Modelling of the Performance of Timber Structures

COST Action E55

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Reliability of timber trusses under eccentric loads

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Timber construction was, for decades, executed without any formal design

- **Simple plane structures**
- **Subject mostly to axial forces**

However, a loss of know-how lead to badly built structures with errors that can affect safety

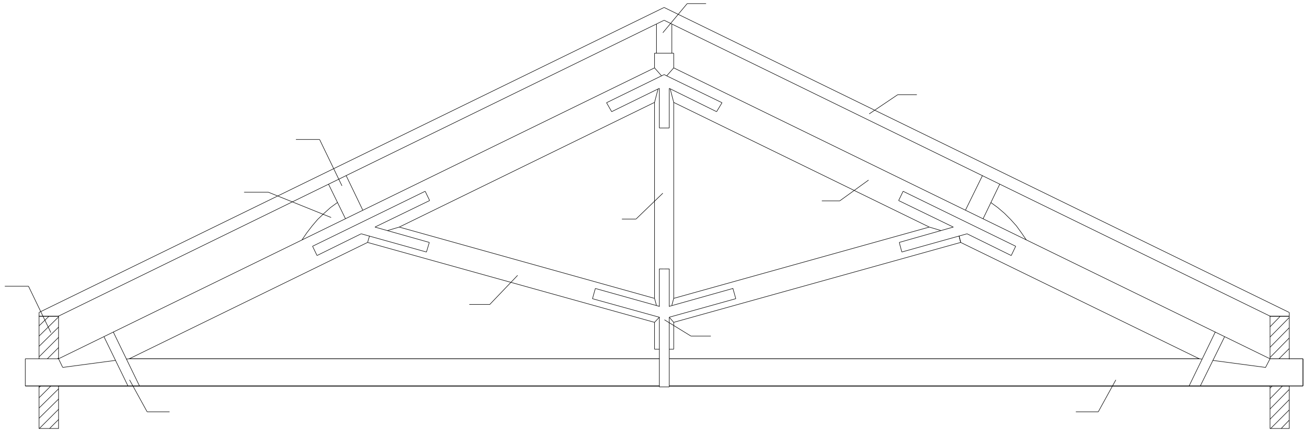
TRUSS TYPOLOGIES

SURVEY

Howe truss
7m < L < 12 m

King post truss
< 7 m

GEOMETRY

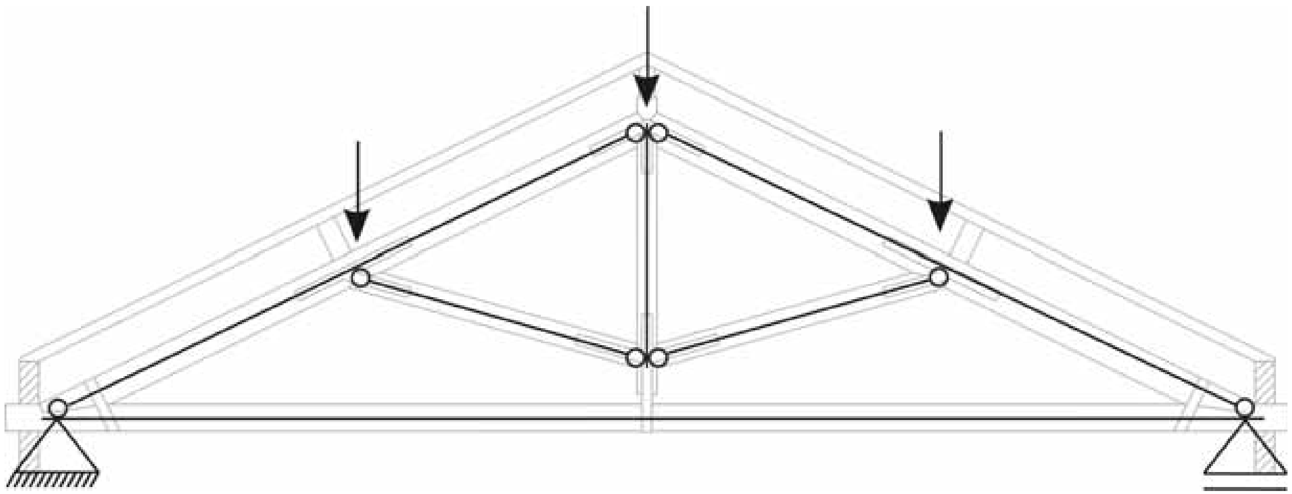


Free span close to 6m

Distance between trusses 3.5-4 m

Roof with 25-30º slope, covered with ceramic tiles

Wood elements of Maritime Pine, Chesnut and Eucaliptus



Loads applied at nodes

Stirrup strap working only in tension

- Rafters in compression and bending
- Tie-beam in tension

Common errors

SURVEY

Increase in bending moments in main rafters

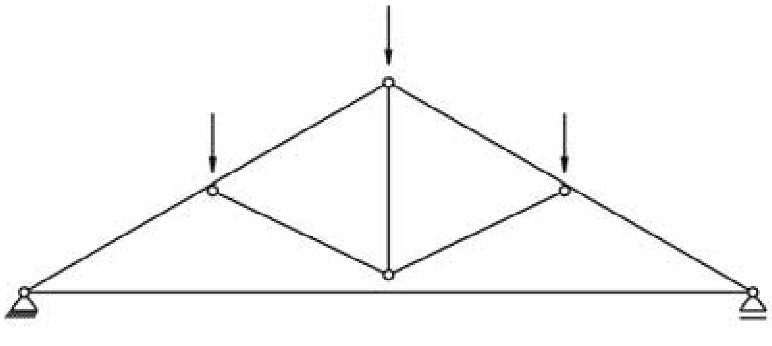
Common errors

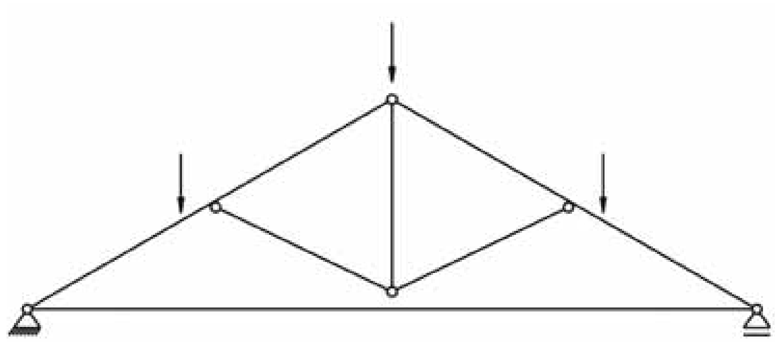
SURVEY

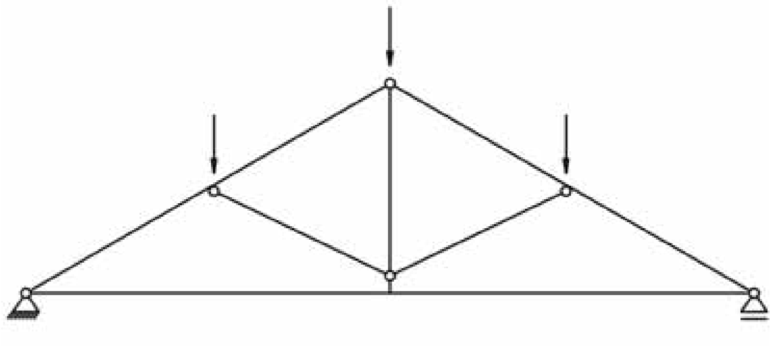
Increase in moments in tie-beam

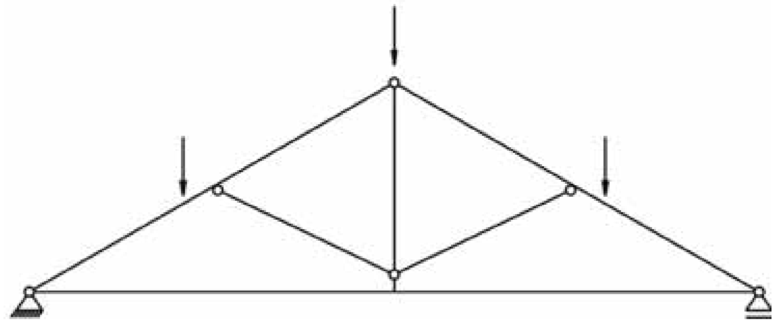
Common errors

SURVEY









In a deterministic framework, it is difficult to measure the effect of these errors on safety

A probabilistic analysis allows the comparison of probability of failure and reduction of safety in a consistent manner

Moreover, it is possible to analyze the safety of the structural system, rather than element by element

Actions	Permanent Loads	Normal	Typical Portuguese Tipologies
	Snow	Gamma	H = 1000m Portugal

Materials	Bending MOE	Lognormal	Maritime Pine
	Bending strenght	Lognormal	
	Tension paralell to grain	Lognormal	
	Compression paralell to grain	Lognormal	

Correlated

Based on JCSS model code, Portuguese specifications, and EC

Maritime Pine classified according to Portuguese Code

$f_{m,k}$ = 18 MPa

Dimensions

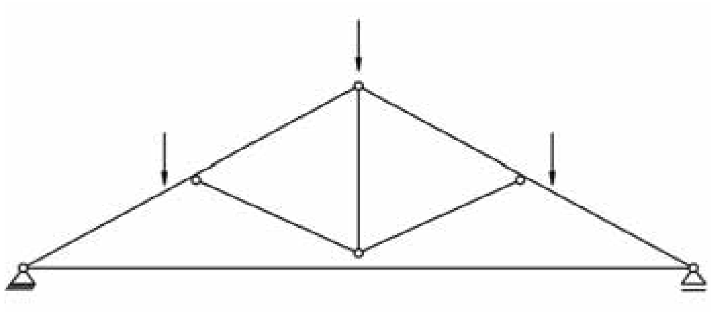
Principal Rafter	22×7 cm
Tie Beam	12×7 cm
Strut and King Post	7×7 cm

Over-designed Tie Beam

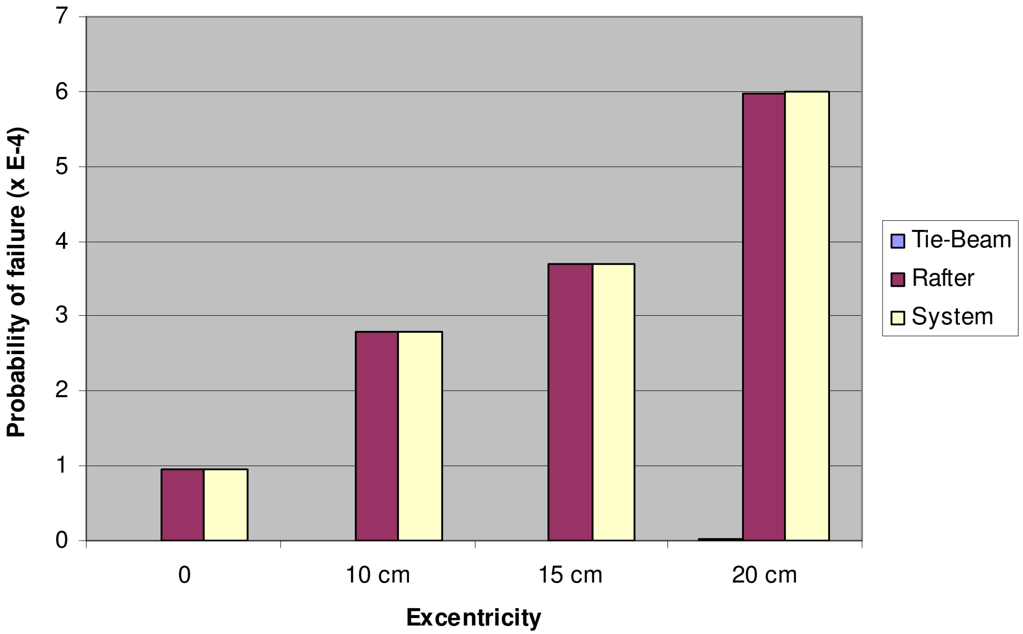
Dimensions

Principal Rafter	22×7 cm
Tie Beam	7×7 cm
Strut and King Post	7×7 cm

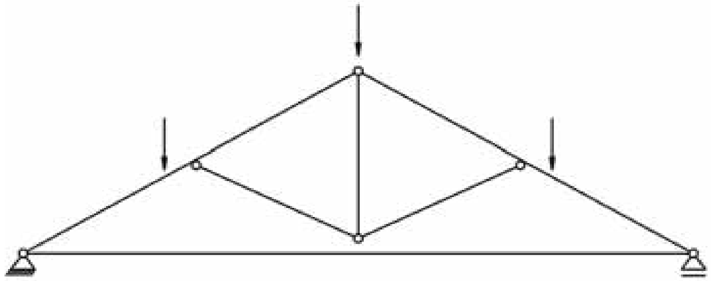
PURLINS ECCENTRICITY



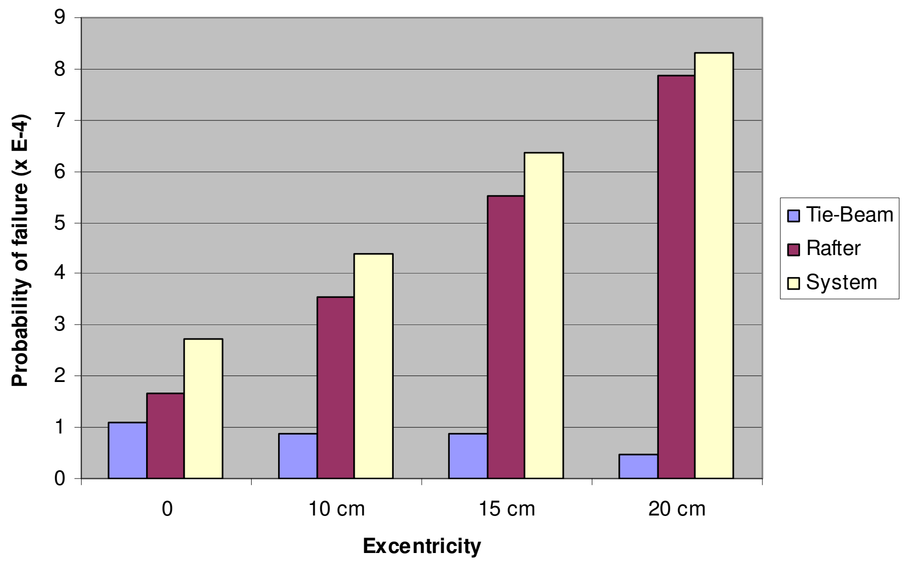
Strong tie-beam



PURLINS ECCENTRICITY

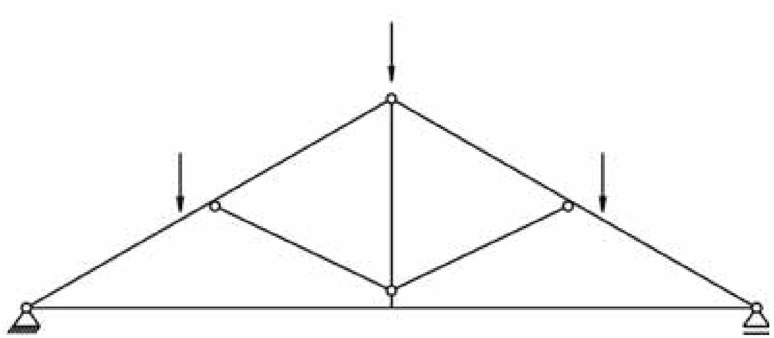


Weak tie-beam

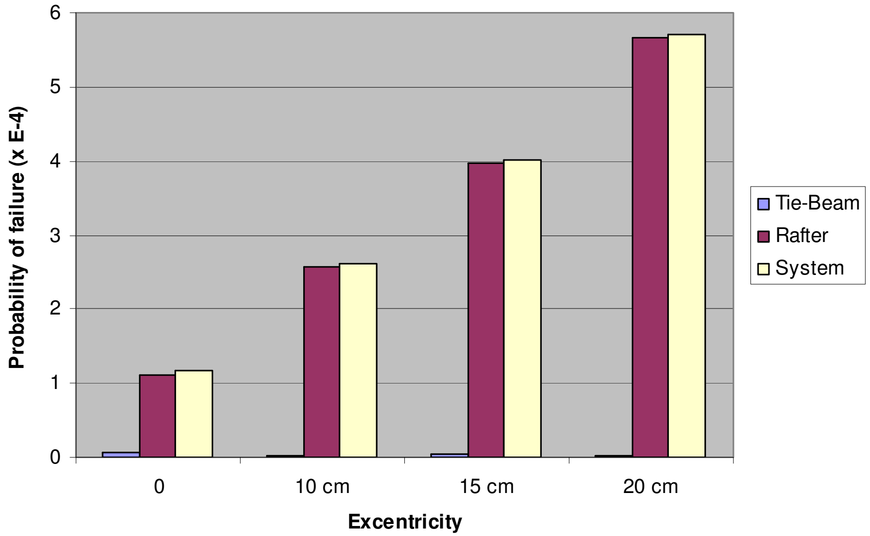


- Increase in probability of failure of tie-beam
- Increase in stresses in rafter
- Increase in p_f not so much associated with failure of tie-beam in particular for higher eccentricities

Compression connection and strong tie-beam

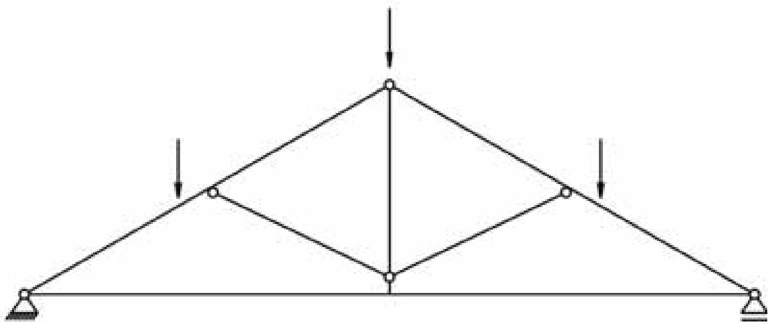


Strong tie-beam

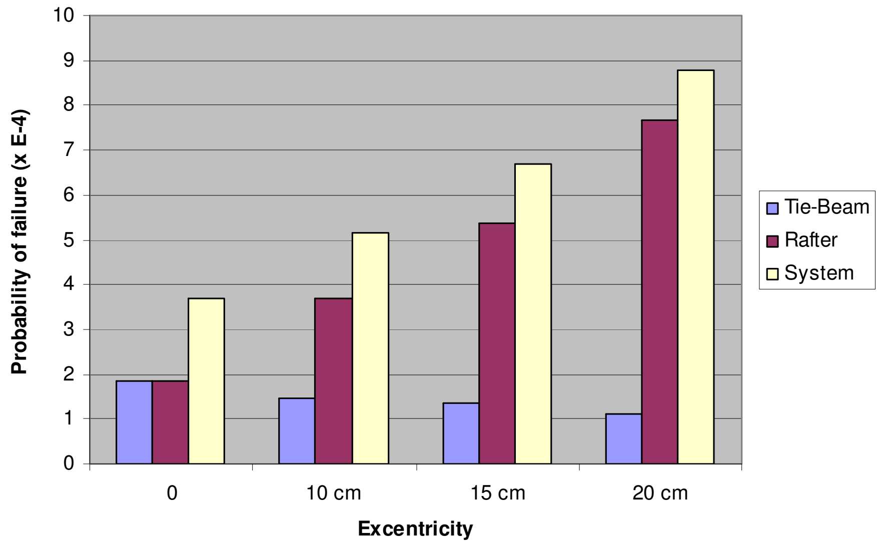


- Small changes in probability of failure, compared to correct connection
- Tie-beam is so over designed that increase in bending moments in not significant

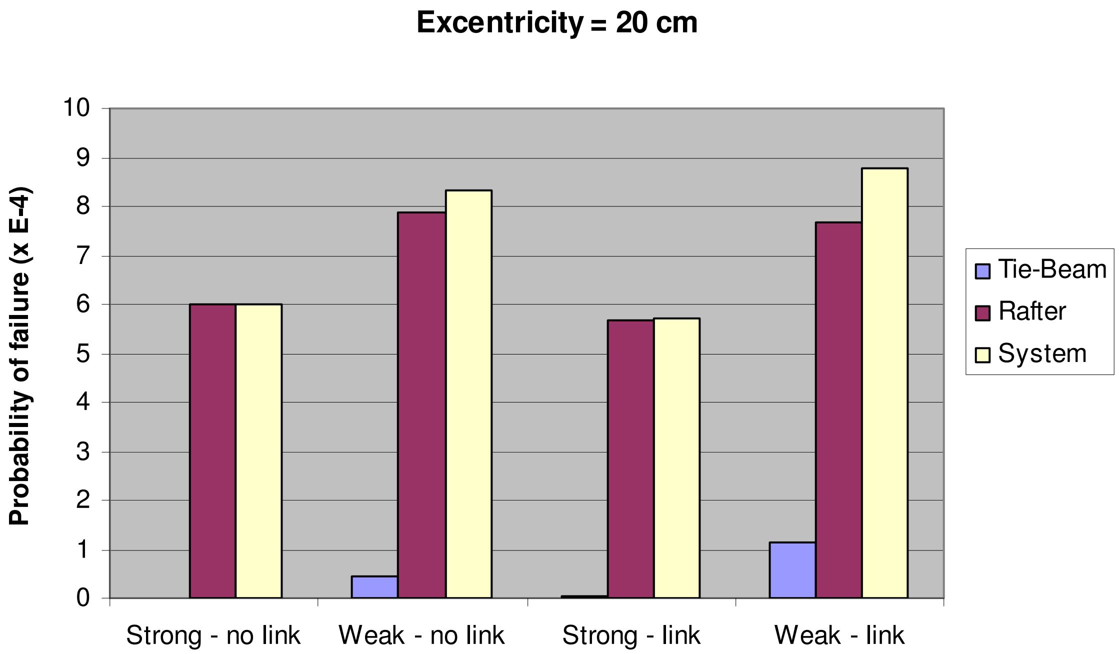
Compression connection and weak tie-beam



Weak tie-beam



- Increase in probability of failure of tie-beam, decreasing with eccentricities
- Increase in stresses in rafter
- Increase in p_f not so much associated with failure of tie-beam in particular for higher eccentricities


Excentricity = 20 cm
Probability of failure (x E-4)
10
9
8
7
6
5
4
3
2
1
0
Strong - no link
Weak - no link
Strong - link
Weak - link
Tie-Beam
Rafter
System

IDEALLY: **King post trusses as plane structure, with the loads applied in the joints, only presents normal stresses.**

IN PRACTICE: **significant variability in the joints geometry and connections techniques (stiffness). Purlins eccentricity. Misconceived connections king post / tie-beam. Patologies in rafter / tie-beam connections. Unsafe supports.**

Analyzed

- **Purlin eccentricity**
- **Rafter / tie-beam connections**

For the analyzed example

- **Eccentricities results in significant reduction in safety**
- **Defective king-post/tie-beam connections do not lead to such a significant reduction in safety due to traditionally over-designed tie-beams**