SCI
Steel Knowledge

Demountable and reusable composite floor systems

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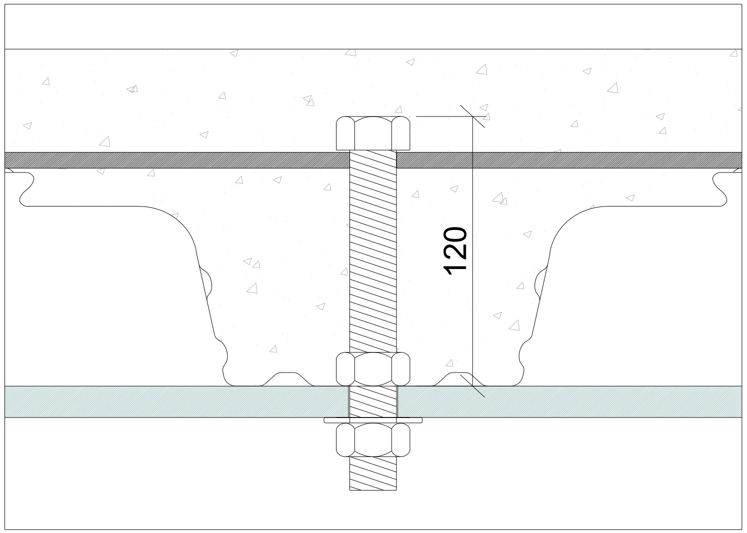
Principles of demountable composite beams

- Shear connectors can be disconnected from the beams and the steel beams are reused
- Composite slab may be cut into segments, demounted and re-used in the same sequence as in the original design
- Shear connectors are more flexible than welded shear connectors
- Long span secondary beams are more efficient and the shear connector arrangement may be varied to optimise performance
- Primary beams may be designed as non-composite to facilitate demounting of the slab

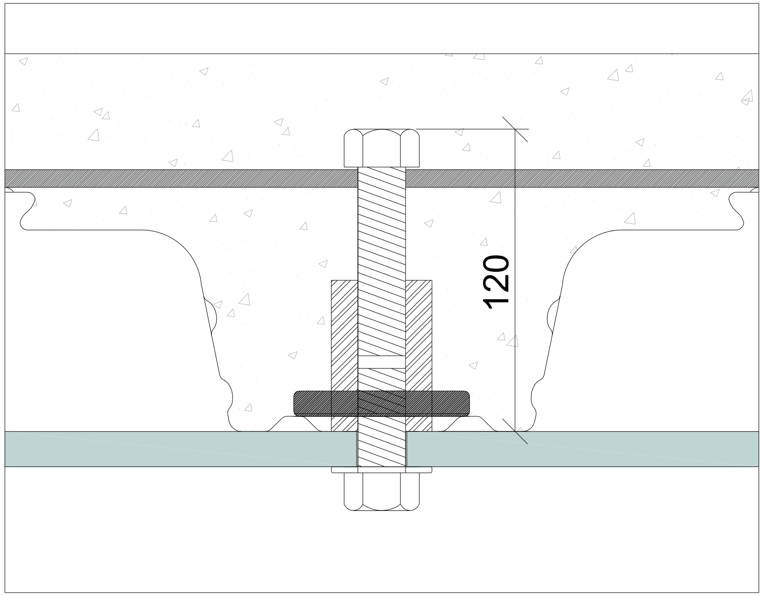
Types of shear connector - bolted

- 20mm dia. bolts have nuts above and below the flange
- Shear connectors may have threaded ends
- Close fit holes (21mm diameter)



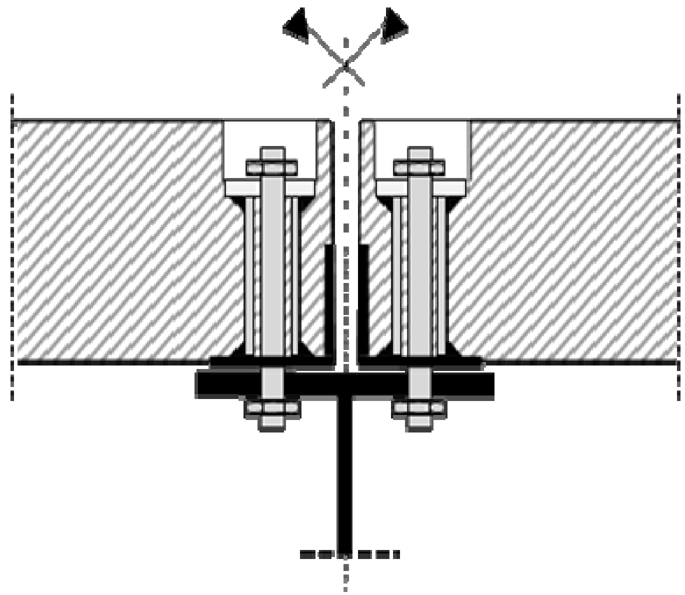
Types of shear connector - coupler

- Bolts are fixed above and below to couplers
- Coupler is left cast into slab
- Close fit holes



Types of shear connector - friction

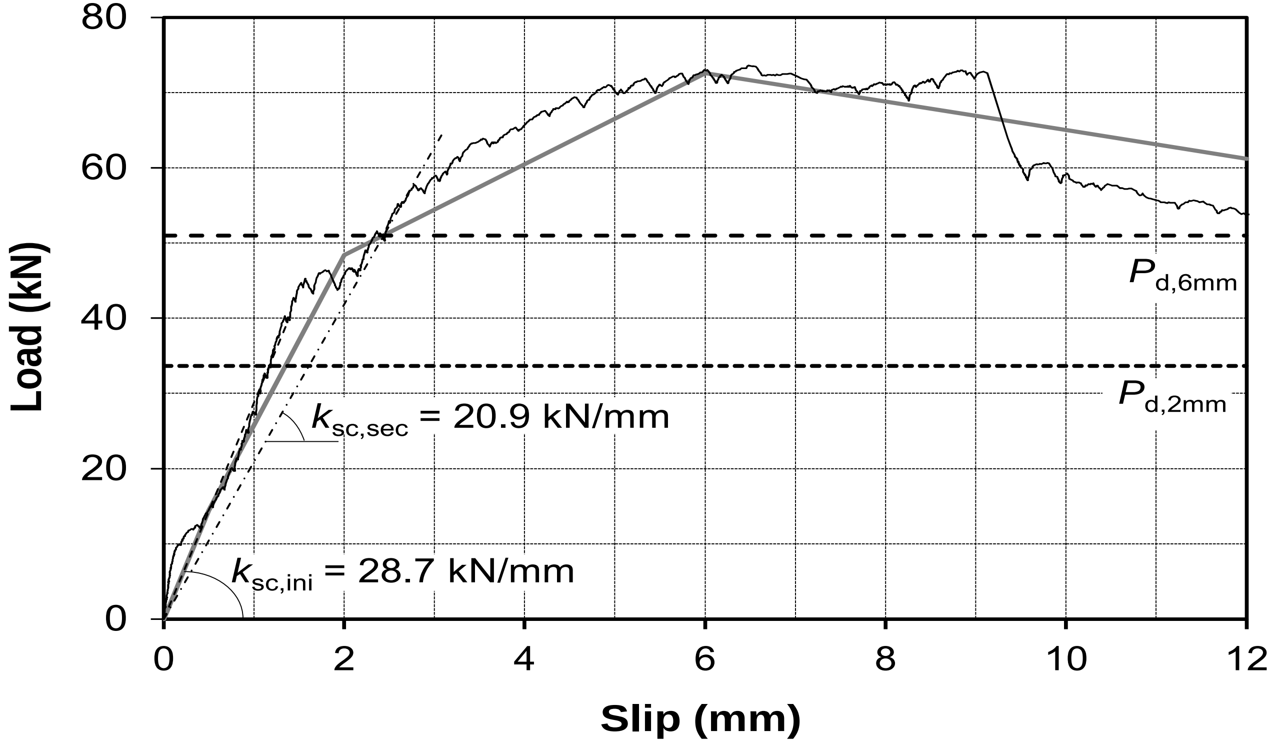
- Cylinders are cast in the slab
- Friction grip bolts are used
- Normal clearance holes



Ways of re-using the composite slab

- Use a full depth edge trim along the beams
- Partial depth edge trim to form a pre-determined cut line through the mesh reinforcement
- In demounting, make a transverse cut through the topping
- Slab segments should be suitable for lifting and transportation – 2.7m width x 3 to 4m span is proposed
- Slab segments are re-used by grout filling the cut lines (see later presentation by Prof Lam)

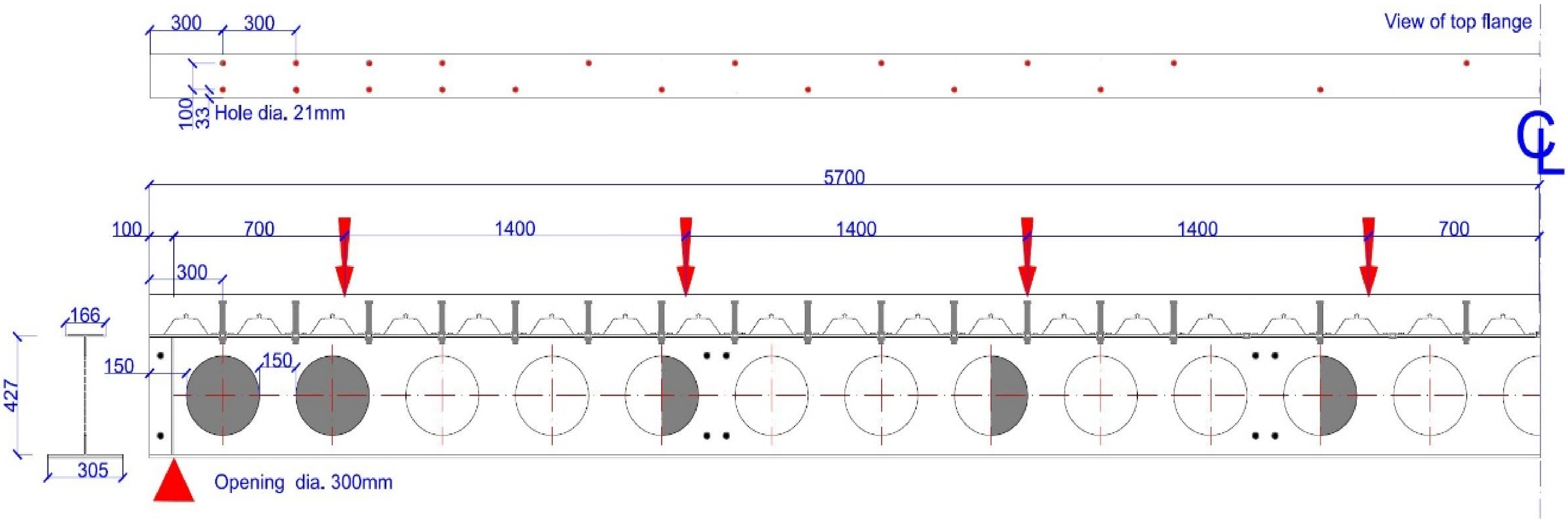
Typical push test results



Tests on composite beams

- Shear connector tests at Univ. Bradford and Univ. Luxembourg
- Composite beam tests at TU Delft and Univ. Luxembourg
- Cellular beam test with bolted shear connectors at Univ. Bradford
- Assembly, demounting and re-assembly of composite car park structure at TU Delft

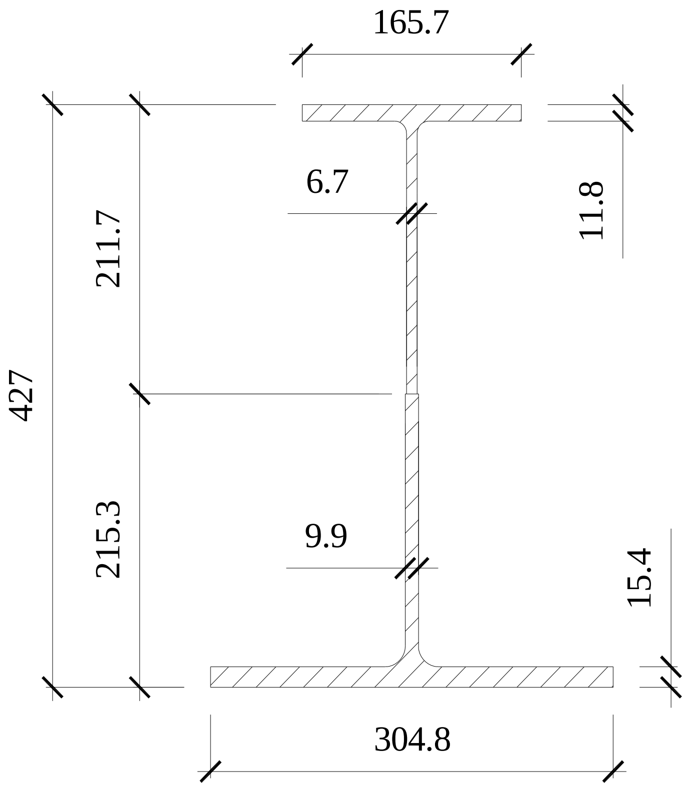
Test on composite cellular beam -11.2m span

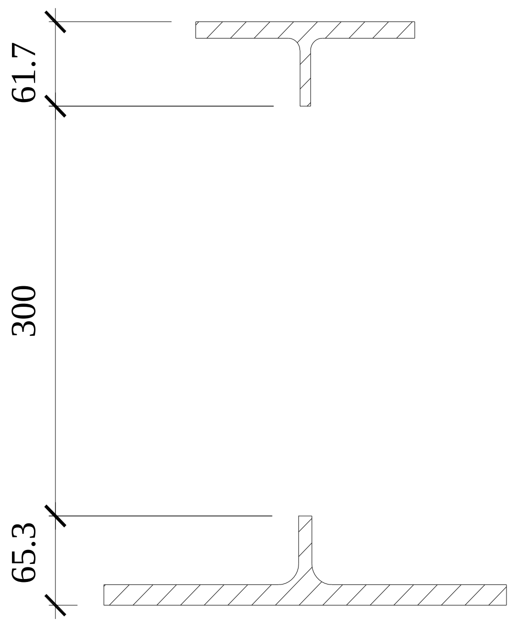


Details of cellular beam test

- Cellular beam is composed of:
  - 305x 165 x 46 kg/m top Tee
  - 305x 305 x 97 kg/m bottom Tee
  - Asymmetry of 2.4:1
- Beam dimensions
  - Span of 11.2m
  - Slab width of 2.8m (= L/4)
  - Beam depth of 427mm (L/h = 26)
  - Slab depth of 150mm (using 80mm decking)

Cellular beam section





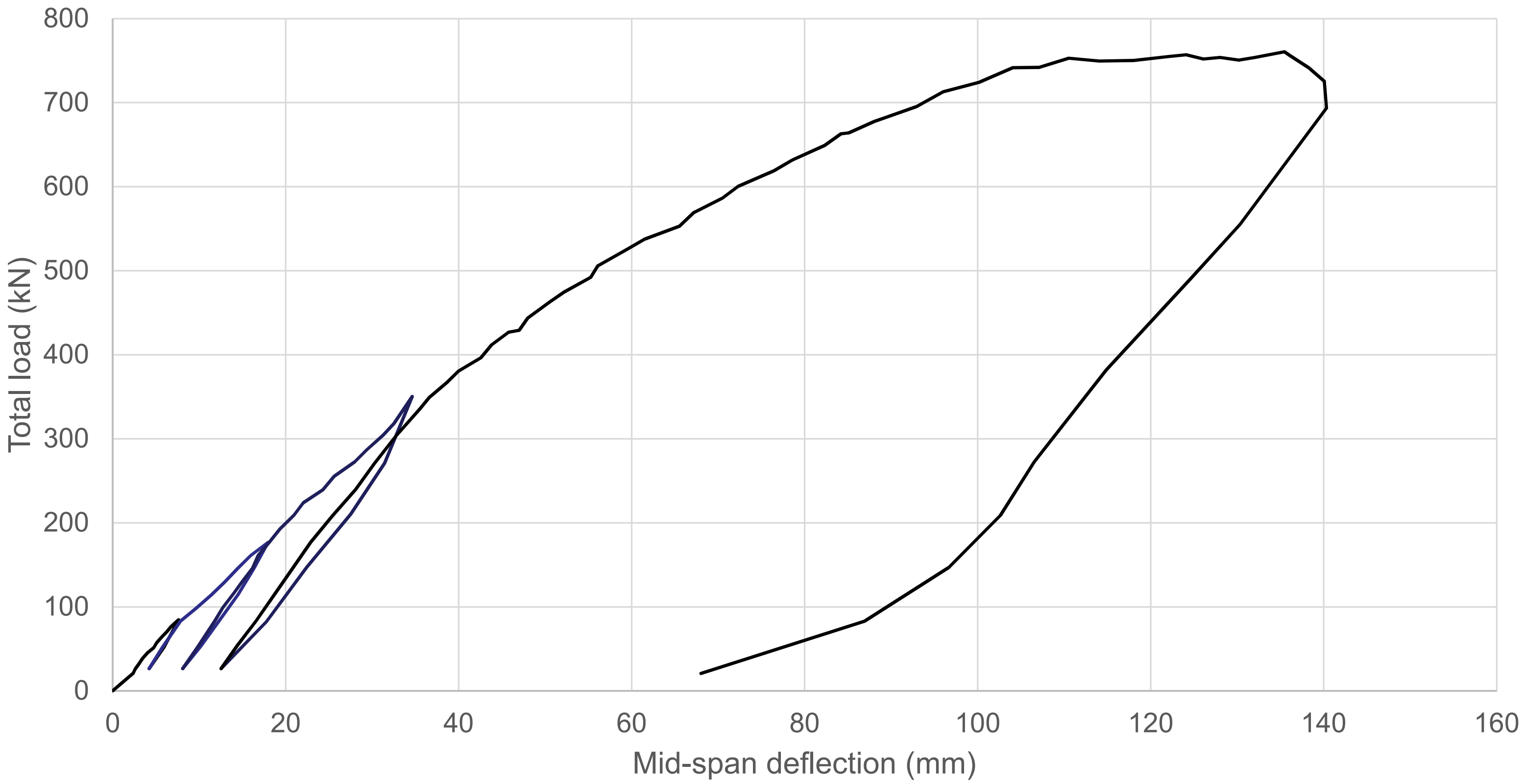
305x165 x 46 kg/m UB top Tee

305x305 x 97 kg/m UC bottom Tee

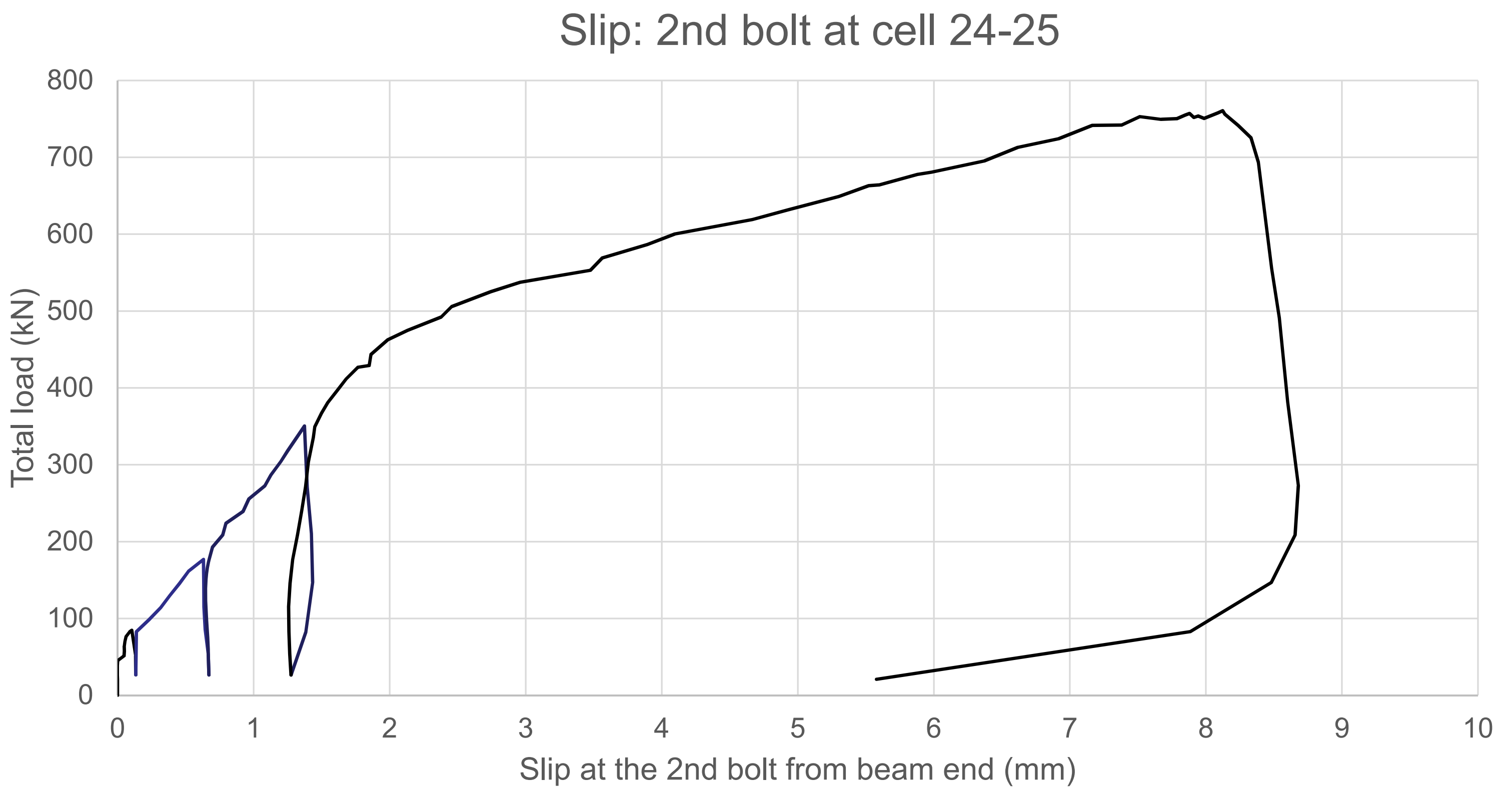
Beam details with edge trim to form cut lines for demounting

Cellular beam test at failure

Cellular beam load-deflection curve



Cellular beam – bolted shear connector slip



Cellular beam test – key results

- Failure load is 24.1 kN/m^2 plus self-weight of 3 kN/m^2
- Deflection at 5 kN/m^2 = 16mm (=L/700)
- End-slip at failure = 6 to 8mm
- Degree of shear connection was 38% (for 70 kN shear connector resistance) < 84% to Eurocode 4 for 2.4:1 asymmetry
- Failure mode by yielding of the bottom Tee in tension
- Evidence of web-post yielding in shear between the openings

Cellular beam test at failure

Summary of cellular beam test results

Parameter	Test	Theory	Ratio	Comment
Bending resistance	1190 kNm	1073 kNm	1.11	Based on shear connector resistance of 70 kN and steel mill certs.
Pure vertical shear resistance	425 kN at support 318 kN at first cell	340 kN at cell 3	0.93	
Vierendeel bending resistance		318 kN	1.0	
Web-post shear or buckling resistance	Horizontal shear= 257 kN at web-post 3/4	229 kN-shear 275 kN-buckling	1.12 0.93	Horizontal shear failure of the top web controls
Deflection under self-wt. of concrete	29.5mm wet and 28.3mm dry	28.3mm	1.0	Close using the bending stiffness at the opening
Deflection under 5 kN/m^2 imposed load	16.0mm	16.8mm	0.95	Theory is based on shear connector stiffness of 30 kN/mm

Design methods for demountable composite beams

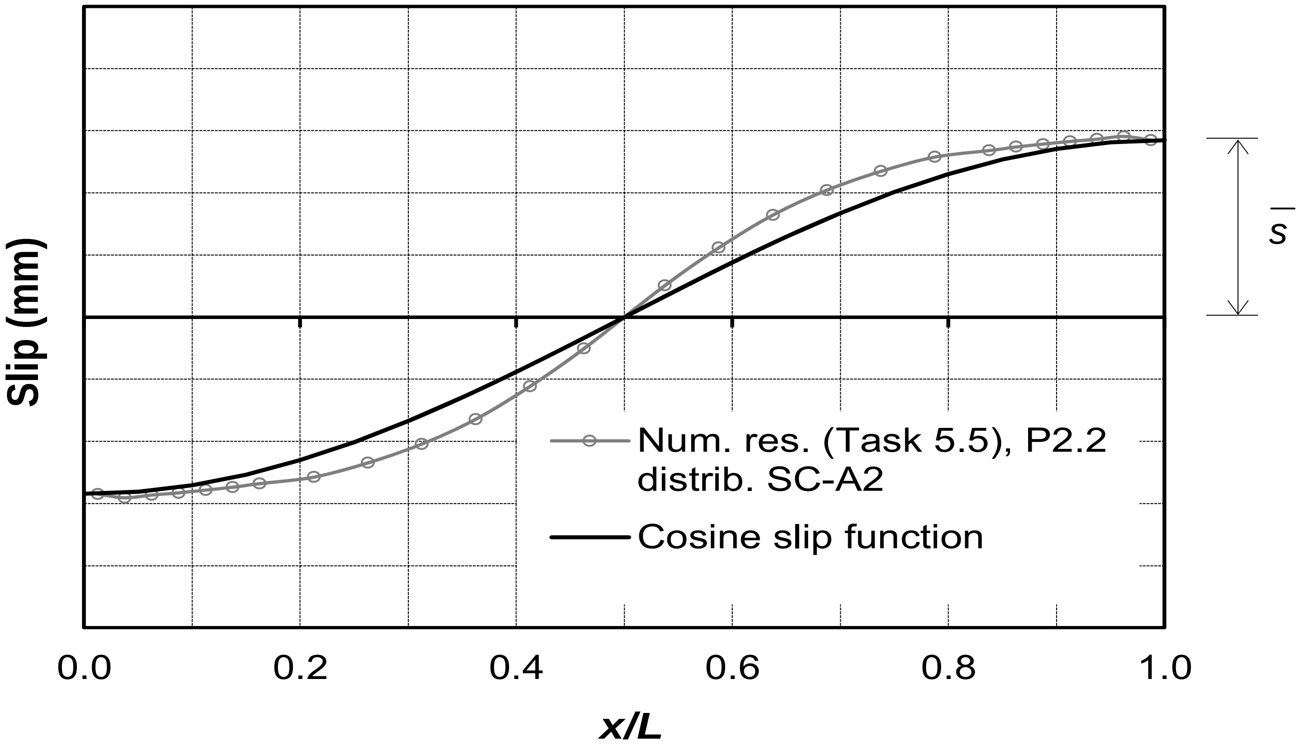
- Plastic method to Eurocode 4 with modifications due to the load-slip relationship of the shear connectors
- Utilisation factor, UF < 0.9 to avoid permanent deformation in first cycle of use
- Minimum degree of shear connection taking account of UF
- Elastic method is used for serviceability to calculate deflections and end slip
- Elastic method may also be used at the ultimate limit state (as a lower bound for all cases and also for Class 3 or 4 sections)

Effective inertia of composite section

$$I_{eff} = I_s + \frac{I_c}{n} + \frac{\left(h + h_p + 0.5h_c\right)^2 A_s}{\left[1 + \frac{nA_s}{A_c} + \left(\frac{\pi}{L}\right)^2 E_s A_s \left(\frac{s_{sc}}{k_{sc}}\right)\right]}$$

k_{sc} = shear stiffness of shear connectors
≈ 30 kN/mm for bolted shear connectors
s_{sc} = equivalent spacing of shear connectors

Load-slip distribution along beam



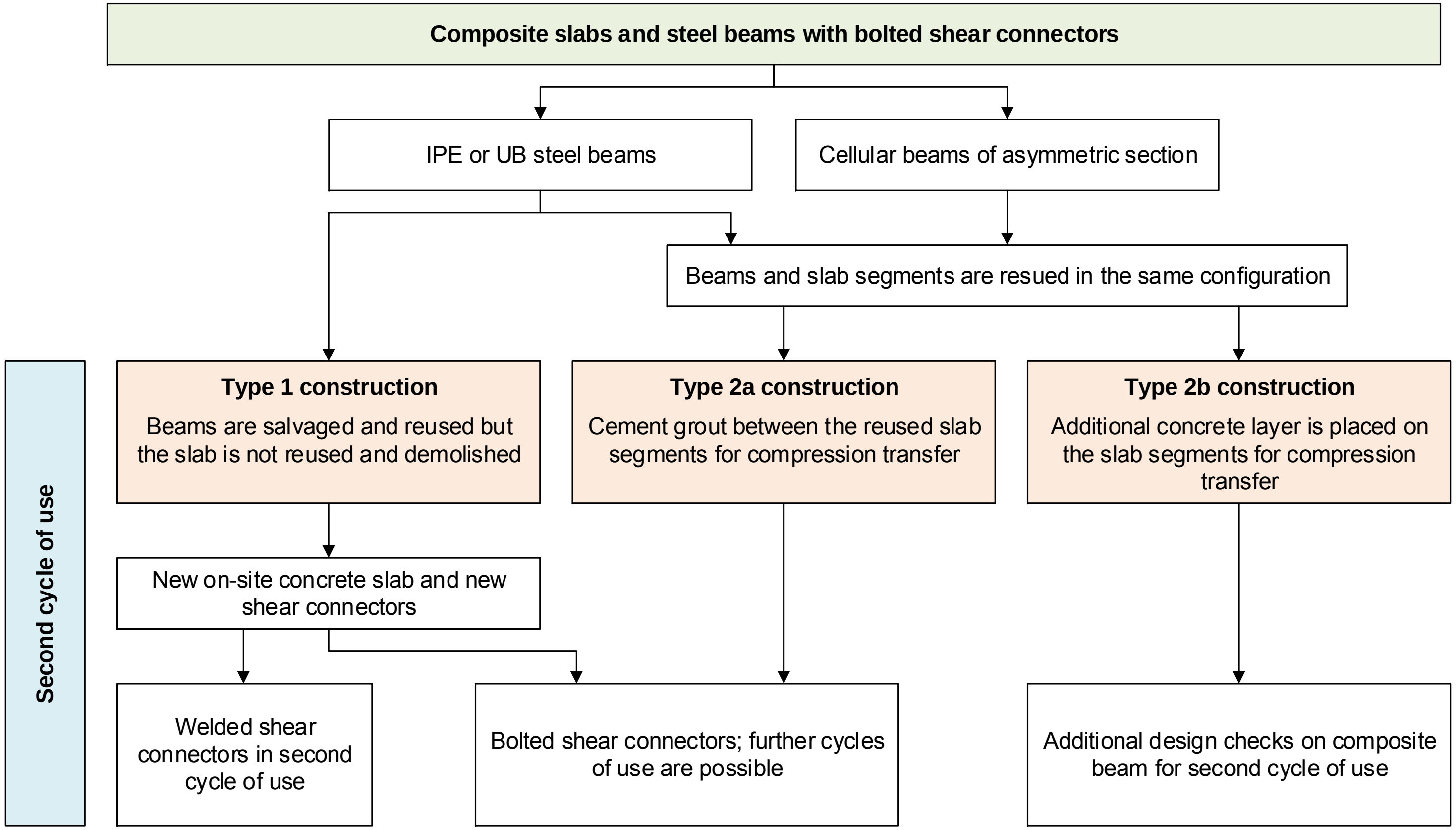
Elastic limits for demountable composite beams

- Stresses depend on un-propped or propped construction
- End slip at serviceability ≤ 1.2mm
- End slip at ultimate limit state ≤ 2mm, so that deformations are not permanent in the first use cycle
- Additional deflection due to the flexibility of the shear connectors is calculated
- Equivalent spacing of shear connectors is dependent on their distribution

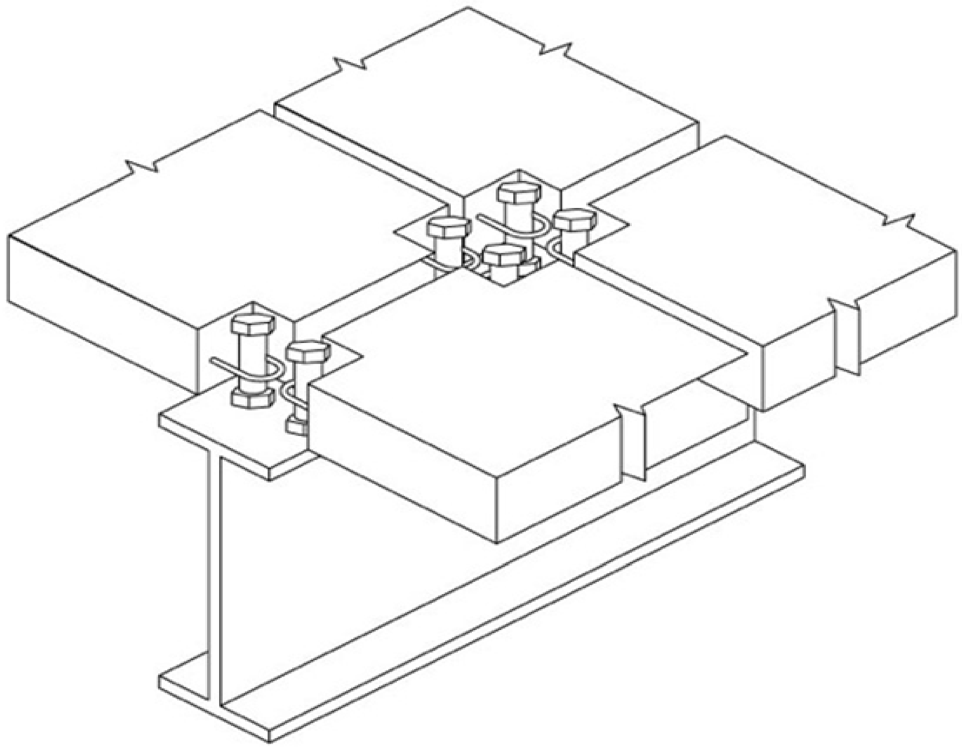
Reuse of demountable composite beams

- Beam and slab are re-used
  - The composite slab is cut into segments and re-used in the same order on the same beam
  - The beams are re-used in the same configuration i.e. the building is moved
- Beam is re-used
  - The beam is disconnected from the slab
  - The slab is demolished
  - The beam can be re-used with a new slab

Reuse of composite slabs in demountable construction



Use of precast slabs in demountable composite construction



Conclusions on demountable composite construction

- Use long span composite construction to optimise performance and to minimise the components
- Demountable shear connectors have equivalent shear resistance to welded studs
- But they are more flexible, and so deflection calculations should include this effect
- Utilisation in first use, UF $\leq$ 0.9 to avoid permanent deformation
- Minimise the degree of shear connection for most economic use
- Elastic design may be used with optimised shear connector distribution for both Serviceability and Ultimate limit states

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