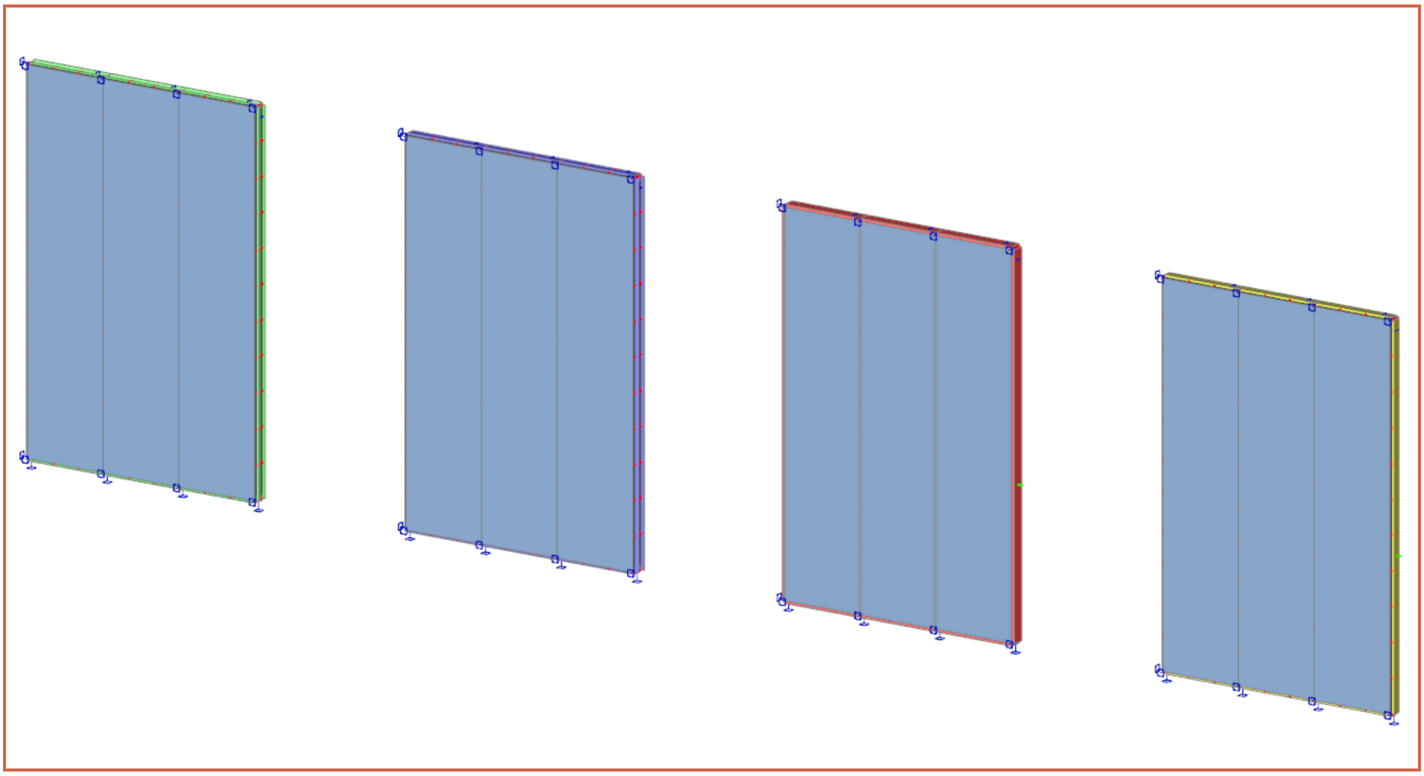
TECHNICAL REPORT

COMPARISON OF THE STRENGTH AND STIFFNESS OF THE JUUNOO WALL PARTITION KIT WITH OTHER COMMERCIAL SYSTEMS



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3 DOCUMENT HISTORY

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	Base document
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	Update of geometry
Revision 2	March 18th, 2019
	Additional comparisons added in summary

4 SUMMARY

This document includes a comparative study between 4 different commercial interior wall systems in terms of mechanical strength and stiffness. The wall systems are typically used in combination with plasterboard. The wall systems that are compared in this study are:

- A wooden structure built from rectangular beams of 38 x 89 mm,
- A wooden structure built from rectangular beams of 38 x 58 mm,
- A Metal Stud structure, and
- The JuuNoo system

Testing methods for the determination of the strength and safety of interior partition walls in Belgium are given in the technical WTCB report TV 233 of December 2017. For this comparative study, three of those testing methods were considered:

- A dynamic load due to a collision of a heavy soft body,
- A vertical static eccentric load, and
- A differential pressure

The results are presented in Figure 1 and Figure 2 in which the different systems are ordered from best to worst.

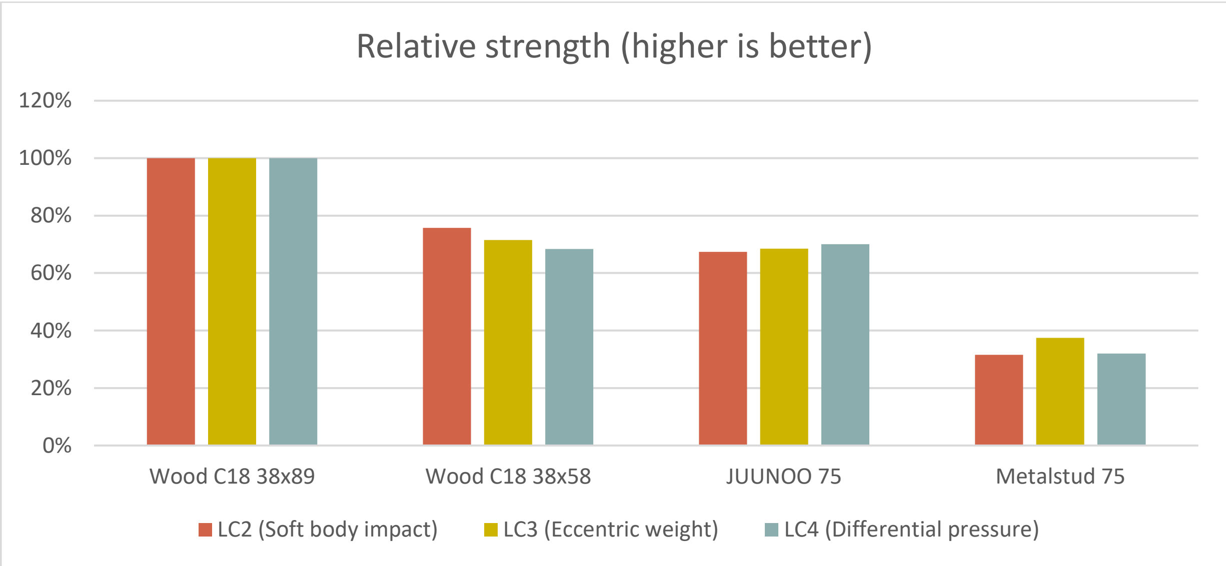


Figure 1 - Relative strength

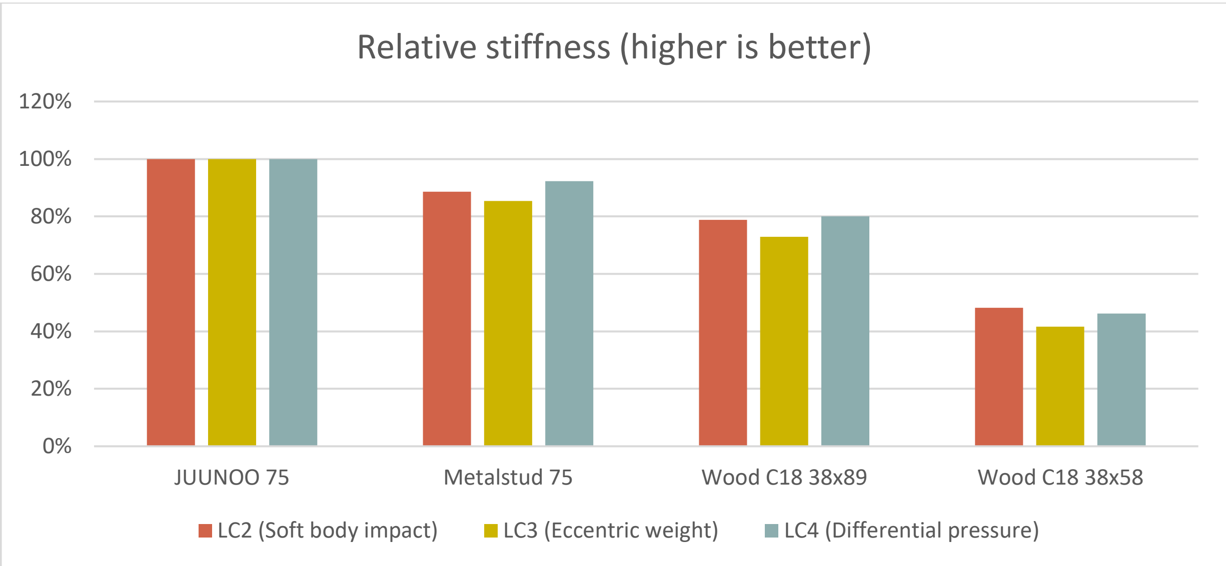


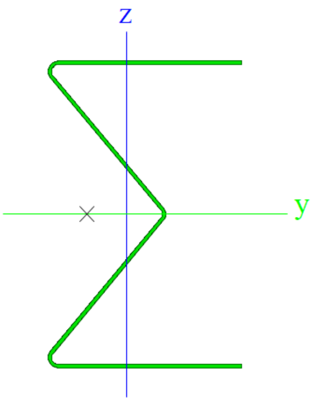
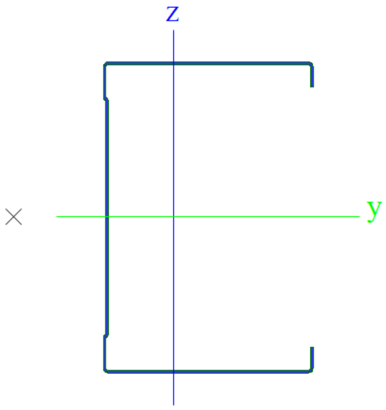
Figure 2 - Relative stiffness

From Figure 1 it is concluded that the wooden frames are the strongest, directly followed by the JuuNoo system, which is approximately as strong as a 38 x 58 mm wooden structure. The frame with the lowest strength is the one built from Metal Stud profiles, which is ½ to ⅓ weaker than the JuuNoo system. The wooden frames, however, have a much lower stiffness than the steel structures; this is concluded from Figure 2. The JuuNoo system has the highest stiffness, directly followed by the Metal Stud frames which is 10% more flexible.

By directly comparing the performance of the JuuNoo system with Metal Stud frames using Figure 1, it is concluded that JuuNoo frames are 76% stronger. This is a direct consequence of their cross sectional properties. Comparing the general section properties, summarized in Table 1, the strong section modulus (around the local y-axis) of the JuuNoo profile is 20% greater than that of the Metal Stud profile. In the other direction, the section modulus of the JuuNoo profile is 25% smaller than that of the Metal Stud profile.

Also note that, according to Eurocode, the true "effective" properties of thin walled cross sections loaded in bending are calculated in a different manner and depend on the stresses in the different parts of the profile. The effective section moduli calculated according to EN 1993-1-5 §4.4 are presented at the bottom of Table 1.

Table 1 - Section properties of the JuuNoo and Metal Stud profiles

JuuNoo	Metal Stud
▪ Surface area A = 146.53 mm² ▪ Section modulus around the y-axis $W_{el,y}$ = 3,477 mm³ ▪ Section modulus around the z-axis $W_{el,z}$ = 775 mm³	▪ Surface area A = 110.84 mm² ▪ Section modulus around the y-axis $W_{el,y}$ = 2,905 mm³ ▪ Section modulus around the z-axis $W_{el,z}$ = 1,041 mm³
	
▪ True section modulus around y-axis $W_{eff,y}$ = 2,024 mm³ ▪ True section modulus around z-axis $W_{eff,z}$ = 776 mm³	▪ True section modulus around y-axis $W_{eff,y}$ = 895 mm³ ▪ True section modulus around z-axis $W_{eff,z}$ = 1,030 mm³

In the GYPROC instruction manual, the maximum height of a plasterboard wall constructed with MSV75 profiles is set from 300 cm to 550 cm, depending on the number of layers of plasterboard. Because walls constructed with JuuNoo profiles are stronger than those constructed with MSV75 profiles, **it is concluded that walls created using the JuuNoo system can be at least as tall.**

Maximale hoogte van een wand?

Afhankelijk van de hoogte van de wand of voorzetwand zal je andere soorten MSH/
MSV-profielen moeten gebruiken en/of dubbel beplaten.

Voorzetwanden	MSH50/MSV50	MSH75/MSV75	MSH100/MSV100
enkel beplating	240 cm	300 cm	400 cm
dubbel beplating	260 cm	350 cm	425 cm
Scheidingswanden	**MSH50/MSV50**	**MSH75/MSV75**	**MSH100/MSV100**
enkel beplating	300 cm	450 cm	500 cm
dubbel beplating	400 cm	550 cm	650 cm

De opgegeven waarden gelden voor gebouwen zoals woningen, hotels, kantoren enz. en bij gebruik van Gyproc-platen van 12,5 mm en Gyproc Metal Stud-profielen (staaldikte 0,6 mm).

Figure 3 - Extract from the "GYPROC Doe-Boek" version 2011, page 21

For more information concerning the comparative study, please refer to the next chapters.

5 REFERENCED DOCUMENTS AND FILES

5.1 INPUT DOCUMENTS AND FILES

Type	Description or reference
Digital file	I75 + C75_V16.stp
Digital file	Metalstud_75mm.dxf
Instruction manual	Gyproc Doe-Boek - De praktische handleiding voor de creatieve doe-het-zelver, Nieuwe editie 2011, 112 p.

5.2 REFERENCED STANDARDS, GUIDELINES OR OTHER LITERATURE

Type	Description or reference
Standard	EN 1990 - Eurocode - Basis of structural design (2002)
Standard	EN 1993-1-1 - Eurocode 3 - Design of steel structures - Part 1-1 - General rules and rules for buildings (2005)
Standard	EN 1995-1-1 - Eurocode 5 - Design of timber structures - Part 1-1 - General - Common rules and rules for buildings (2004)
Standard	EN 10346 - Continuously hot-dip coated steel flat products - Technical delivery conditions (2009)
Standard	EN 338 - Structural timber - Strength classes (2016)
Technical document	WTCB TV 233, December 2007
PhD Thesis	Thermal and mechanical properties of gypsum boards and their influences on fire resistance of gypsum board based systems, Ima Rahmanian, University of Manchester, Faculty of Engineering and Physical Sciences (2011)

6 SOFTWARE

Type	Name	Version
Finite element software	Scia Engineer	2018
Office software	Microsoft Office	2016

7 FINITE ELEMENT MODEL

7.1 GEOMETRY

Four partition walls with different interior structure were modelled in SCIA Engineer, based on the input provided by JuNovation. The main features of the model are:

- 4 walls with identical build-up were modelled. A single wall consists of 4 vertical profiles and two horizontal profiles at the top and the bottom.
- The internal structures of the walls were modelled using deformable beams with the appropriate sections.
- The plasterboard panels were modelled using thin shells which were attached using stiff dummy beams at regular intervals representing the screws between the plasterboard and the frame.

The model is illustrated in Figure 4 and Figure 5.

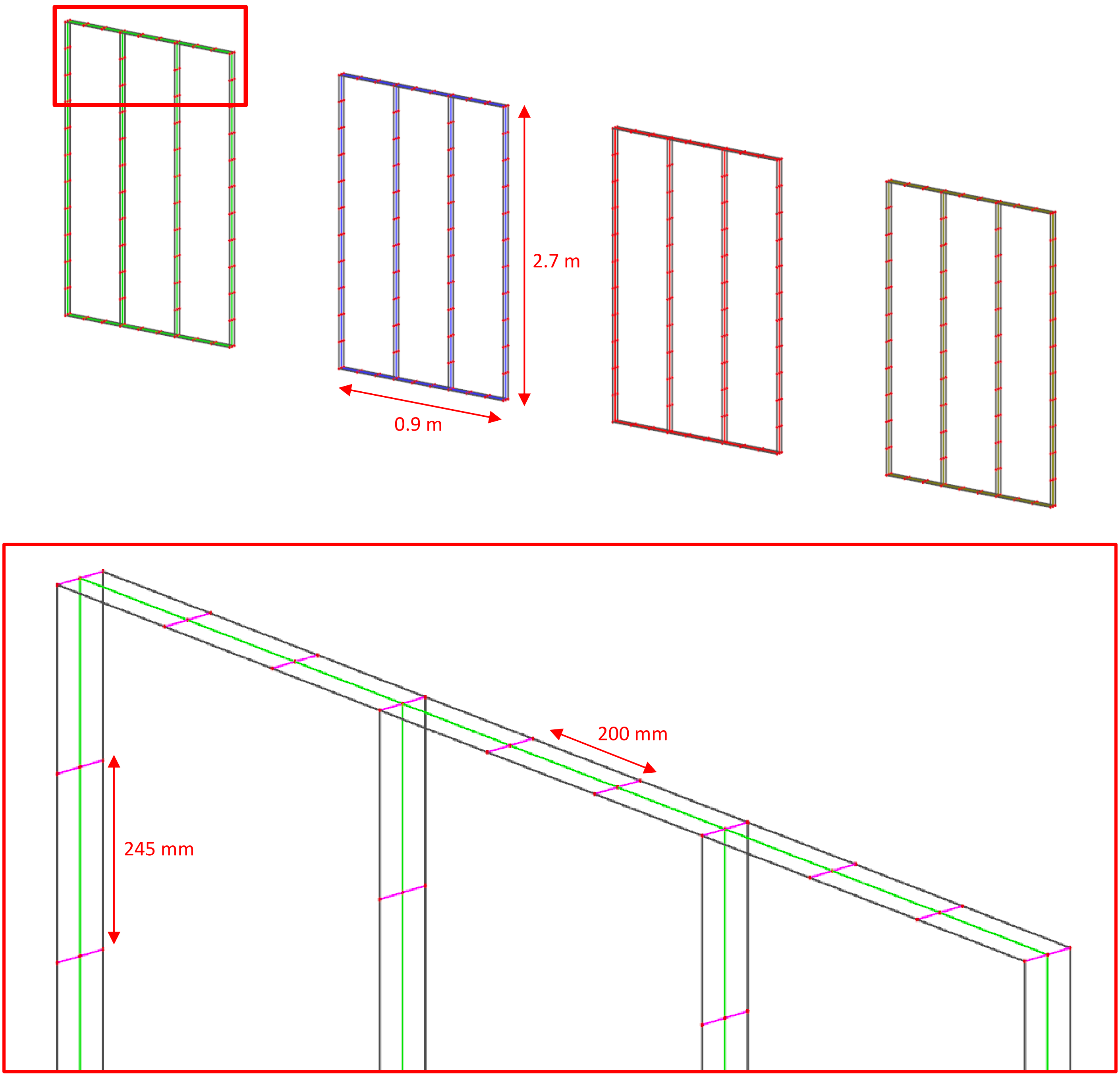


Figure 4 - Finite element model - wireframe view

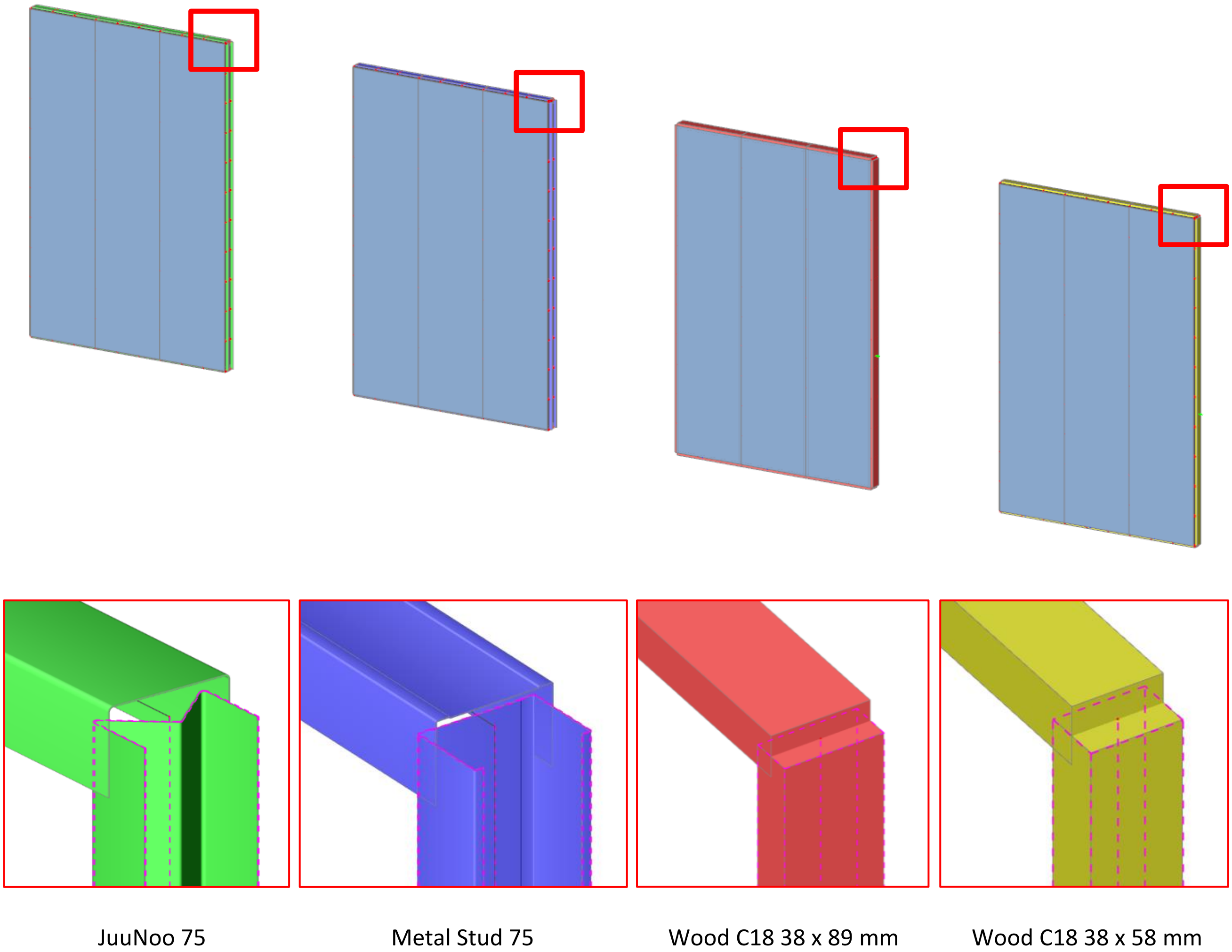


Figure 5 - Finite element model - sections visualized

7.2 MATERIAL PROPERTIES

7.2.1 S250GD

Name	S250GD
Applies to	JuuNoo and Metal Stud profiles
Material model	Linear elastic
Reference	EN 10346, EN 1993-1-1
Modulus of elasticity [GPa]	210
Coefficient of Poisson	0.3
Density [kg/m^3]	7850
Yield strength [MPa]	250
Ultimate tensile strength [MPa]	330
Additional remarks	/

7.2.2 C18

Name	C18
Applies to	Wooden frames
Material model	Linear elastic
Reference	EN 338, EN 1995-1-1
Modulus of elasticity [GPa]	9
Coefficient of Poisson	0
Density [kg/m^3]	380
Bending strength $f_{m,k}$ [MPa]	18.0
Tensile strength $f_{t,0,k}$ [MPa]	10.0
Tensile strength $f_{t,90,k}$ [MPa]	0.8
Compressive strength $f_{c,0,k}$ [MPa]	18.0
Compressive strength $f_{c,90,k}$ [MPa]	2.2
Shear strength $f_{v,k}$ [MPa]	3.4
Modulus $E_{0,05}$ [MPa]	6000
Modulus $E_{90,mean}$ [MPa]	300
Additional remarks	/

7.2.3 PLASTERBOARD

Name	Plasterboard
Applies to	Plasterboard plates
Material model	Linear elastic
Reference	Phd. Thesis, see chapter 5.2
Modulus of elasticity [GPa]	1.57
Coefficient of Poisson	0.3
Density [kg/m³]	742
Ultimate tensile strength [MPa]	/*
Additional remarks	*The stresses in the plasterboard are not checked as this is not the goal of the analyses.

7.3 LOAD CASES

Three load cases were considered:

- A dynamic load due to a collision of a heavy soft body,
- A vertical static eccentric load, and
- A differential pressure

7.3.1 DYNAMIC LOAD DUE TO A COLLISION OF A HEAVY SOFT BODY

According to the document TV 233, the wall has to withstand a collision with a heavy soft body with a mass of 50 kg; dropped as illustrated in Figure 6. Considering usage class III, the wall is to withstand an impact of 300 Nm.

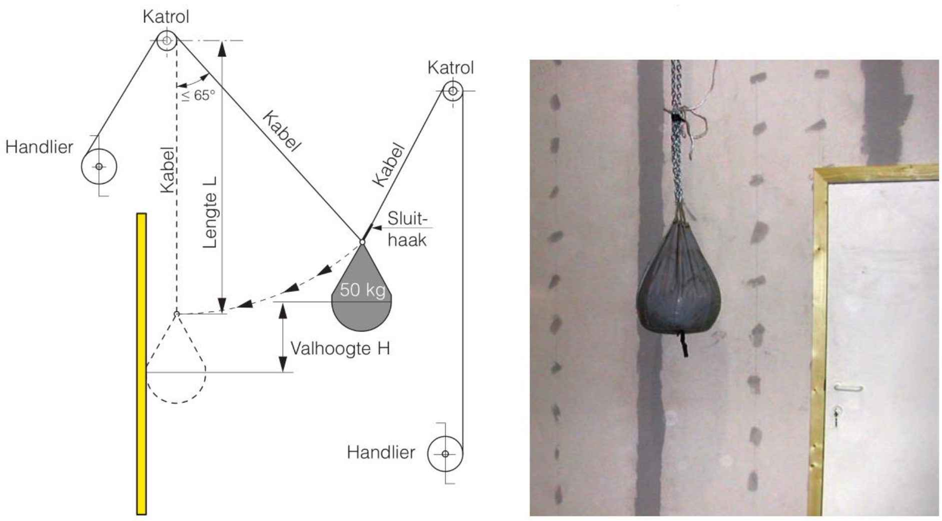


Figure 6 - Extract from WTCB TV 233, figure 11 – Experimental set-up for determining the resistance against shocks of a heavy soft body

To determine the equivalent static horizontal load of the collision, a preliminary model with a horizontal concentrated load of 1 kN is created to determine the elastic response of the panels. For a load of 1 kN the panel deforms 11.374 mm. Therefore, the stiffness of the set-up is 87,919 N/m.

The maximum theoretical indentation for an impact energy of 300 Nm is:

$$x = \sqrt{\frac{2E}{k}} = \sqrt{\frac{2 \cdot 300}{87919}} = 0.0826\ m$$

This value corresponds to a load of 87,919 x 0.0826 = 7,263 N ≈ 7,000 N. This force was applied at the centre of the middle panel as illustrated in Figure 7.

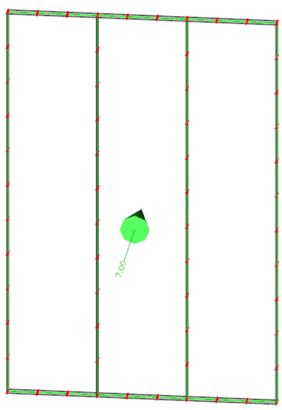
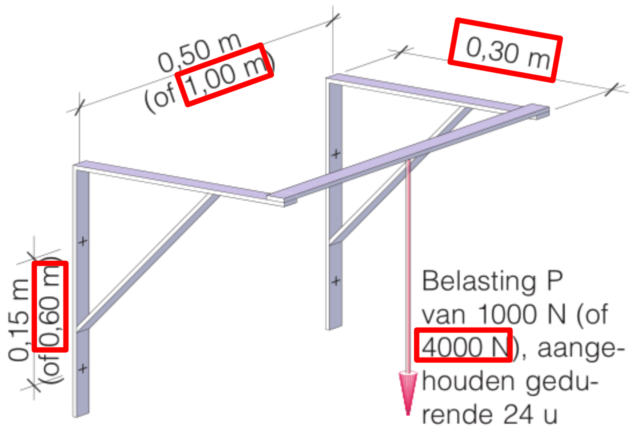


Figure 7 - Dynamic impact load

7.3.2 VERTICAL STATIC ECCENTRIC LOAD

The wall has to withstand a vertical static eccentric weight of 4000 N at a distance of 0.3 m as illustrated in Figure 8.



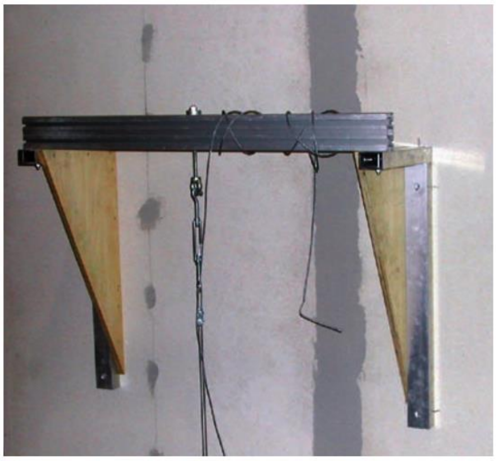


Figure 8 - Extract from WTCB TV 233, figure 14 – Experimental set up for the determination of the resistance against a vertical eccentric load

The load was applied in the model as 8 concentrated loads of 1 kN as illustrated in Figure 9.

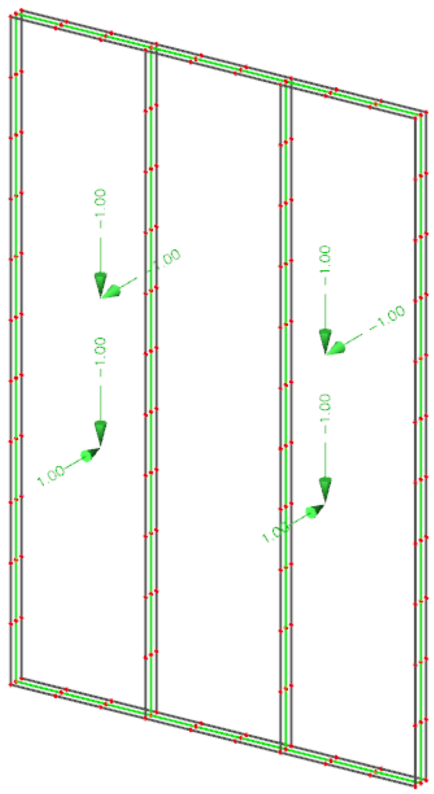


Figure 9 - Eccentric weight

7.3.3 DIFFERENTIAL PRESSURE

An arbitrary pressure of 600 Pa was taken into account, see Figure 10.

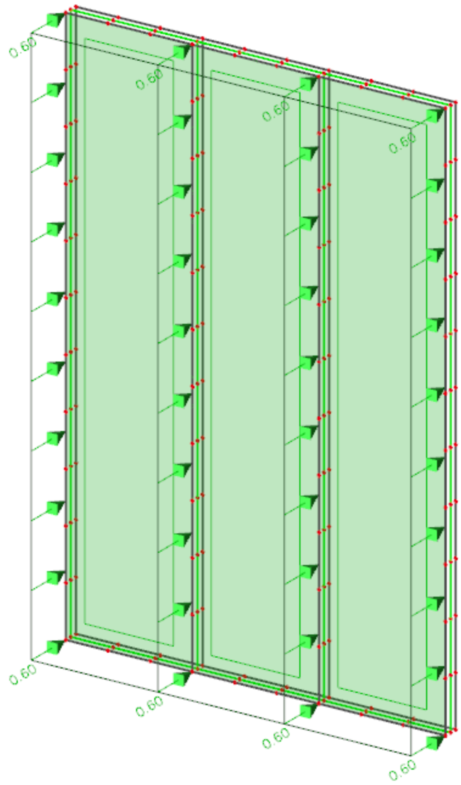


Figure 10 - Differential pressure

7.4 BOUNDARY CONDITIONS

The top and bottom nodes of the vertical members were fully fixed. The boundary conditions are identical for all considered frames, see Figure 11.

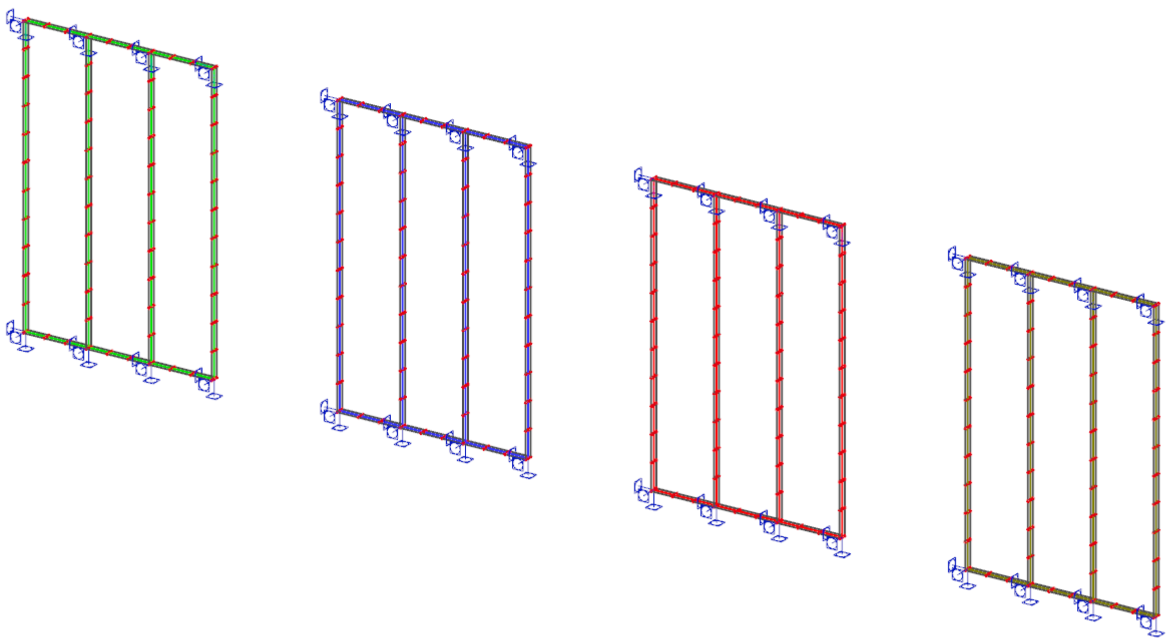


Figure 11 - Boundary conditions

8 RESULTS

8.1 INTRODUCTION

The results of the finite element analyses are presented in this section. They are organized as follows:

- Section 8.2: Sectional check of the steel members
- Section 8.3: Sectional check of the wooden beams
- Section 8.4: Deformation
- Section 8.5: Comparison

Note that the results of the steel frames are presented separately from the results of the wooden frames because the materials are checked using a different part of Eurocode.

8.2 CHECK OF THE STEEL MEMBERS (JUUNOO AND METAL STUD) ACCORDING TO EN 1993-1-1

The members are checked using the automatic sectional check of SCIA Engineer. The unity checks or sectional utilizations are summarized in Table 2 and illustrated in Figure 12 to Figure 14.

Table 2 - Unity checks of the steel members

	LC2 (Soft body impact)	LC3 (Eccentric weight)	LC4 (Differential pressure)
JuuNoo 75	1.57	0.23	0.32
Metal Stud 75	3.35	0.42	0.70

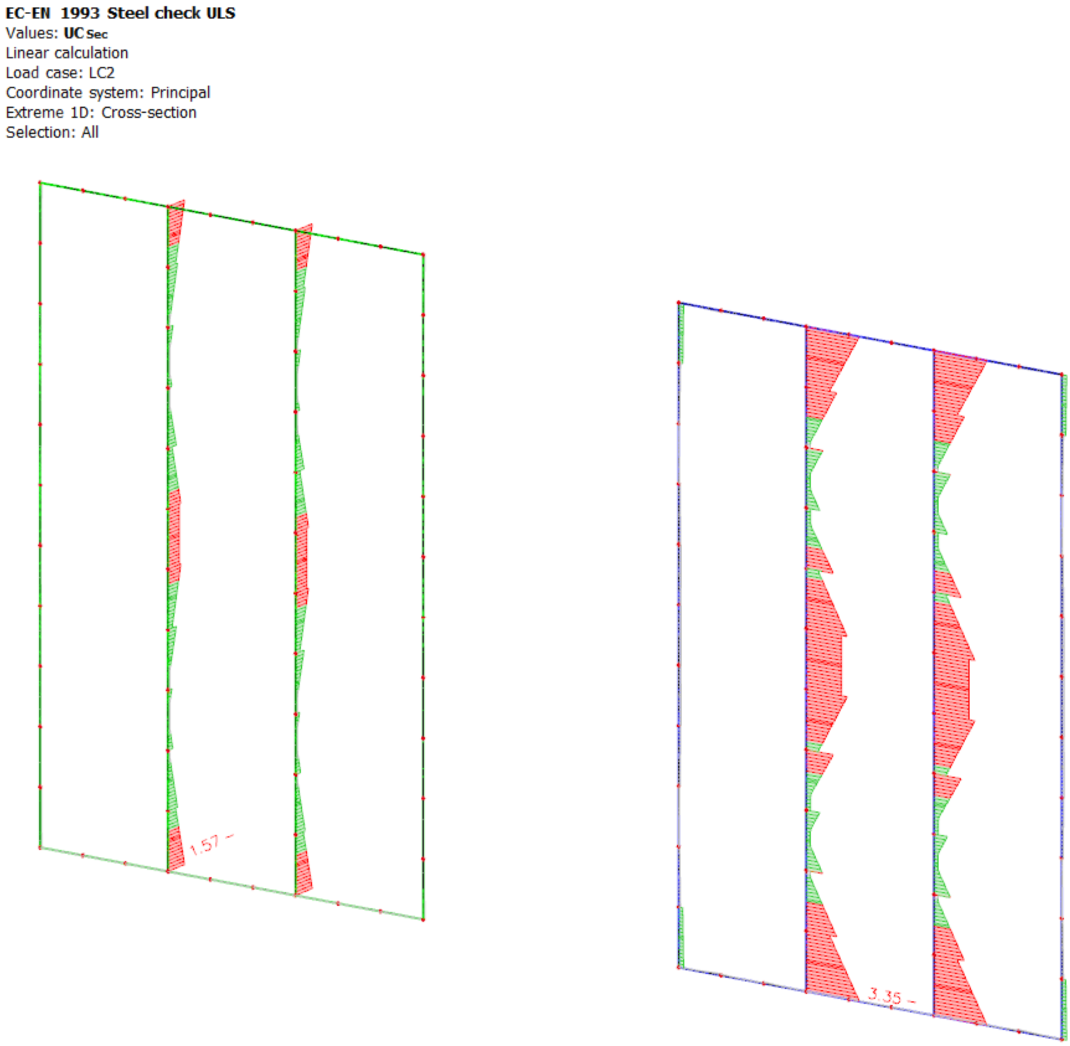


Figure 12 - Unity checks - soft body impact load

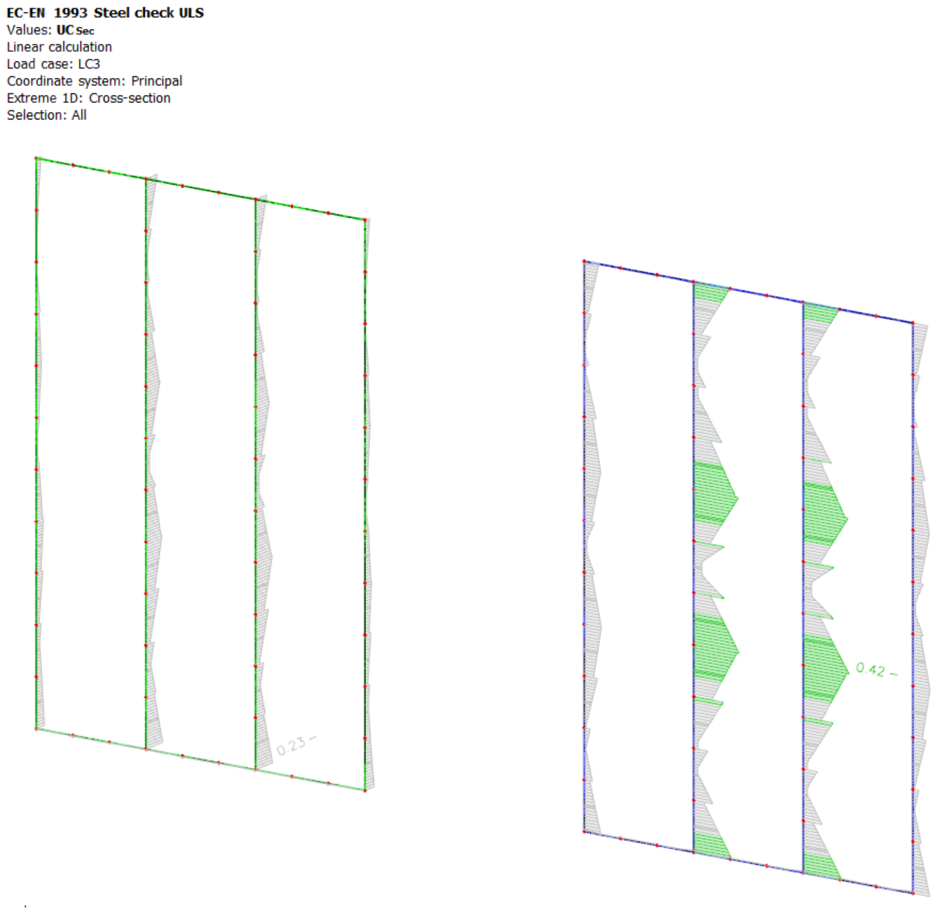


Figure 13 - Unity checks - eccentric weight

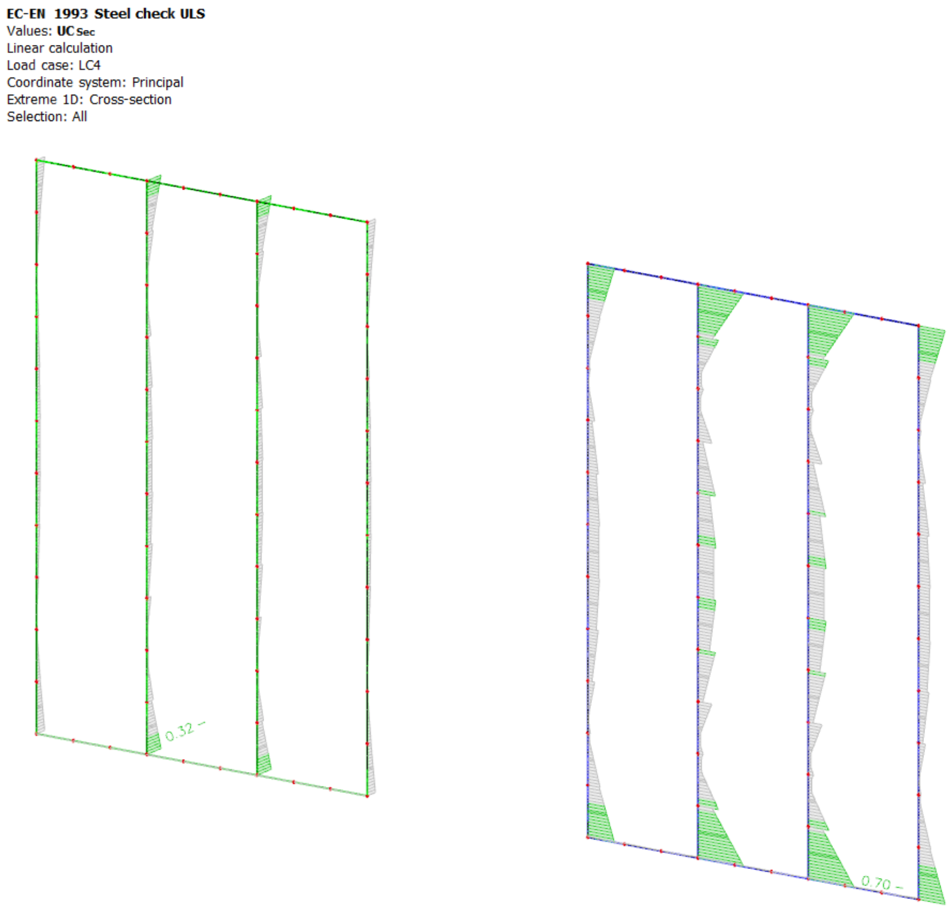


Figure 14 - Unity checks - differential pressure

8.3 CHECK OF THE WOODEN BEAMS ACCORDING TO EN 1995-1-1

The wooden beams are manually checked according to EN 1995-1-1. The main stress components in the beams are:

- Normal stress (mainly due to bending), and
- Shear stress due to horizontal loads

The stresses were extracted from SCIA Engineer, processed according to EN 1995-1-1 and summarized in Table 3 and Table 4.

Table 3 - Stress components in the wooden sections 38 x 89 mm

	LC2 (Soft body impact)	LC3 (Eccentric weight)	LC4 (Differential pressure)
Normal (bending) stress $\sigma_{m,y,d}$ [MPa]	14.2	1.8	3
Shear stress τ_d [MPa]	0.9	0.3	0.2
Combined stress $\sigma_{c,\alpha,d}$ [MPa]	13.45	11.58	13.41
Combined stress strength $f_{c,\alpha,d}$ [MPa]	14.71	13.29	14.66
Stress angle α [°]	3.627	9.462	3.814
γ_M	1.3		
k_h	1.110		
k_{mod}	0.9		
$f_{m,d}$ [MPa]	13.83		
$f_{t,0,d}$ [MPa]	7.685		
$f_{c,0,d}$ [MPa]	13.83		
$f_{c,90,d}$ [MPa]	1.691		
$f_{v,d}$ [MPa]	2.613		
$k_{c,90}$	1.0		
Bending check	1.03	0.13	0.22
Shear check	0.34	0.11	0.08
Combined stress check	**1.06**	**0.16**	**0.22**

Table 4 - Stress components in the wooden sections 38 x 58 mm

	LC2 (Soft body impact)	LC3 (Eccentric weight)	LC4 (Differential pressure)
Normal (bending) stress $\sigma_{m,y,d}$ [MPa]	20.5	2.9	4.8
Shear stress τ_d [MPa]	1.2	0.4	0.3
Combined stress $\sigma_{c,\alpha,d}$ [MPa]	20.54	2.93	4.81
Combined stress strength $f_{c,\alpha,d}$ [MPa]	14.71	13.29	14.66
Stress angle α [°]	3.350	7.853	3.576
γ_M	1.3		
k_h	1.209		
k_{mod}	0.9		
$f_{m,d}$ [MPa]	15.07		
$f_{t,0,d}$ [MPa]	8.372		
$f_{c,0,d}$ [MPa]	15.07		
$f_{c,90,d}$ [MPa]	1.842		
$f_{v,d}$ [MPa]	2.846		
$k_{c,90}$	1.0		
Bending check	1.36	0.19	0.32
Shear check	0.42	0.14	0.11
Combined stress check	**1.40**	**0.22**	**0.33**

The maximum unity checks or sectional utilizations are summarized in Table 5.

Table 5 - Unity checks of the steel members

	LC2 (Soft body impact)	LC3 (Eccentric weight)	LC4 (Differential pressure)
Wood 38 x 89 mm	1.06	0.16	0.22
Wood 38 x 58 mm	1.40	0.22	0.33

8.4 DEFORMATIONS

The displacements per load case are summarized in Table 6 and illustrated in Figure 15 to Figure 17.

Table 6 - Maximum displacements in [mm]

	LC2 (Soft body impact)	LC3 (Eccentric weight)	LC4 (Differential pressure)
JuuNoo 75	7.8	0.35	1.2
Metal Stud 75	8.8	0.41	1.3
Wood 38 x 89 mm	9.9	0.48	1.5
Wood 38 x 58 mm	16.2	0.84	2.6

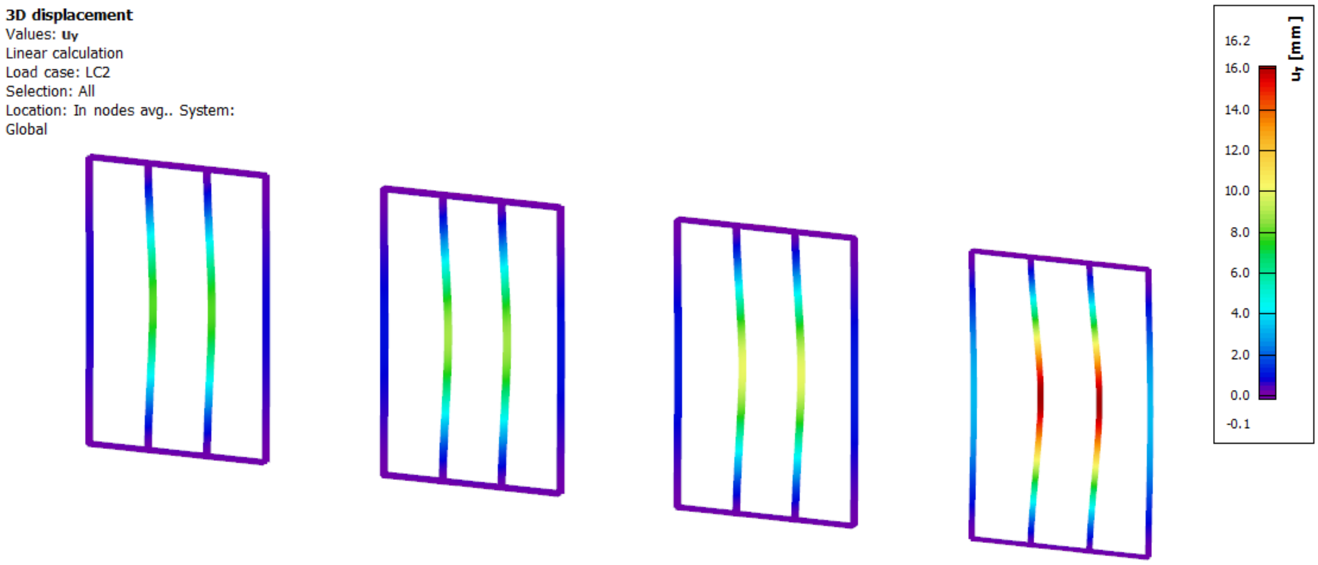


Figure 15 - Displacements caused by a soft body impact

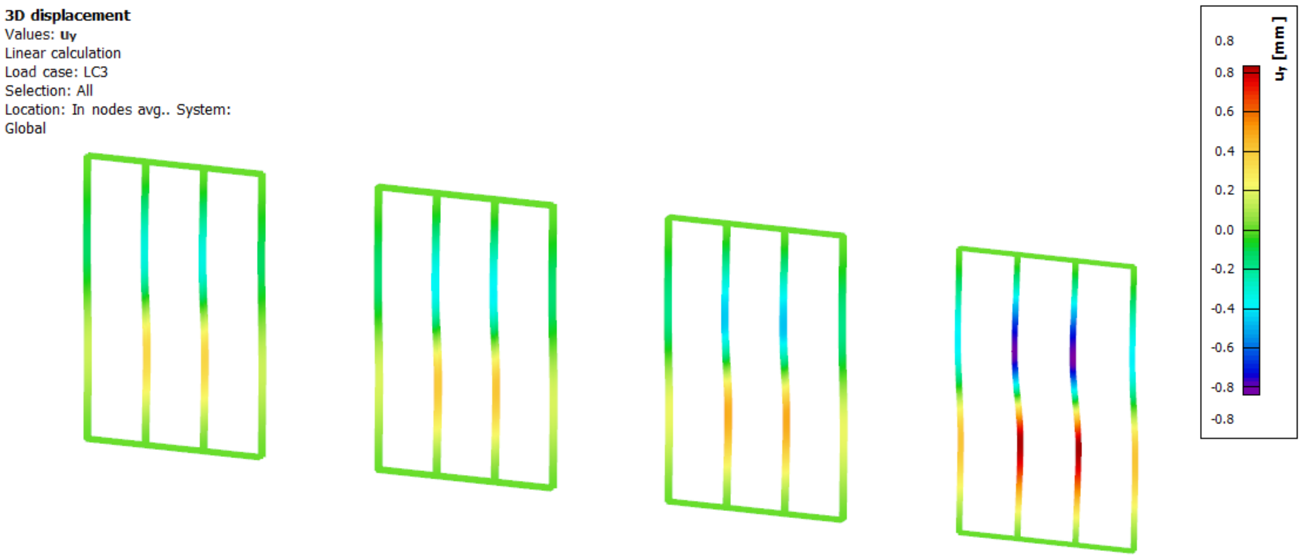


Figure 16 - Displacements caused by an eccentric weight

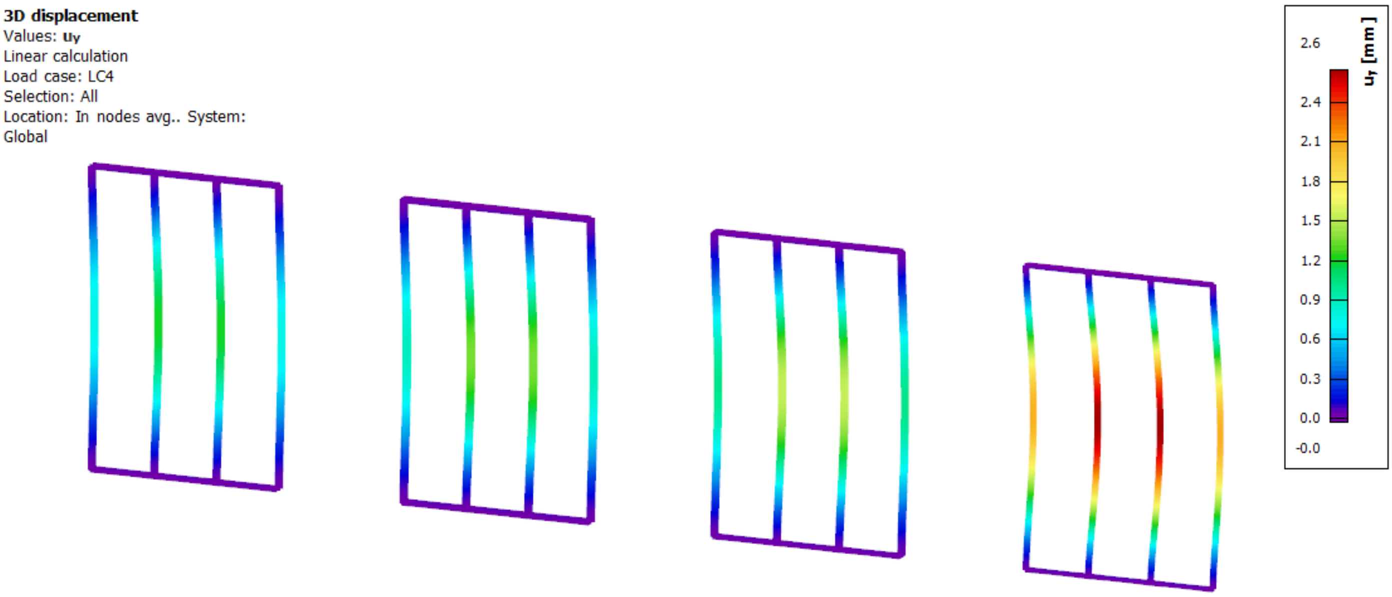


Figure 17 - Displacements caused by differential pressure

8.5 COMPARISON

Sections 8.2 to 8.4 handle the utilizations and displacements of the members, which are difficult to use for the purpose of comparison. More interesting properties for use in a comparison are the strength and stiffness, which can be derived from the utilizations and displacements by simply inverting them. The strength and stiffness are summarized in Table 7 and Table 8.

Table 7 - Relative strength

	LC2 (Soft body impact)	LC3 (Eccentric weight)	LC4 (Differential pressure)
JuuNoo 75	0.637	4.348	3.125
Metal Stud 75	0.299	2.381	1.429
Wood 38 x 89 mm	0.945	6.348	4.459
Wood 38 x 58 mm	0.716	4.539	3.048

Table 8 - Relative stiffness

	LC2 (Soft body impact)	LC3 (Eccentric weight)	LC4 (Differential pressure)
JuuNoo 75	0.128	2.857	0.833
Metal Stud 75	0.114	2.439	0.769
Wood 38 x 89 mm	0.101	2.083	0.667
Wood 38 x 58 mm	0.062	1.190	0.385

Note that these values are still difficult to interpret. To make them easier for interpretation, the highest values are set to a value of 1.0 (= 100%) and the other values are scaled along. The final results are summarized in Table 9 and Table 10 and illustrated using bar graphs in Figure 18 and Figure 19.

Table 9 - Relative strength (normalized)

	LC2 (Soft body impact)	LC3 (Eccentric weight)	LC4 (Differential pressure)
JuuNoo 75	67%	68%	70%
Metal Stud 75	32%	38%	32%
Wood 38 x 89 mm	100%	100%	100%
Wood 38 x 58 mm	76%	72%	68%

Table 10 - Relative stiffness (normalized)

	LC2 (Soft body impact)	LC3 (Eccentric weight)	LC4 (Differential pressure)
JuuNoo 75	100%	100%	100%
Metal Stud 75	89%	85%	92%
Wood 38 x 89 mm	79%	73%	80%
Wood 38 x 58 mm	48%	42%	46%

From Table 9 it is concluded that the wooden frames are the strongest, directly followed by the JuuNoo system, which is approximately as strong as a 38 x 58 mm wooden structure. The frame with the lowest strength is the one built from Metal Stud profiles, which is ½ to ⅓ weaker than the JuuNoo system. The wooden frames, however, have a much lower stiffness than the steel structures; this is concluded from Table 10. The JuuNoo system has the highest stiffness, directly followed by the Metal Stud frames which is 10% more flexible.

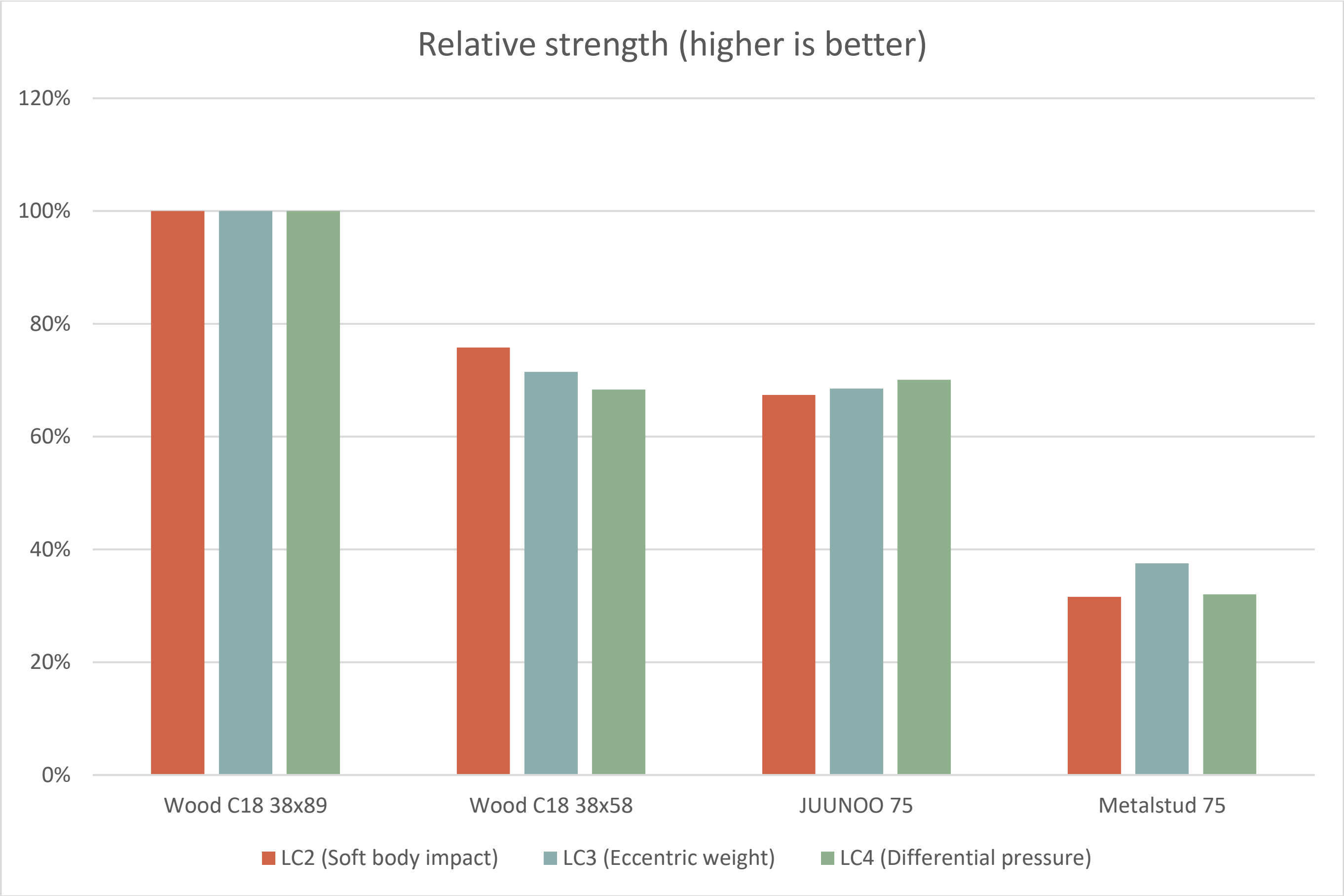


Figure 18 - Relative strength (normalized)

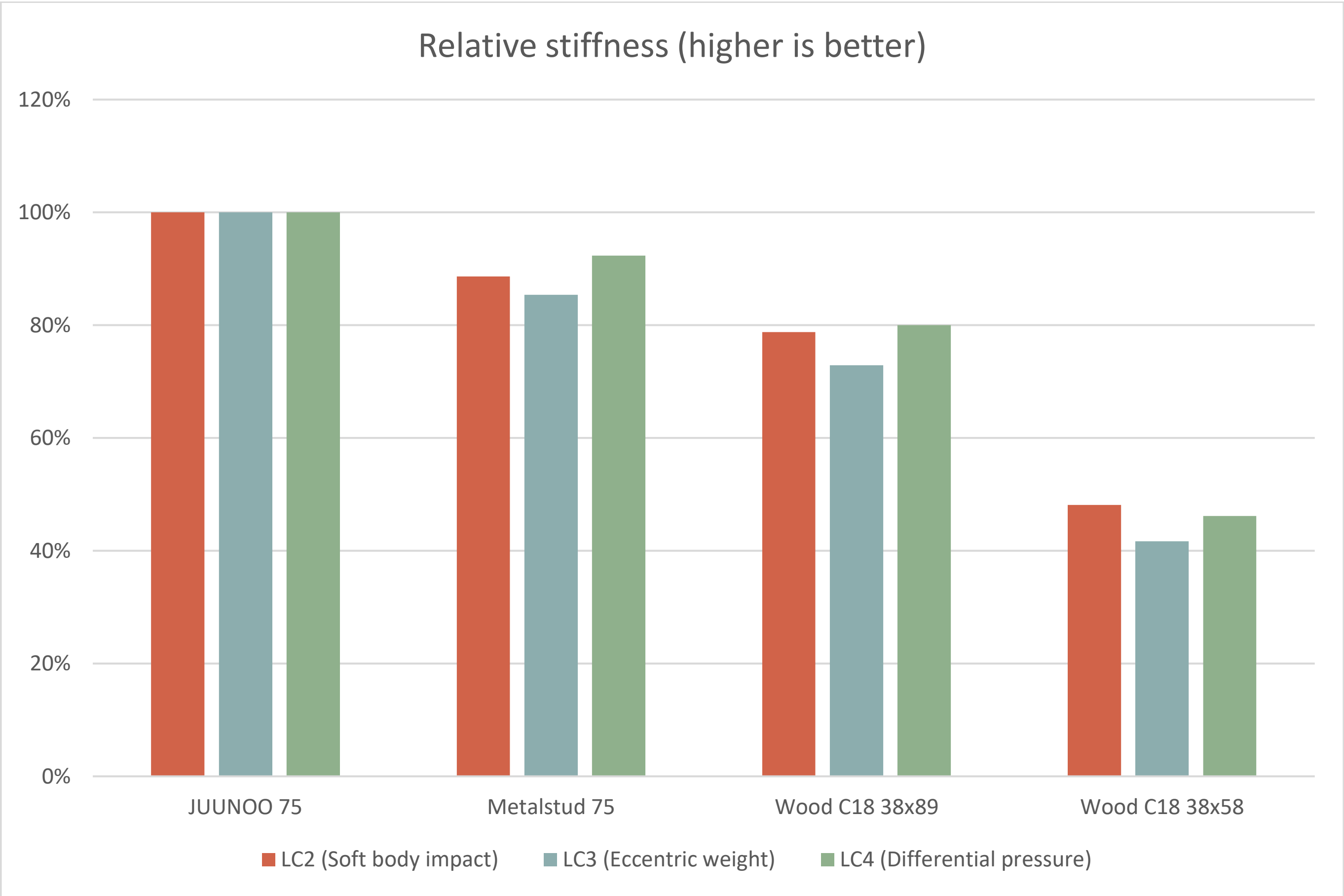


Figure 19 - Relative stiffness (normalized)

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