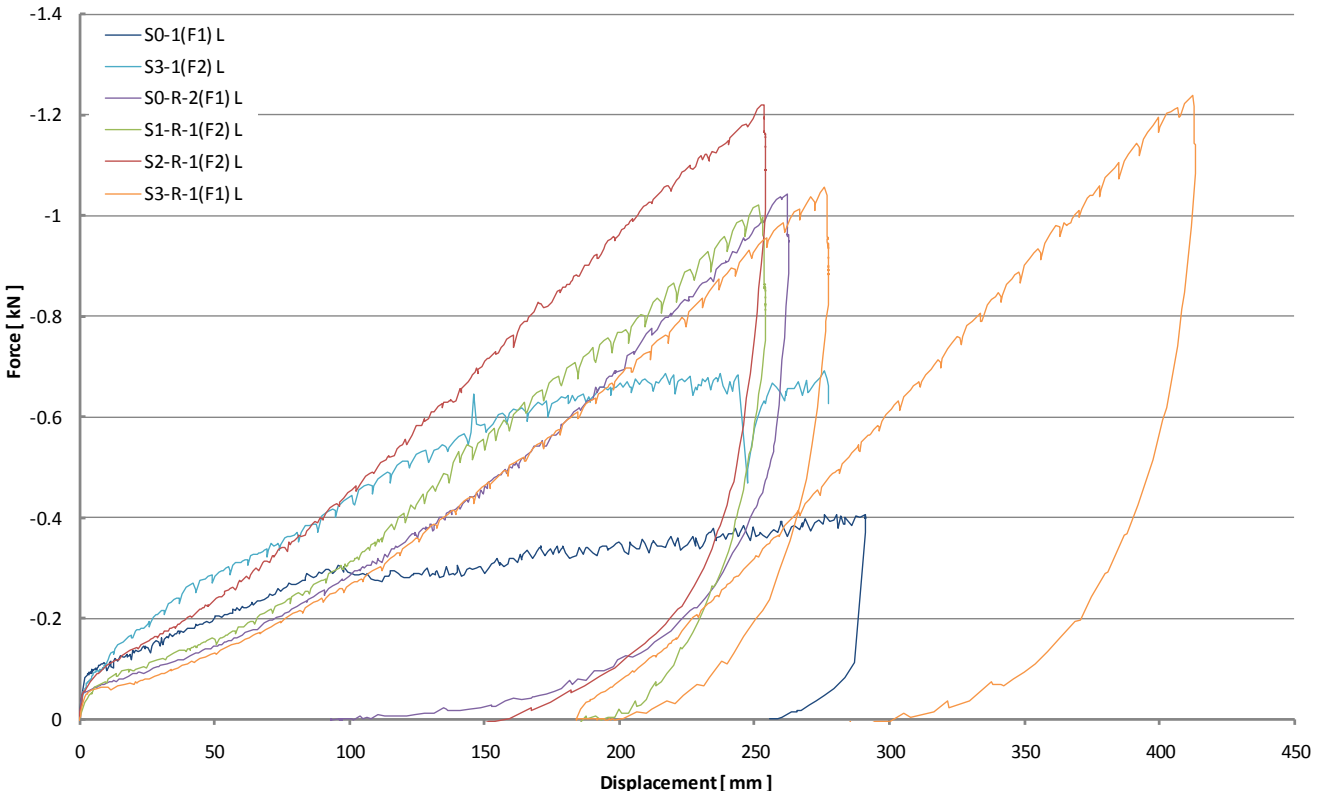


5. Connection optimization

Rotational stiffness experiments (lateral loading)

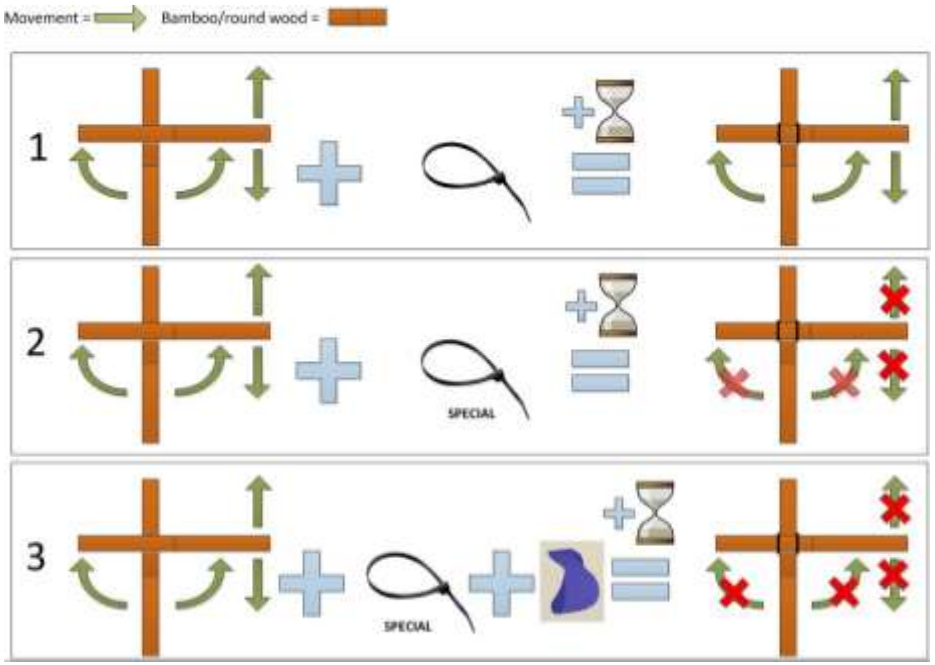
5. Connection optimization

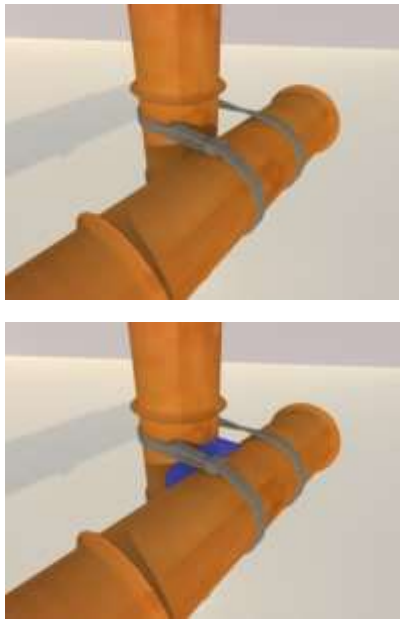
Rotational stiffness experiments (lateral loading)



6. Conclusions

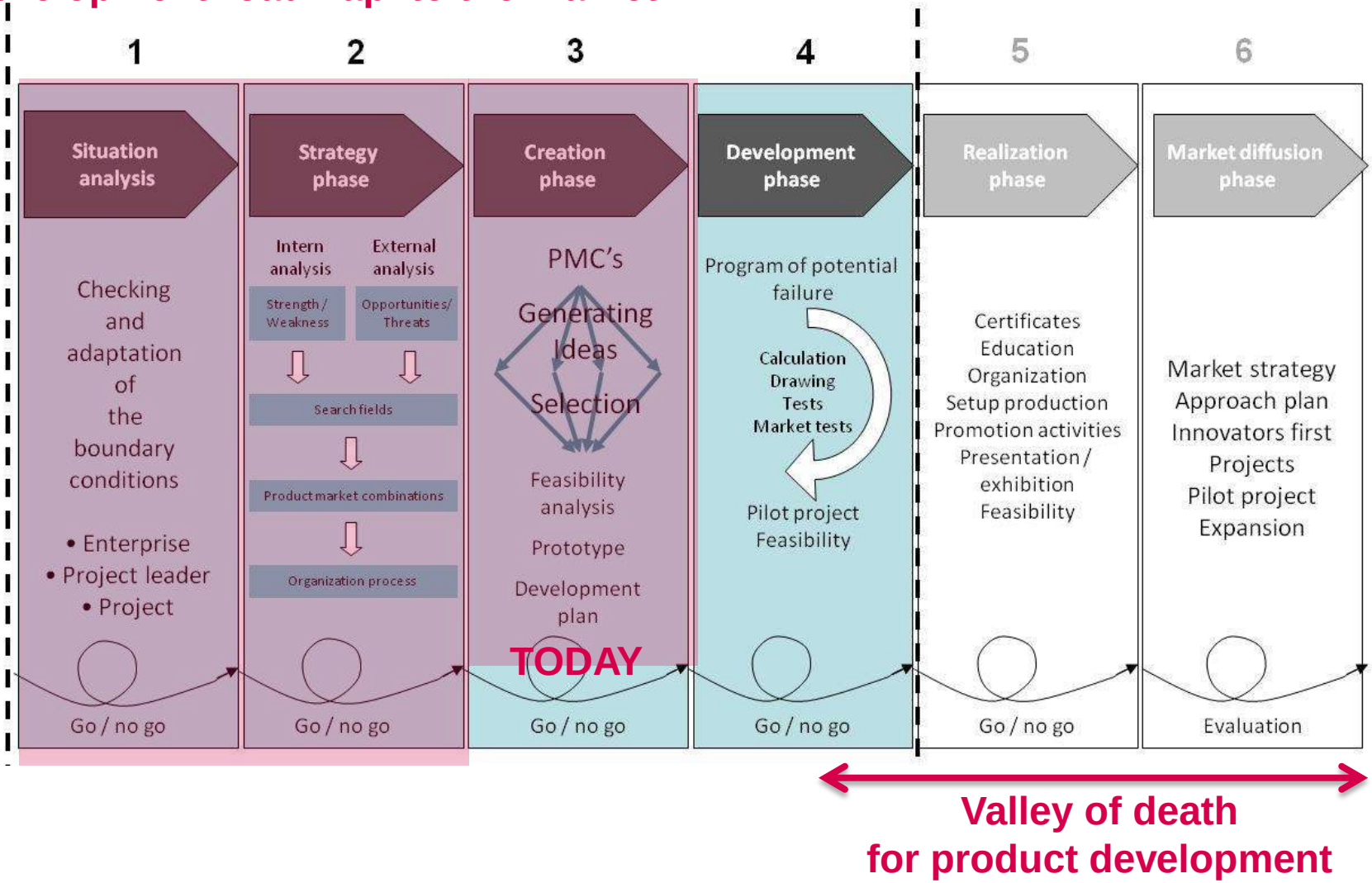
- **Conventional tie-wraps are versatile and intuitive in use, but NOT suitable for safe structural connections**
- **Friction between poles and straps under axial loading can be substantially increased by applying friction-increasing properties/component**
- **Rotational stiffness can be substantially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

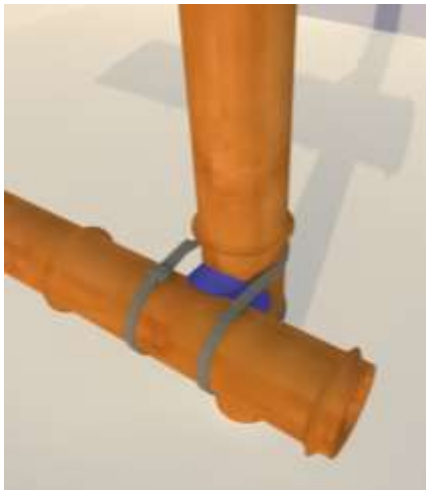
- **TU/e**

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!

Structural strap connections for bamboo and wooden shelter frames

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

TU/e Technische Universiteit Eindhoven University of Technology

Where innovation starts