Column-Slab-FINISH
(Stefan Zöllig)
SYSTEM SOLUTION FOR
POINT SUPPORTED FLAT SLABS WITH CLT-ELEMENTS
(OF SPRUCE WOOD)

... a rear species ...
STATE OF THE ART

5.0 - 7.0m
STATE OF THE ART
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Quelle: http://www.structuremag.org
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POINT SUPPORTED FLAT SLAB

Comparison ceiling height / construction height

Point Supporten vs. Standard
POINT SUPPORTED FLAT SLAB | CHALLENGES
POINT SUPPORTED FLAT SLAB | CHALLENGES
POINT SUPPORTED FLAT SLAB | CHALLENGES
POINT SUPPORTED FLAT SLAB  |  CHALLENGES

- Compression failure
- Rolling shear failure
- CLT joint
POINT SUPPORTED FLAT SLAB  │ ETH - ZÜRICH

SAMPLEPROJECT: Boîte Avenir

(Zöllig, S.)
POINT SUPPORTED FLAT SLAB | ETH - ZÜRICH

Tests with beech LVL - plywood

(Zöllig, S.)
But how handle the high forces?
POINT SUPPORTED FLAT SLAB | CONCRETE CAPITAL
POINT SUPPORTED FLAT SLAB | DESIGN CRITERION
POINT SUPPORTED FLAT SLAB  │  STATE OF THE ART
CONCRETE  │  APPLICATION
POINT SUPPORTED FLAT SLAB | CHALLENGES WITH SPRUCE
POINT SUPPORTED FLAT SLAB | CHALLENGES

STEP 1: CONCENTRATED LOAD APPLICATION
POINT SUPPORTED FLAT SLAB | IDEA
POINT SUPPORTED FLAT SLAB | IDEA
POINT SUPPORTED FLAT SLAB | IDEA
POINT SUPPORTED FLAT SLAB | IDEA

Note: CLT-elements with a balanced ratio of the stiffness
POINT SUPPORTED FLAT SLAB | IDEA

core + cantilevers
POINT SUPPORTED FLAT SLAB  |  IDEA
POINT SUPPORTED FLAT SLAB | IDEA
POINT SUPPORTED FLAT SLAB | IDEA
POINT SUPPORTED FLAT SLAB | IDEA

Column
upper floor
SPIDER CONNECTOR | PROTOTYPE (Vers. 0)
SPIDER CONNECTOR | FINAL

- Arm with VGU washer
- Coupling cone
- King screw
- Steel cylinder
- Bottom plate
- Coupling disc + top plate
- Screws
SPIDER CONNECTOR

Philosophy: “Activation of all load carrying capacities”

1 Support (assembling)

[Diagram showing a CLT-element and a column head with a drillhole of 80 mm]
SPIDER CONNECTOR

Philosophy: “Activation of all load carrying capacities”

1. Support
2. Suspension
3. Reinforcement (V+M)
SPIDER CONNECTOR

Philosophy: “Activation of all load carrying capacities”

① Support
② Suspension
③ Reinforcement
④ Transfer
SPIDER CONNECTOR

Philosophy: “Activation of all load carrying capacities”

1. Support
2. Suspension
3. Reinforcement
4. Transfer
5. Fire protection
SPIDER CONNECTOR

Philosophy: “Activation of all load carrying capacities”

① Support
② Suspension
③ Reinforcement
④ Transfer
⑤ Fire protection
⑥ Sound insulation
SPIDER CONNECTOR

Philosophy: “Activation of all load carrying capacities”

1. Support
2. Suspension
3. Reinforcement
4. Transfer
5. Fire protection
6. Sound insulation
7. CLT joint?
SPIDER CONNECTOR

LOAD BEARING BEHAVIOR
SPIDER CONNECTOR

LOAD BEARING BEHAVIOR | COMPONENTS
SPIDER CONNECTOR

LOAD BEARING BEHAVIOR | COMPONENTS
SPIDER CONNECTOR

LOAD BEARING BEHAVIOR | COMPONENTS

arms as bending plates

Variation of the screw distances
SPIDER CONNECTOR

LOAD BEARING BEHAVIOR | TOTAL MODEL

Slab: 200/7l

- 5 m -

- 2.5 m -
EXPERIMENTAL PUNCHING TESTS

1000 kN
TEST SETUP

- Load upper floors
- Floor load: 10 kN/m²

- CLT 7l | 200 mm
- GL 32h
- Screws
- Spider

- \( A_{\text{support}} = 400 \text{ cm}^2 \)
- \( A_{\text{support}} = 400 \text{ cm}^2 \)
- \( A_{\text{support}} = 321 \text{ cm}^2 \)
TEST SETUP

- load upper floors
- floor load: 10 kN/m²
- CLT 71 | 200 mm
- screws
- Spider
- 200

$A_{support} = 400 \text{ cm}^2$
REFERENCE – unreinforced
1) REFERENCE – unreinforced

Note EC 5, Annex K:

\[ f_{c,90,Rk} = f_{c,90,lay,k} \cdot k_{c,90} = 3 \cdot 1,8 = 5,4 \text{ N/mm}^2 \]
REFERENCE - unreinforced

Compression perp. to the grain

plastically deformation
RESULTS

Load upper floors

Load: 10 kN/m²

CLT 71 | 200 mm

Screws

Spider

\[ A_{\text{support}} = 400 \text{ cm}^2 \]
REINFORCEMENT WITH SELF TAPPING SCREWS

compression reinforcement with 25 FTS 9/160
REINFORCEMENT WITH SELF TAPPING SCREWS

$A_{\text{support}} = 400 \text{ cm}^2$

$\sigma_{c,90} = \frac{400}{200^2} \cdot 10^3 = 10 \text{ N/mm}^2$
REINFORCEMENT WITH SELF TAPPING SCREWS
REINFORCEMENT WITH SELF TAPPING SCREWS

- Compression failure
- Rolling shear failure
RESULTS

load upper floors

floor load: 10 kN/m²

CLT 71 | 200 mm

200 kN

350 kN

A_{support} = 400 cm²

A_{support} = 400 cm²

A_{support} = 321 cm²
③ SPIDER CONNECTOR - ASSEMBLING

superelevation
③ SPIDER CONNECTOR – TEST SETUP
3 SPIDER CONNECTOR

- **bending/tension failure**
- **rolling shear failure**

**Graph:**
- Kraft \([\text{K}\text{N}]\) vs. Verformung \([\text{mm}]\)
- Black line: unreinforced
- Red line: support reinforcement with screws
- Green line: Spider-Connector

**Support:**
- \(A_{\text{support}} = 321 \text{ cm}^2\)

**Image:**
- Spider Connector with dimensions
- 200 mm
RESULTS

load upper floors

floor load: 10 kN/m²

CLT 7s | 200 mm

200 kN

350 kN

700 kN

screws

A_{support} = 400 cm²

A_{support} = 400 cm²

A_{support} = 321 cm²
CHARACTERISTIC PARAMETERS

load upper floors

floor load: 10 kN/m²

CLT 7L | 200 mm

1

2

3

screws

Spider

\[
F_{\text{est},Rk} = 170kN
\]

\[
F_{\text{est},Rd} = k_{\text{mod}} \cdot \frac{F_{\text{est},Rk}}{\gamma_M} = 108kN
\]

\( A_e = 10 \text{ m}^2 \)

floor load: 10 kN/m²

screws

Spider

\[
F_{\text{est},Rk} = 300kN
\]

\[
F_{\text{est},Rd} = 192kN
\]

\( A_e = 18 \text{ m}^2 \)

100 %  +178 %  +285 %

(1 m²)

(4 m²)

100 %  +178 %  +285 %

(1 m²)

(4 m²)

Spider

load upper floors

floor load: 10 kN/m²

CLT 7L | 200 mm

1

2

3

screws

Spider

\[
F_{\text{est},Rk} = 650kN
\]

\[
F_{\text{est},Rd} = 400kN
\]

\( A_e = 40 \text{ m}^2 \)
POINT SUPPORTED FLAT SLAB | TOTAL CONCEPT

STEP 1

STEP 2

column strip

endless strip

1.25-3.50 m

middle strip
SPIDER CONNECTOR SYSTEM | BOARD JOINT

SCREWS – STATE OF THE ART
+ Work with well known components
- Load bearing behaviour?
- Stiffness?
- Screw bonded system probably necessary (…)
- Ceiling underside
- Fire protection
SPIDER CONNECTOR SYSTEM | BOARD JOINT

Tests
SPIDER CONNECTOR SYSTEM | BOARD JOINT

Bending stiffness [Nmm²]

100 %

50 %
SPIDER CONNECTOR SYSTEM | BOARD JOINT

SCREWS

+ Work with well known
- Load bearing behaviour
- Stiffness
- Screw bonded system necessary
- Ceiling underside?
<table>
<thead>
<tr>
<th>SPIDER CONNECTOR SYSTEM</th>
<th>BOARD JOINT</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCREWS</td>
<td>versus</td>
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</table>

| + Work with well known  |
| - Fire protection       |
| - Load carrying behaviour |
| - Stiffness             |
| - Screw bonding necessary |
| - Ceiling underside?    |

| - Working with unknown |
| +/- Fire protection?   |
| +/- Load carrying behaviour? |
| +/- Stiffness?          |
| + Screw bonding not necessary |
| + Uniform ceiling underside |
SPIDER CONNECTOR SYSTEM | BOARD JOINT

POLYMER CONCRETE: Consistency adjustable
POLYMER CONCRETE: Bending stiffness

Reference: 100%  
PC: 97%  

3% decrease
SPIDER CONNECTOR SYSTEM | BOARD JOINT
PC-DOVETAIL: Fire protection

tension strength 45 MPa

fire lamella
POINT SUPPORTED FLAT SLAB | TOTAL CONCEPT

STEP 1

STEP 2

1.25-3.50 m

column stripe

endless stripe

middle stripe
POINT SUPPORTED FLAT SLAB | SERVICEABILITY STATE

GOOD VIBRATIONS   (Start October 2018)
**SPIDER CONNECTOR**

*Column – Slab – Finish*

«Build without joists»

CLT–board: 20 - 32 cm  
Column grid: 5,0 – 7,0m  
Net load: \( \leq 10 \text{ kN/m}^2 \)
SPIDER CONNECTOR | APPLICATION AREA

CARPORT
SPIDER CONNECTOR | APPLICATION AREA
POINT SUPPORTED FLAT SLAB | TOTAL CONCEPT

STEP 1

STEP 2

1.25-3.50 m

column strip

endless strip

middle strip

rothoblaas
CANTILEVERS
BALCONY | EUROCODE 1

- 4 kN/m²
- 0.5 kN/m
- 8.5 kNm/m
- 0.5 kNm/m
CANTILEVERS | PROBLEM

Cantilevers – Balcony, projecting roofs, … building physics optimized
CANTILEVERS | PROBLEM

Balcony

Facade

Thermal insulation

Wall

Airtight layer

Slab
Please mind the gap.
„PLEASE MIND THE GAP“
BALCONY | STATE OF THE ART

Cantilevers with CLT-elements
BALCONY | STATE OF THE ART

Cantilevers with beams

Continuous Beam

Facade

Wall
BALCONY | STATE OF THE ART

Beams | decoupled version?
BALCONY | STATE OF THE ART

Beams | decoupled version?

Balcony beam | Slab-beam

Steel profile | JOINT

Facade | Thermal insulation | Wall | Airthigt layer

M = F ∙ e

Tension

Compression

M = F ∙ e
Forces due to net loads

Tension/Compression = \( \frac{M_d}{e} = \frac{1,5 \cdot 8}{0,16} = 75 \text{ kN/m} \)

Shear = \( V_d = 1,5 \cdot 4 \cdot 2 = 12 \text{ kN/m} \) (1200 kg/m)
BALCONY | CASE OF DAMAGE?
CANTILEVERS | PROBLEM

Cantilevers – Balcony, projecting roofs, … building physics optimized
CANTILEVERS | CONCRETE THERMAL DECOUPLING

120 – 260 EUR / m
BRIDGE CONNECTOR

Philosophy: “Activation of all load carrying capacities”
BRIDGE CONNECTOR

Assembling

- Airtight layer
- Building bracket
- Building slab
- Outwall
BRIDGE CONNECTOR

Assembling

Thermal insulation

Tension element

Coupling-element

Fire protection board

Airtight layer

Building bracket

Building slab

Outwall
BRIDGE CONNECTOR

Assembling

- Facade
- Thermal insulation
- Tension element
- Cantilever bracket
- Cantilever
- Fire protection board
- Airtight layer
- Building bracket
- Coupling-element
- Outwall
- Building slab
BRIDGE CONNECTOR

Assembling
BRIDGE CONNECTOR | VARIABILITY
BRIDGE CONNECTOR | SOUND INSULATION
BRIDGE CONNECTOR | RESONANCE FREQUENCY TESTS
BRIDGE CONNECTOR | NEW CONSTRUCTION METHOD

Ground plan

Building

External Wall

Balcony
BRIDGE CONNECTOR | NEW CONSTRUCTION METHOD

CLT-Slab

Bridge Connector
BRIDGE CONNECTOR | NEW CONSTRUCTION METHOD

CLT-Slab

Bridge Connector

Prefabrication
Cantilever elements
BRIDGE CONNECTOR | NEW CONSTRUCTION METHOD

CLT-Slab
Bridge Connector
Prefabrication
Cantilever elements

„Fair weather installation“
Tag der Befestigung
PROJECT PARTNERS

- SPECIAL THANKS TO