



Fire Behaviour of Steel and Composite Floor Systems

Worked examples



Table of content

- **Worked examples**
 - Floor layout

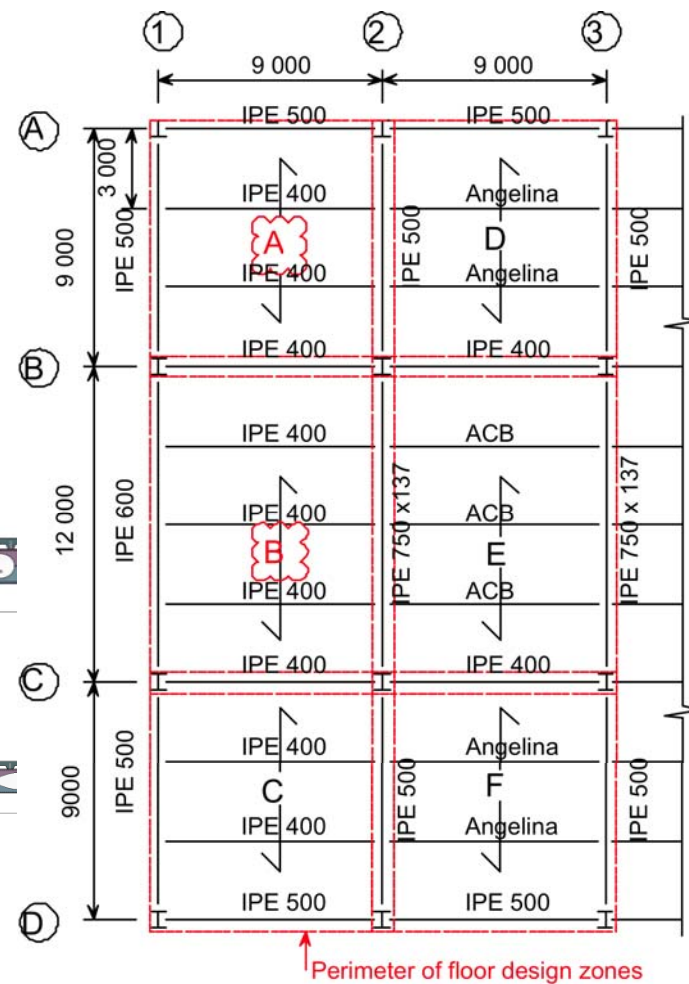
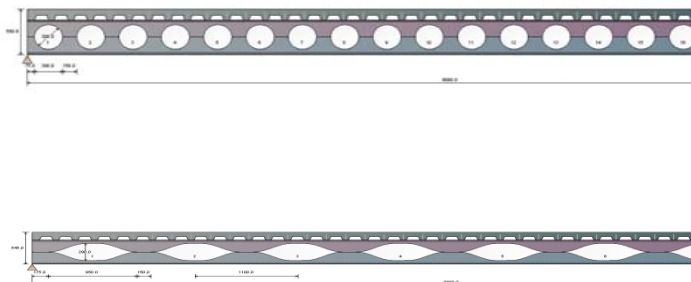




Table of content

• Worked examples

Beam Section (S355)	Location of beam	Construction Type	Degree of Shear Connection (%)	Number of shear studs per group and spacing
IPE 400	Secondary internal beam	Composite	51	1 @ 207mm
IPE 500	Secondary edge beam	Non composite	-	
IPE 500	Primary internal beam	Composite	72	2 @ 207mm
IPE 750 x 137	Primary internal beam	Composite	71	2 @ 207 mm
IPE 600	Primary edge beam	Non composite	-	
ACB IPE 300+IPE 300	Secondary internal beam	Composite	52	2 @ 207 mm
Angelina IPE270 + IPE 270	Secondary internal beam	Composite	52	2 @ 207 mm

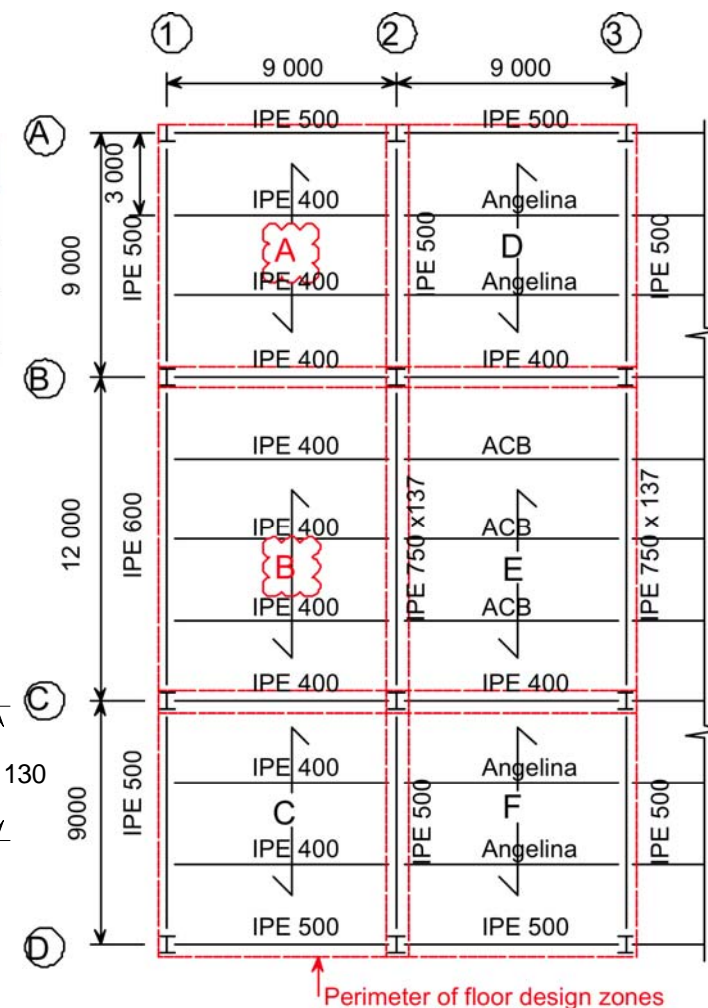
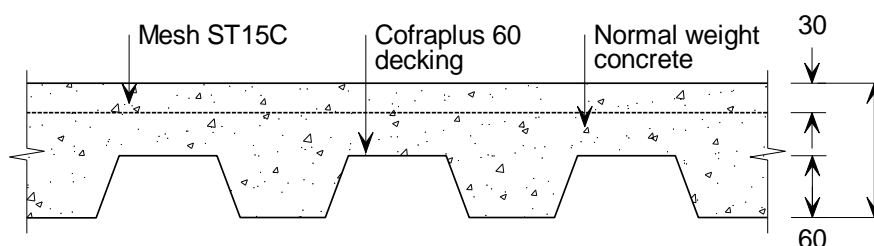
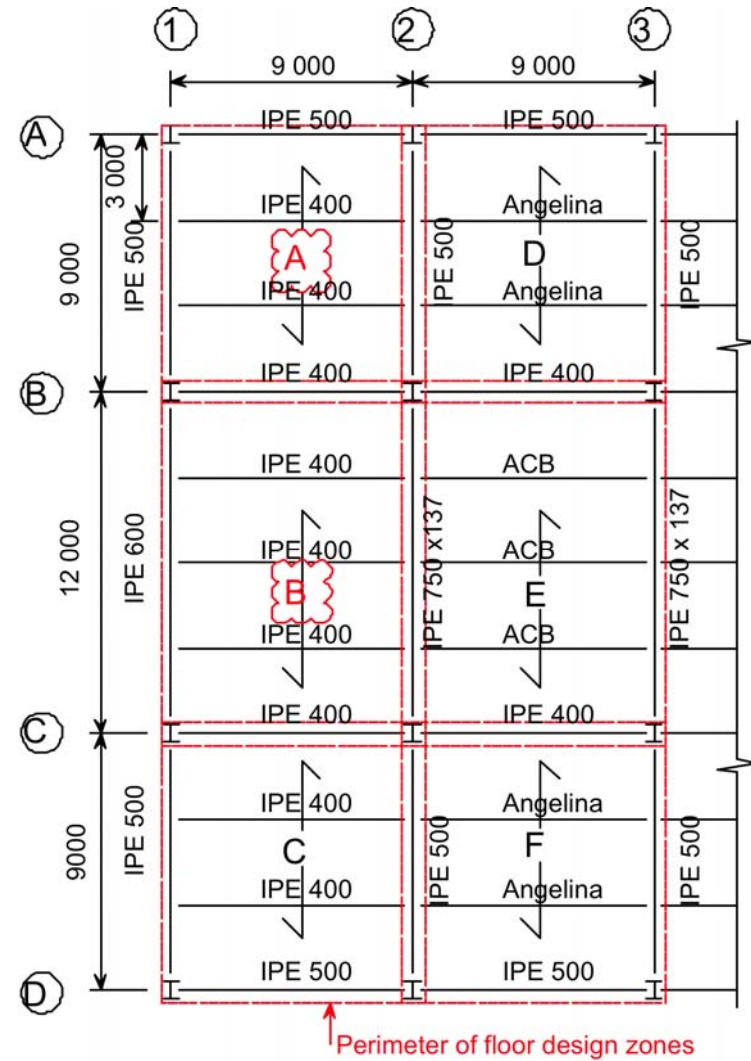




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- **Worked examples**
 - Floor zone B
 - Floor zone E





Loading details



- **Normal (Cold)**

- Leading variable action: 5 kN/m²
- Accompanying variable action: 0 kN/m²
- Dead load including beam, excluding slab: 1.2 kN/m²
- Calculated slab weight including mesh: 2.28 kN/m²

- **Fire (Hot)**

- Combination factor for permanent action: 1.0
- Combination factor for leading variable action: 0.5
- Combination factor for accompanying variable action: 0.5



Floor zone B



- **General data**

Floor zone B

Floor zone E

Construction
details

MACS+ - Membrane Action of Composite Structures in Case of Fire

File View Options Language Help

Project G.A. Deck Slab Beams Loading Fire & Analysis Detailed report

Project properties

Project details

Project name: Example A

Client name: BmS

Client company: BmS

Job number:

Prepared by: RH

Company name: BmS

Comments:

Job file properties: Example A.frc

Reset Prev Next

Checking software updates...

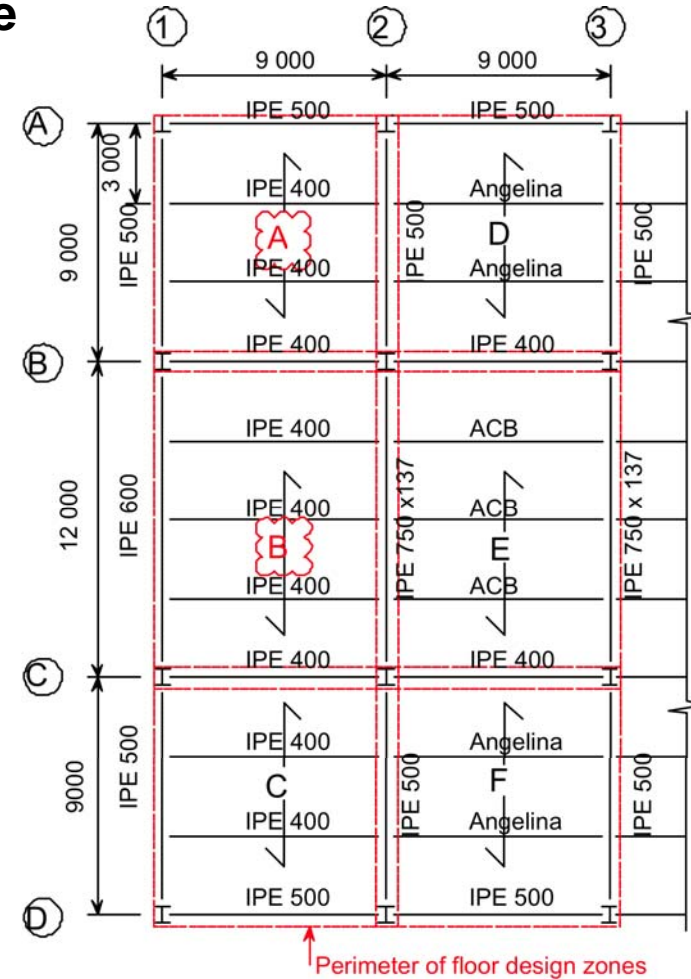
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11:16 5-12-2012



Floor zone B

- 9 x 12 m floor design zone



Floor zone B

Floor zone E

Construction
details



Floor zone B



- 9 x 12 m floor design zone: Input field general arrangement

Floor zone B

Floor zone E

Construction details

MACS+ - Membrane Action of Composite Structures in Case of Fire

File View Options Language Help

Project G.A. Deck Slab Beams Loading Fire & Analysis Detailed report

General arrangement

General arrangement

Spans

Span 1: m Span 2: m

Unprotected beams

Number of internal unprotected beams:

Graphical output

Spans and beams

Span 1 = 9 m

Span 2 = 12 m

Project name: Example A Reset Prev Next

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Floor zone B

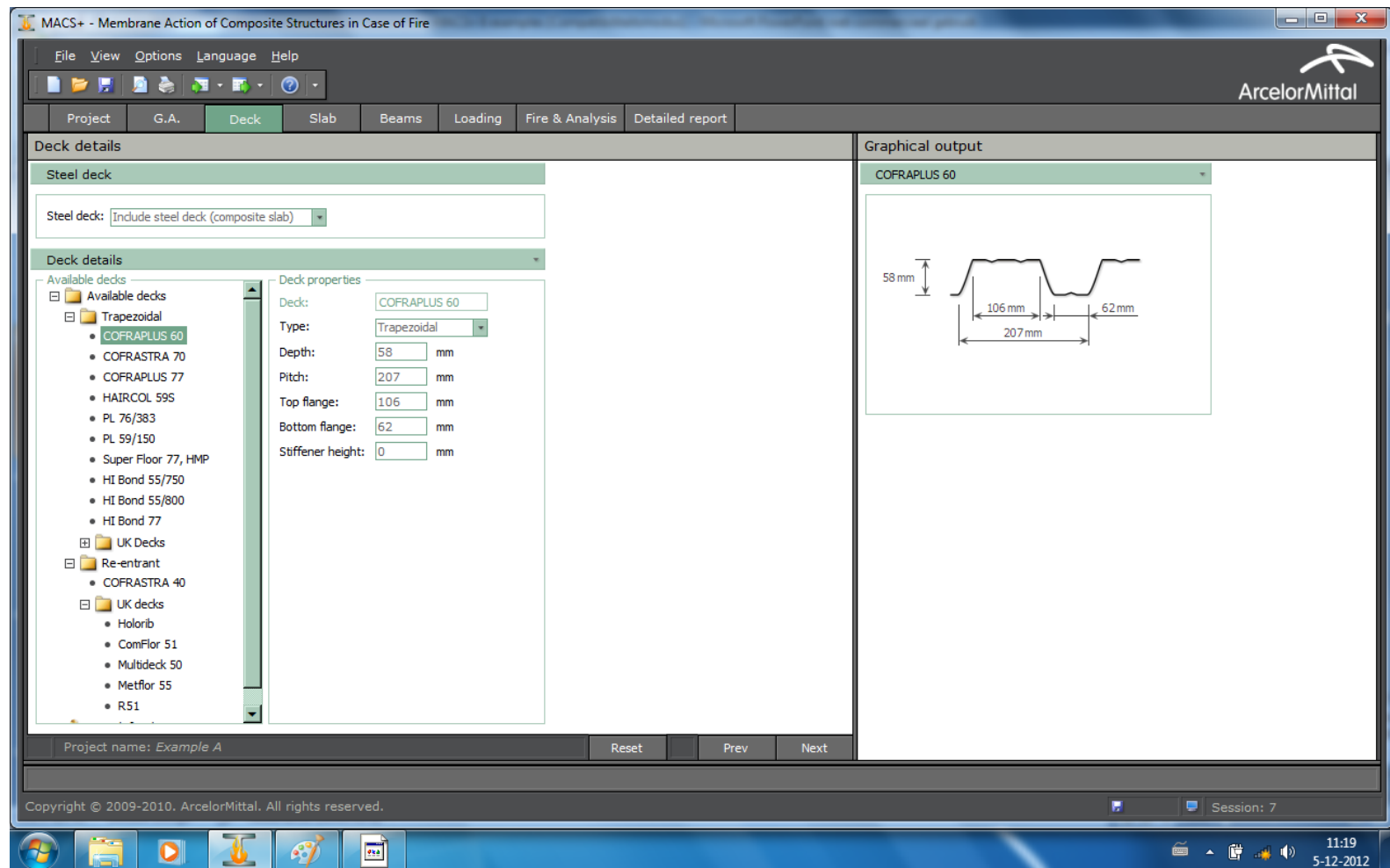


- Input field steel sheet: Cofraplus 60

Floor zone B

Floor zone E

Construction details





Floor zone B



- Input field floor slab

Floor zone B

Floor zone E

Construction details

MACS+ - Membrane Action of Composite Structures in Case of Fire

File View Options Language Help

Project G.A. Deck Slab Beams Loading Fire & Analysis Detailed report

Slab details

Concrete

Concrete type: Normal Slab depth: 130 mm
Cylinder compressive strength of concrete (f_{ck}): 25 N/mm²

Mesh

Mesh type: ST 15 C
Longitudinal mesh area: 142 mm²/m Bar size: 6 mm
Transverse mesh area: 142 mm²/m Bar size: 6 mm
☐ Do not check for opposite mesh orientation

Average mesh axis distance: 30 mm Mesh yield stress: 500 N/mm²

Project name: Example A Reset Prev Next

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Graphical output

Mesh orientation

Span 1 = 9 m
Span 2 = 12 m
Transverse mesh
Longitudinal mesh

Slab section

30 mm
130 mm
58 mm
Internal beam
Span 1



Floor zone B



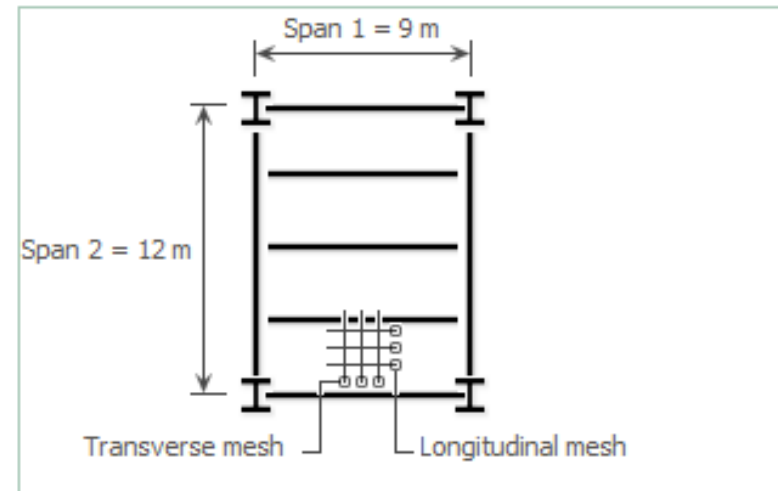
- Input field floor slab

Floor zone B

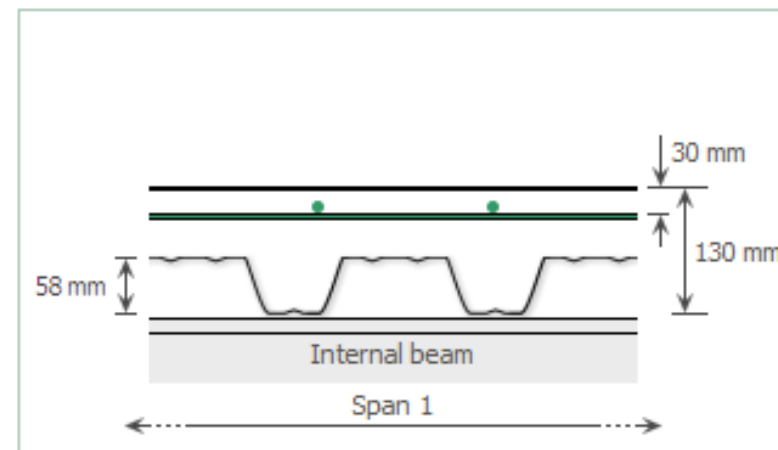
Floor zone E

Construction details

Mesh orientation



Slab section





Floor zone B



- Input field beams

Floor zone B

Floor zone E

Construction details

MACS+ - Membrane Action of Composite Structures in Case of Fire

File View Options Language Help

Project G.A. Deck Slab **Beams** Loading Fire & Analysis Detailed report

Beams details

Unprotected beams

Sections and steel grade

Beam type: Solid beam

Families: European sections

Steel grade: S355

Available sections

☒ IPE (European I Beams)

☐ HE (European Wide Flange Beams)

☐ HL (European Wide Flange Beams)

☐ HD (European Wide Flange Columns)

Unprotected

Section size: IPE 400

Degree of shear connection: 51 %

Side A perimeter beam

Sections and steel grade

Beam type: Solid beam

Families: European sections

Steel grade: S355

Available sections

☒ IPE (European I Beams)

☐ HE (European Wide Flange Beams)

☐ HL (European Wide Flange Beams)

☐ HD (European Wide Flange Columns)

Side A

Beam location: Edge beam

Construction type: Composite

Section size: IPE 400

Degree of shear connection: 51 %

Side B perimeter beam

Sections and steel grade

Beam type: Solid beam

Families: European sections

Steel grade: S355

Available sections

☒ IPE (European I Beams)

☐ HE (European Wide Flange Beams)

☐ HL (European Wide Flange Beams)

☐ HD (European Wide Flange Columns)

Side B

Graphical output

Beams

Side A IPE 400

Side B IPE 750x137

Side C IPE 400

Side D IPE 600

Unprotected IPE 400

Project name: Example A

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Floor zone B



- Input field actions

Floor zone B

Floor zone E

Construction
details

MACS+ - Membrane Action of Composite Structures in Case of Fire

File View Options Language Help

Project G.A. Deck Slab Beams Loading Fire & Analysis Detailed report

Loading details

Normal (Cold)

Leading variable action: 5 kN/m²

Accompanying variable action: 0 kN/m²

Dead load including beam, excluding slab: 1.2 kN/m²

Calculated slab weight including mesh: 2.28 kN/m²

☒ Auto-calculate slab weight

Fire (Hot)

Combination factor for permanent action: 1.0

Combination factor for leading variable action: 0.5

Combination factor for other variable action: 0.5

Graphical output

Loading diagram

Project name: Example A

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Floor zone B



- Input field Fire & Analysis

Floor zone B

Floor zone E

Construction
details

MACS+ - Membrane Action of Composite Structures in Case of Fire

File View Options Language Help

Project G.A. Deck Slab Beams Loading **Fire & Analysis** Detailed report

Fire & Analysis

Analysis method

Analysis: Standard temperature-time curve

Fire resistance period

Fire resistance period: 60 min

Parametric temperature-time curve

Compartment length: 27 m Window height: 1.8 m
Compartment width: 18 m Window length: 30 m
Compartment height: 3.6 m Glazing breakage: 95 %
Fire load: 511 MJ/m² Wall lining (B) factor: 720 J/m²s^{1/2}K
Growth rate: Medium Combustion factor: 0.8

User defined temperature-time curve

Starting time: sec Starting temperature: °C
Ending time: sec Ending temperature: °C
Intervals:

Load Reload View

Project name: Example A Reset Prev Calculate

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Floor zone B

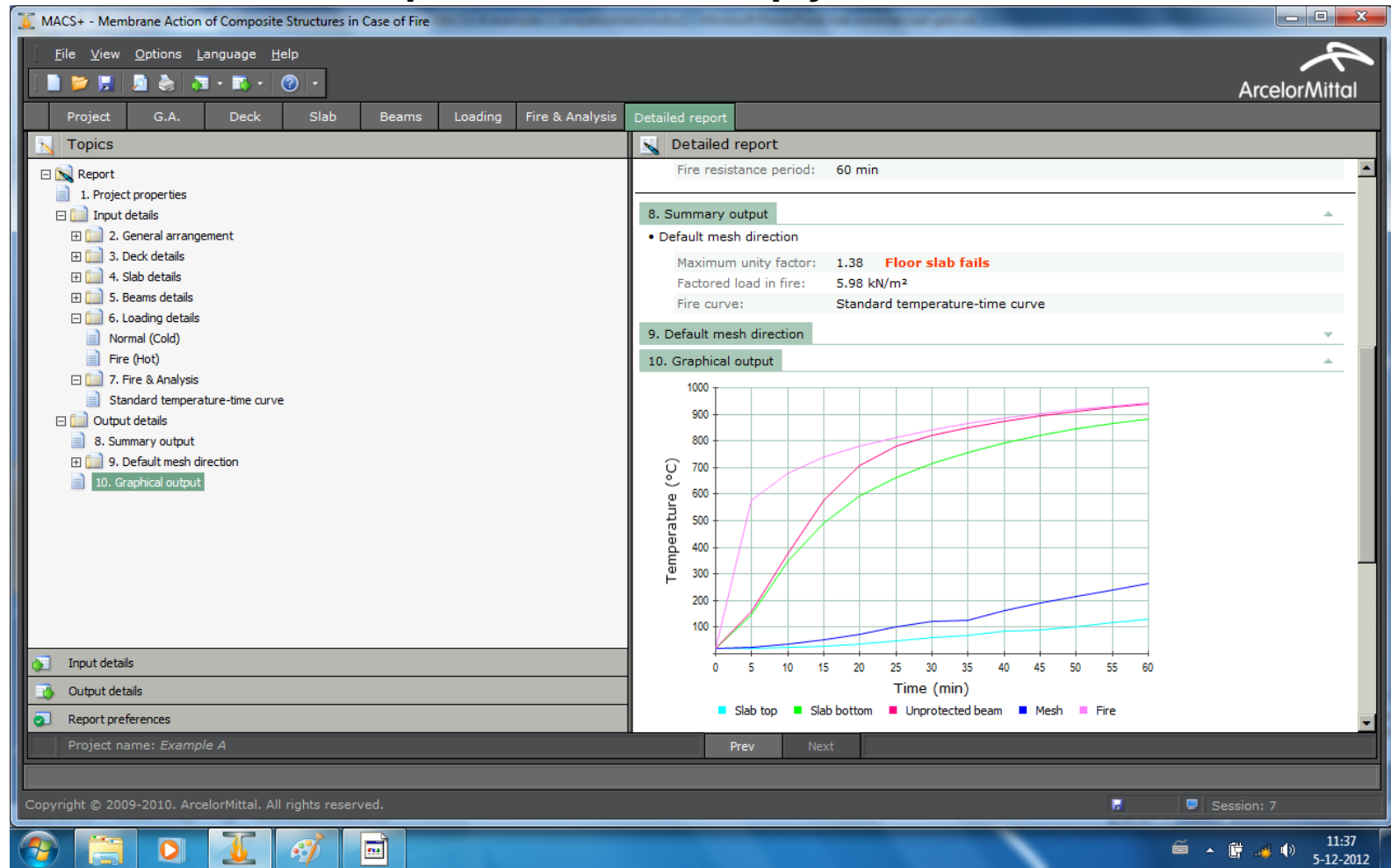


- Results & Output: does not comply: $uc = 1.38$

Floor zone B

Floor zone E

Construction details

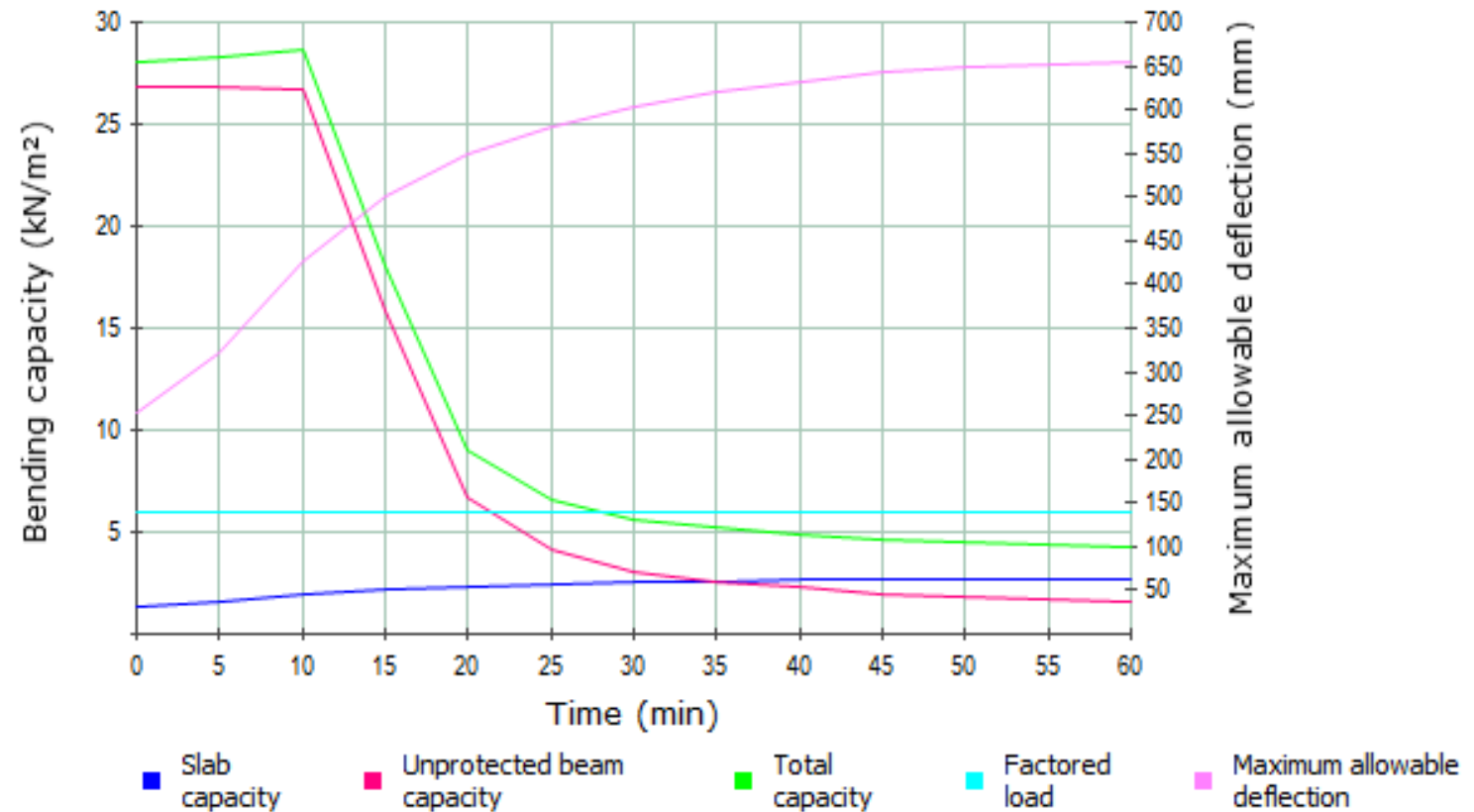




Floor zone B



- Results & Output





Floor zone B



- Mesh from ST 15C (142 mm²/m) to ST 25C (257 mm²/m): complies with $uc = 0.93$

9. Default mesh direction

Longitudinal mesh area: 257 mm²/m Bar size: 7 mm

Transverse mesh area: 257 mm²/m Bar size: 7 mm

Factored load in fire: 5.98 kN/m²

• Tabular results

Time	Beam	Mesh	Slab top	Slab bottom	Beam capacity	Maximum allowable deflection	Slab yield	Enhancement	Slab capacity	Total capacity	Unity factor
mins	°C	°C	°C	°C	kN/m ²	mm	kN/m ²		kN/m ²	kN/m ²	
0	20	20	20	20	26.79	254	0.79	2.94	2.34	29.12	0.21
5	158	24	20	147	26.79	321	0.79	3.48	2.76	29.55	0.20
10	378	37	22	348	26.72	428	0.79	4.31	3.42	30.14	0.20
15	578	53	28	491	15.88	501	0.79	4.89	3.88	19.76	0.30
20	708	74	36	592	6.70	550	0.79	5.28	4.19	10.89	0.55
25	779	102	48	663	4.13	582	0.79	5.53	4.39	8.52	0.70
30	821	120	62	716	3.06	603	0.79	5.69	4.52	7.58	0.79
35	850	125	71	758	2.62	620	0.79	5.83	4.63	7.25	0.83
40	873	163	83	791	2.27	631	0.79	5.92	4.70	6.96	0.86
45	893	190	89	820	1.97	644	0.79	6.01	4.77	6.74	0.89
50	910	214	103	844	1.79	649	0.79	6.06	4.81	6.60	0.91
55	925	238	119	865	1.70	652	0.79	6.08	4.82	6.52	0.92
60	939	263	131	884	1.61	655	0.79	6.10	4.85	6.46	0.93

Maximum unity factor: 0.93 **Floor slab adequate**

Floor zone B

Floor zone E

Construction details



Floor zone B



- Results & Output beams

Floor zone B

Floor zone E

Construction
details

MACS+ - Membrane Action of Composite Structures in Case of Fire

File View Options Language Help

Project G.A. Deck Slab Beams Loading Fire & Analysis Detailed report

Detailed report

- Beam checks

The degree of shear connection of unprotected beam(s) does not satisfy the minimum limit specified by EN1994-1-1

The degree of shear connection of internal beam(s) does not satisfy the minimum limit specified by EN1994-1-1

- Perimeter beam check

Side	Beam type:	Solid beam	Composite	Edge beam
Side A	Section size:	IPE 400		
	Required moment resistance in fire situation:	379.4 kNm		
	Line load in fire situation:	37.47 kN/m		
	Shear connection:	51 %		
	Degree of utilization:	0.58		
	Critical temperature:	613 °C		
Side B	Beam type:	Solid beam	Composite	Internal beam
	Section size:	IPE 750x137		
	Required moment resistance in fire situation:	628.51 kNm		
	Line load in fire situation:	34.92 kN/m		
	Shear connection:	71 %		
	Degree of utilization:	0.24		
	Critical temperature:	719 °C		
Side C	Beam type:	Solid beam	Composite	Internal beam
	Section size:	IPE 400		
	Required moment resistance in fire situation:	379.4 kNm		
	Line load in fire situation:	37.47 kN/m		
	Shear connection:	51 %	This does not satisfy the minimum limit specified by EN1994-1-1	
	Degree of utilization:	0.52		
	Critical temperature:	622 °C		
Side D	Beam type:	Solid beam	Non composite	Edge beam
	Section size:	IPE 600		

Project name: Example A

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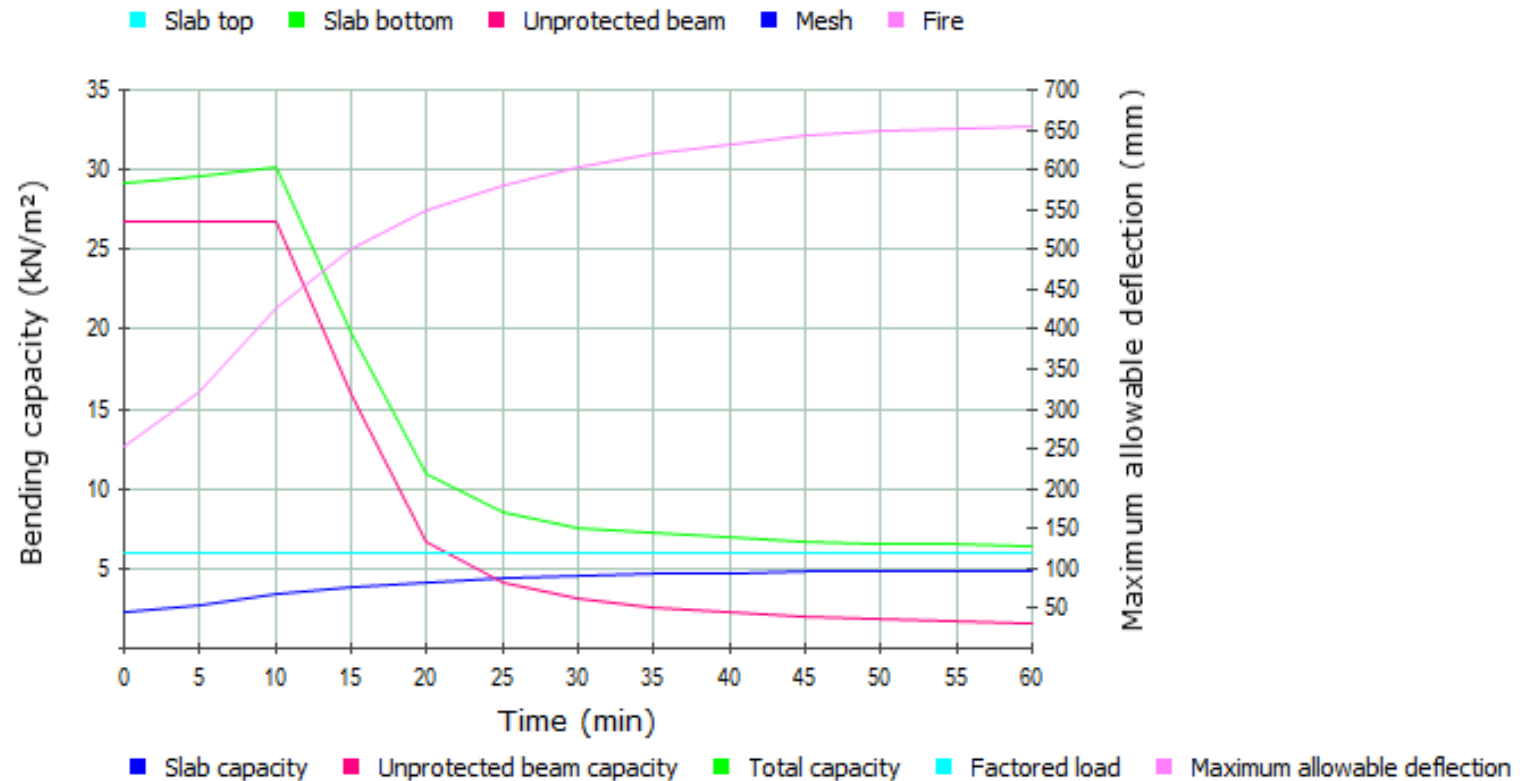
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Floor zone B



Results & Output





Floor zone E

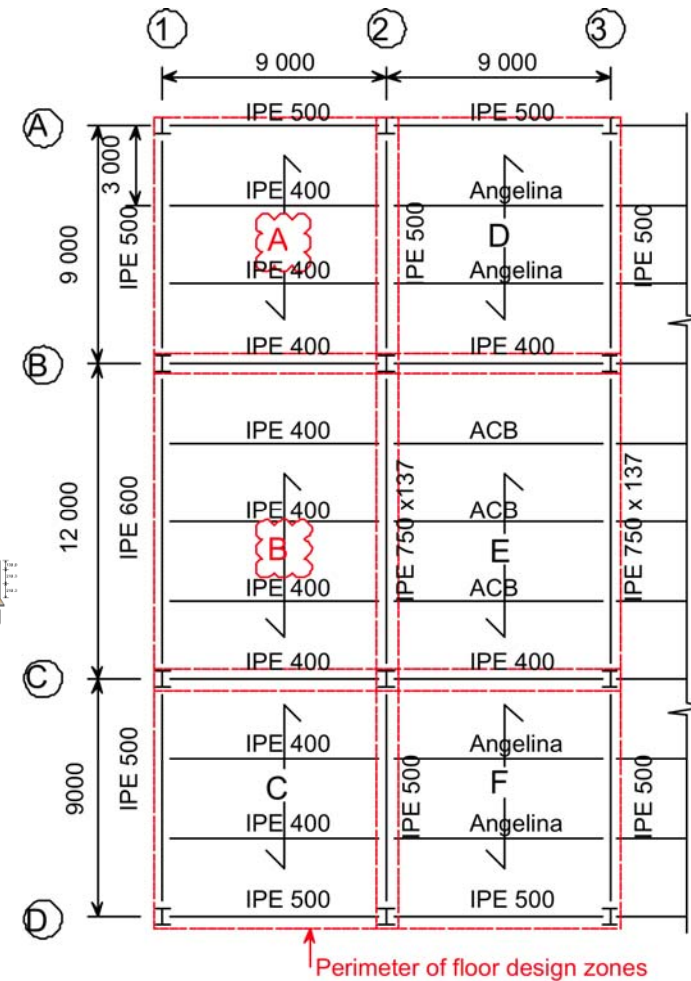
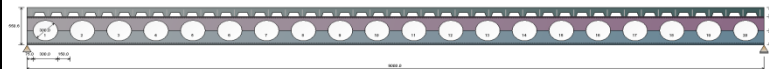


- 9 x 12 m floor design zone with cellular beams

Floor zone B

Floor zone E

Construction details





Floor zone E



- 9 x 12 m floor design zone with cellular beams

Floor zone B

Floor zone E

Construction
details

MACS+ - Membrane Action of Composite Structures in Case of Fire

File View Options Language Help

Project G.A. Deck Slab **Beams** Loading Fire & Analysis Detailed report

Beams details

Unprotected beams

Sections and steel grade

Beam type: Cellular beam

Families: European sections

Steel grade: S355

Available sections

☒ IPE (European I Beams)

☐ HE (European Wide Flange Beams)

☐ HL (European Wide Flange Beams)

☐ HD (European Wide Flange Columns)

Unprotected

☐ Symmetrical cross-section

Degree of shear connection: 52 %

Upper member: IPE 300

Depth of upper member: 250 mm

Lower member: IPE 300

Depth of lower member: 250 mm

Cell diameter: 300 mm

Side A perimeter beam

Sections and steel grade

Beam type: Solid beam

Families: European sections

Steel grade: S355

Available sections

☒ IPE (European I Beams)

☐ HE (European Wide Flange Beams)

☐ HL (European Wide Flange Beams)

☐ HD (European Wide Flange Columns)

Side A

Beam location: Internal beam

Construction type: Composite

Section size: IPE 400

Degree of shear connection: 51 %

Side B perimeter beam

Sections and steel grade

Beam type: Solid beam

Available sections

☒ IPE (European I Beams)

Graphical output

Beams

Side A IPE 400

Side D IPE 750x137

Unprotected IPE 300+IPE 300

Side B IPE 750x137

Side C IPE 400

Project name: Floor zone E

Reset Prev Next

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Floor zone E



- Results & Output: $uc = 1.26$ after 25 minutes

9. Default mesh direction

Longitudinal mesh area: 257 mm²/m Bar size: 7 mm

Transverse mesh area: 257 mm²/m Bar size: 7 mm

Factored load in fire: 5.98 kN/m²

- Tabular results

Time	Beam	Mesh	Slab top	Slab bottom	Beam capacity	Maximum allowable deflection	Slab yield	Enhancement	Slab capacity	Total capacity	Unity factor
mins	°C	°C	°C	°C	kN/m ²	mm	kN/m ²		kN/m ²	kN/m ²	
0	20	56	30	508	13.52	509	0.79	4.95	3.93	17.45	0.34
5	147	74	39	416	13.52	455	0.79	4.52	3.59	17.11	0.35
10	354	90	49	504	11.31	496	0.79	4.85	3.85	15.16	0.39
15	552	110	60	585	4.10	534	0.79	5.15	4.09	8.19	0.73
20	691	117	69	650	0.48	564	0.79	5.38	4.27	4.75	1.26
25	771	124	76	702	0.33	588	0.79	5.57	4.42	4.75	1.26
30	817	157	87	743	0.28	604	0.79	5.70	4.52	4.80	1.25
35	848	182	90	777	0.24	620	0.79	5.83	4.63	4.87	1.23
40	872	203	101	806	0.21	630	0.79	5.91	4.69	4.90	1.22
45	892	227	118	831	0.18	634	0.79	5.94	4.72	4.90	1.22
50	909	251	128	853	0.17	641	0.79	5.99	4.75	4.92	1.22
55	925	273	143	872	0.16	643	0.79	6.01	4.77	4.93	1.21
60	938	294	165	890	0.15	641	0.79	5.99	4.75	4.90	1.22

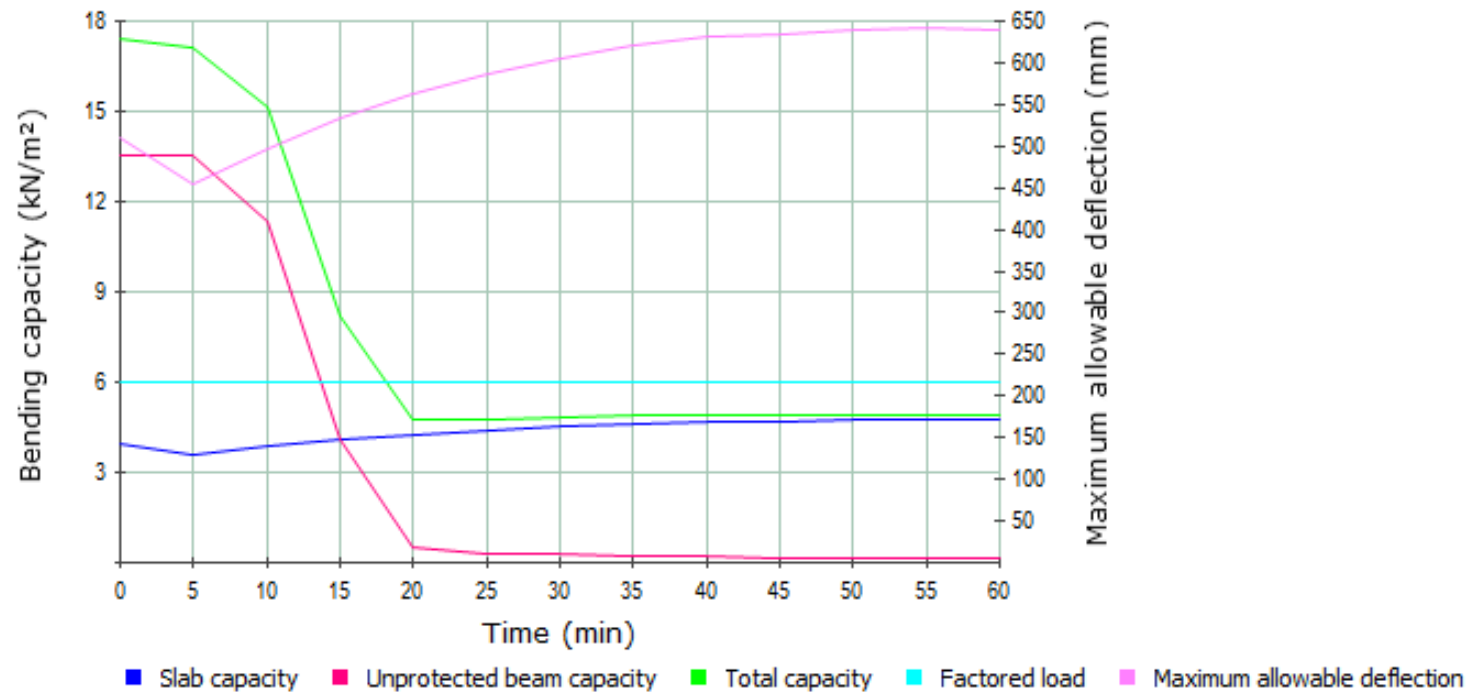
Maximum unity factor: 1.26 **Floor slab fails**



Floor zone E



- Results & Output





Floor zone E

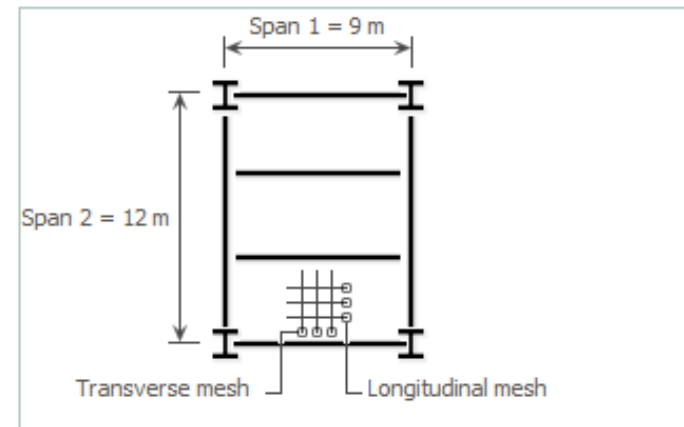
- Option 1: axis distance from 30 to 40 mm (temperature just below 400 ° C, so ca. 100% strength)
- uc of 1.26 after 25 minutes
- improved to
- uc of 1.19 after 25 minutes

Floor zone B

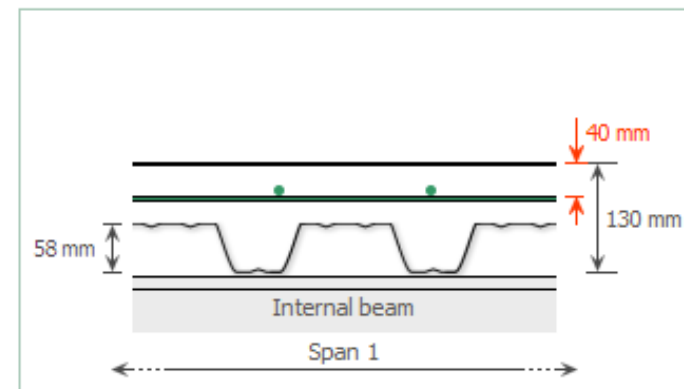
Floor zone E

Construction
details

Mesh orientation



Slab section





Floor zone E



- Option 2: heavier mesh from ST 25C (257 mm²/m) to ST 40C 385 mm²/m): complies with $uc = 0.88$

9. Default mesh direction

Longitudinal mesh area: 385 mm²/m Bar size: 7 mm
 Transverse mesh area: 385 mm²/m Bar size: 7 mm
 Factored load in fire: 5.98 kN/m²

• Tabular results

Time	Beam	Mesh	Slab top	Slab bottom	Beam capacity	Maximum allowable deflection	Slab yield	Enhancement	Slab capacity	Total capacity	Unity factor
mins	°C	°C	°C	°C	kN/m ²	mm	kN/m ²		kN/m ²	kN/m ²	
0	20	76	30	508	13.52	509	1.56	3.72	5.82	19.34	0.31
5	147	101	39	416	13.52	455	1.56	3.42	5.36	18.87	0.32
10	354	121	49	504	11.31	496	1.56	3.65	5.71	17.02	0.35
15	552	148	60	585	4.10	534	1.56	3.86	6.03	10.14	0.59
20	691	169	69	650	0.48	564	1.56	4.02	6.28	6.76	0.88
25	771	187	76	702	0.33	588	1.56	4.15	6.49	6.82	0.88
30	817	220	87	743	0.28	604	1.56	4.24	6.63	6.90	0.87
35	848	250	90	777	0.24	620	1.56	4.33	6.76	7.00	0.85
40	872	276	101	806	0.21	630	1.56	4.38	6.85	7.06	0.85
45	892	302	118	831	0.18	634	1.56	4.41	6.89	7.07	0.85
50	909	328	128	853	0.17	641	1.54	4.55	7.00	7.17	0.83
55	925	352	143	872	0.16	643	1.52	4.66	7.08	7.24	0.83
60	938	375	165	890	0.15	641	1.50	4.74	7.12	7.27	0.82

Maximum unity factor: 0.88 **Floor slab adequate**

Floor zone B

Floor zone E

Construction details



Floor zone E



• Results & Output

Floor zone B

Floor zone E

Construction
details

MACS+ - Membrane Action of Composite Structures in Case of Fire

File View Options Language Help

Project G.A. Deck Slab Beams Loading Fire & Analysis Detailed report

Detailed report

- Beam checks
The degree of shear connection of internal beam(s) does not satisfy the minimum limit specified by EN1994-1-1
- Perimeter beam check

Side	Beam type:	Solid beam	Composite	Internal beam
Side A	Section size:	IPE 400		
	Required moment resistance in fire situation:	434.51 kNm		
	Line load in fire situation:	42.91 kN/m		
	Shear connection:	51 %	This does not satisfy the minimum limit specified by EN1994-1-1	
	Degree of utilization:	0.59		
Side B	Critical temperature:	595 °C		
	Beam type:	Solid beam	Composite	Internal beam
	Section size:	IPE 750x137		
	Required moment resistance in fire situation:	618.53 kNm		
	Line load in fire situation:	34.36 kN/m		
Side C	Shear connection:	71 %		
	Degree of utilization:	0.24		
	Critical temperature:	722 °C		
	Beam type:	Solid beam	Composite	Internal beam
	Section size:	IPE 400		
Side D	Required moment resistance in fire situation:	434.51 kNm		
	Line load in fire situation:	42.91 kN/m		
	Shear connection:	51 %	This does not satisfy the minimum limit specified by EN1994-1-1	
	Degree of utilization:	0.59		
	Critical temperature:	595 °C		
Side D	Beam type:	Solid beam	Composite	Internal beam
	Section size:	IPE 750x137		
	Required moment resistance in fire situation:	618.53 kNm		

Project name: Floor zone E

Prev Next

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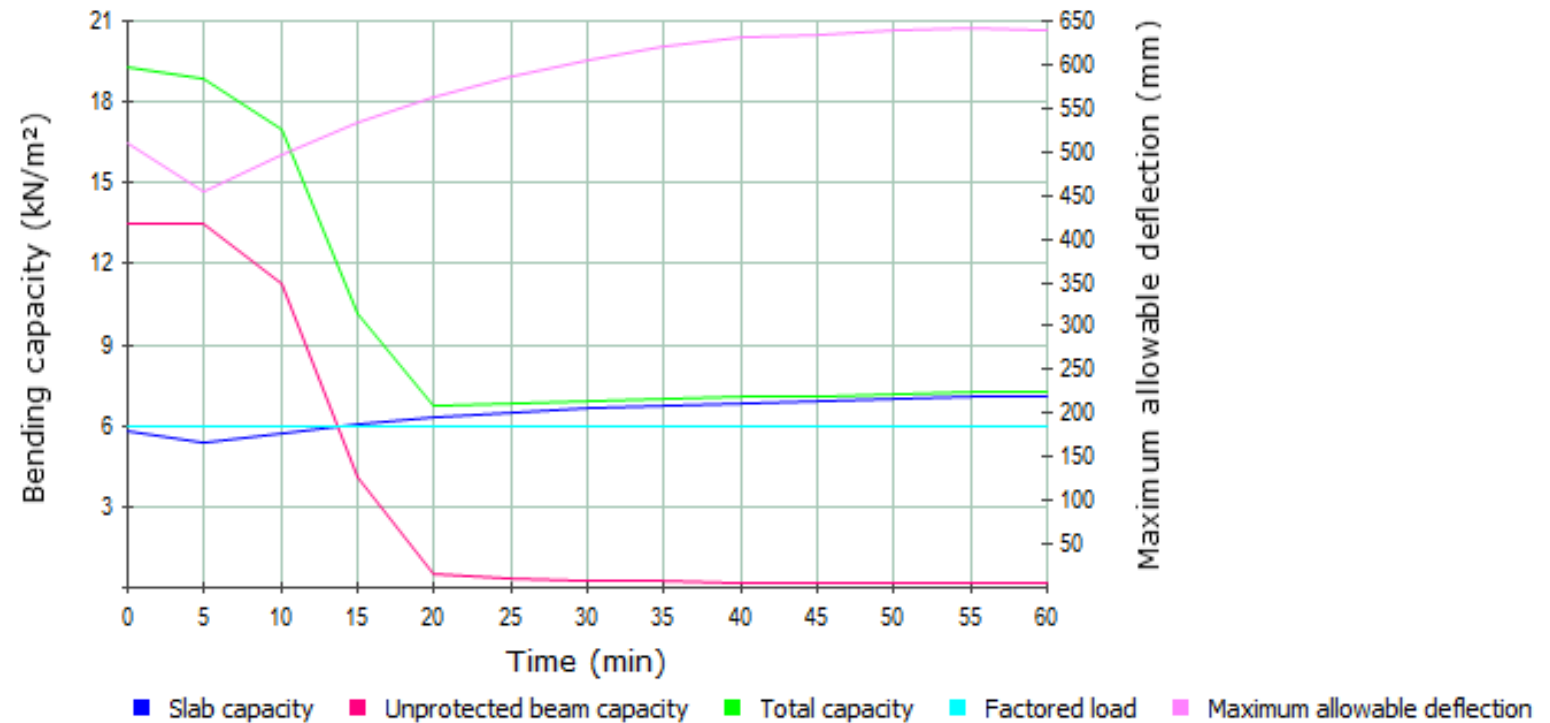
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Floor zone E



- Results & Output

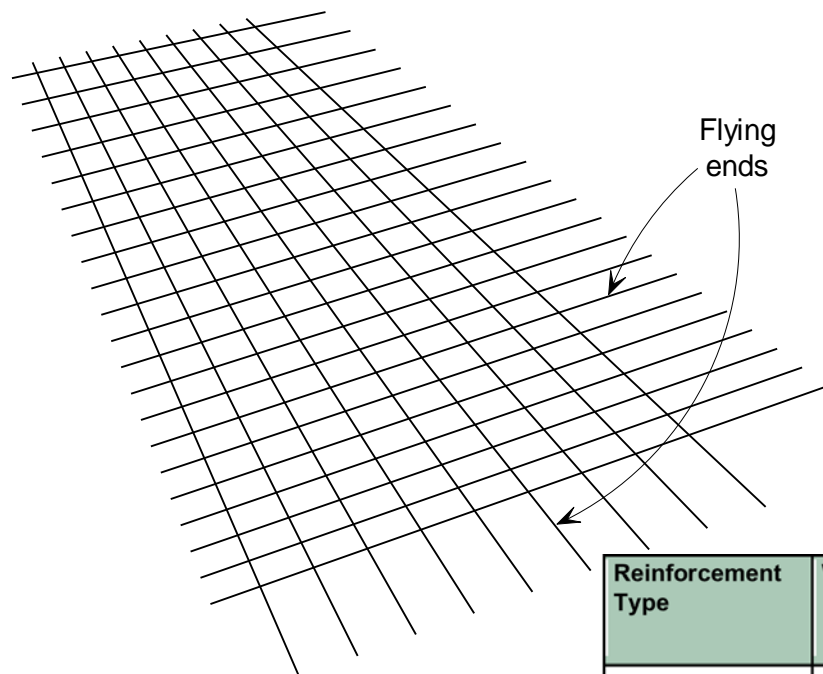




Construction details



Overlapping of the mesh in the slab to ensure continuity of the rebars



Floor zone B

Floor zone E

Construction details

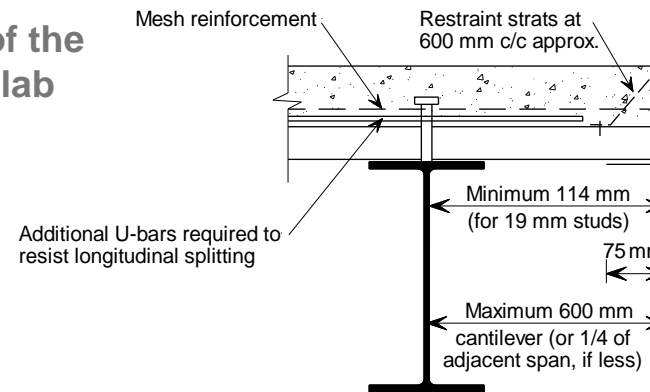
Reinforcement Type	Wire/Bar Type	Concrete class					
		LC 25/28	NC 25/30	LC 28/31	NC 28/35	LC 32/35	NC 32/40
Grade 500 Bar of diameter d	Ribbed	50d	40d	47d	38d	44d	35d
6 mm wires	Ribbed	300	250	300	250	275	250
7 mm wires	Ribbed	350	300	350	275	325	250
8 mm wires	Ribbed	400	325	400	325	350	300
10 mm wires	Ribbed	500	400	475	400	450	350



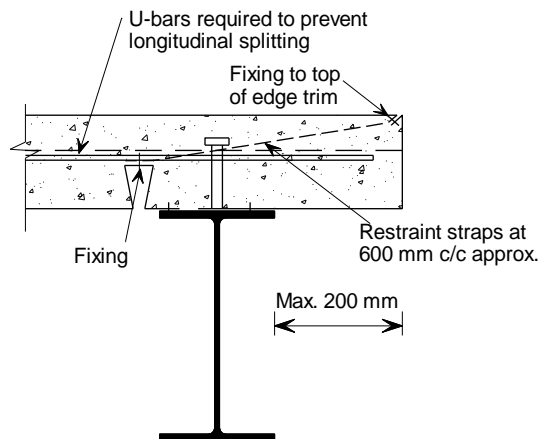
Construction details



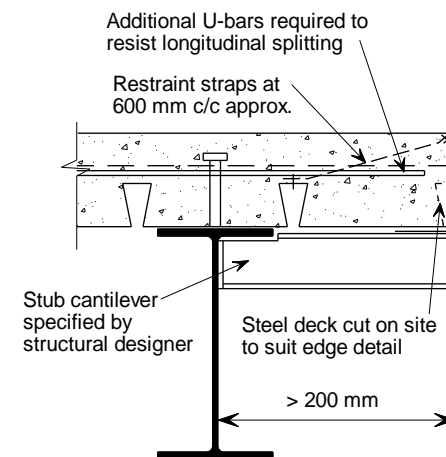
Edge details of the composite slab



a) Typical end cantilever
(decking ribs transverse to beam)



b) Typical edge detail
(decking ribs parallel to beam)



c) Side cantilever with stub bracket
(decking ribs parallel to beam)

Floor zone B

Floor zone E

Construction
details



Construction details

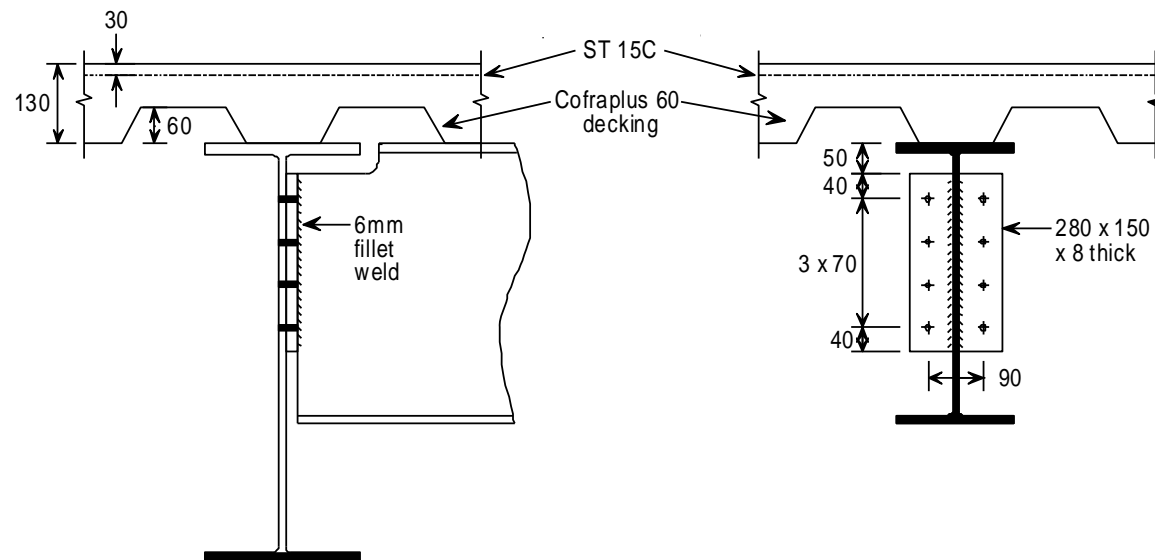


Beam-beam connection

Floor zone B

Floor zone E

Construction details

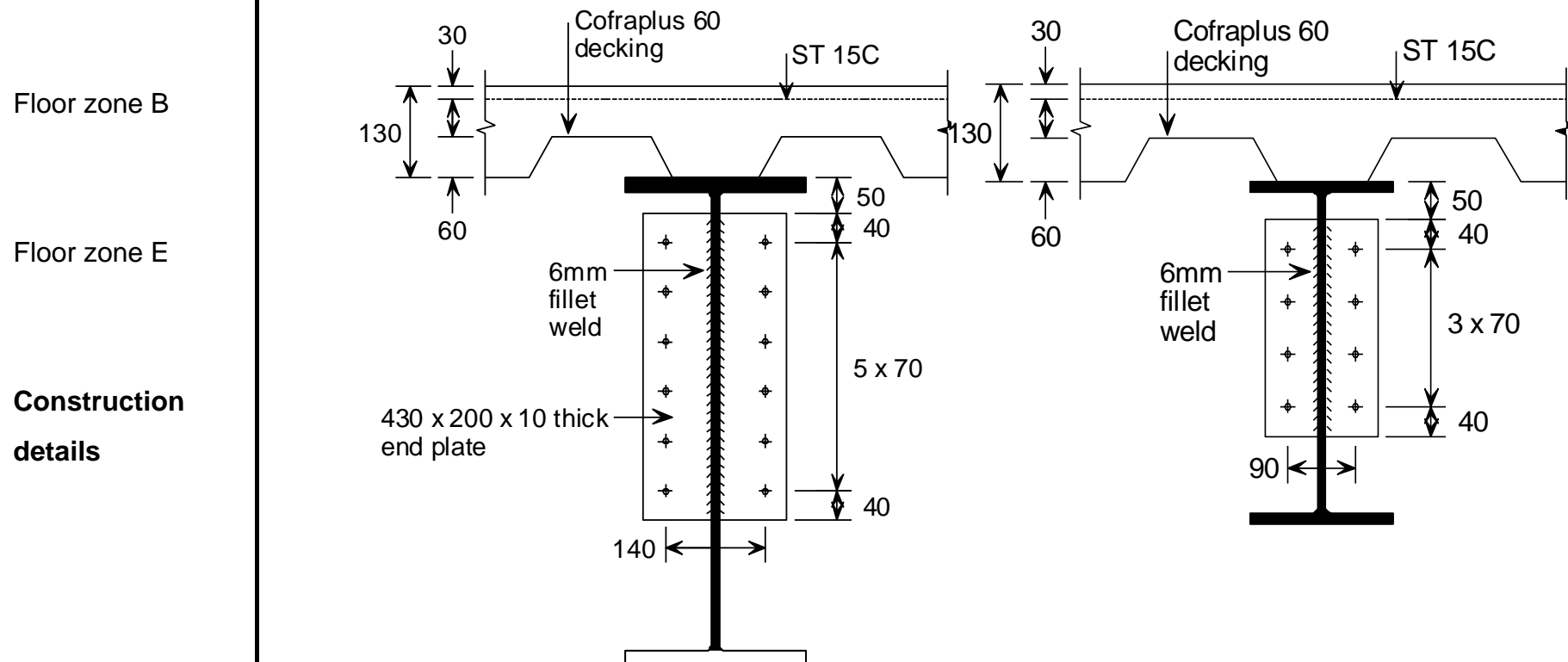




Construction details



Beam-column connection





Construction details



Column protection

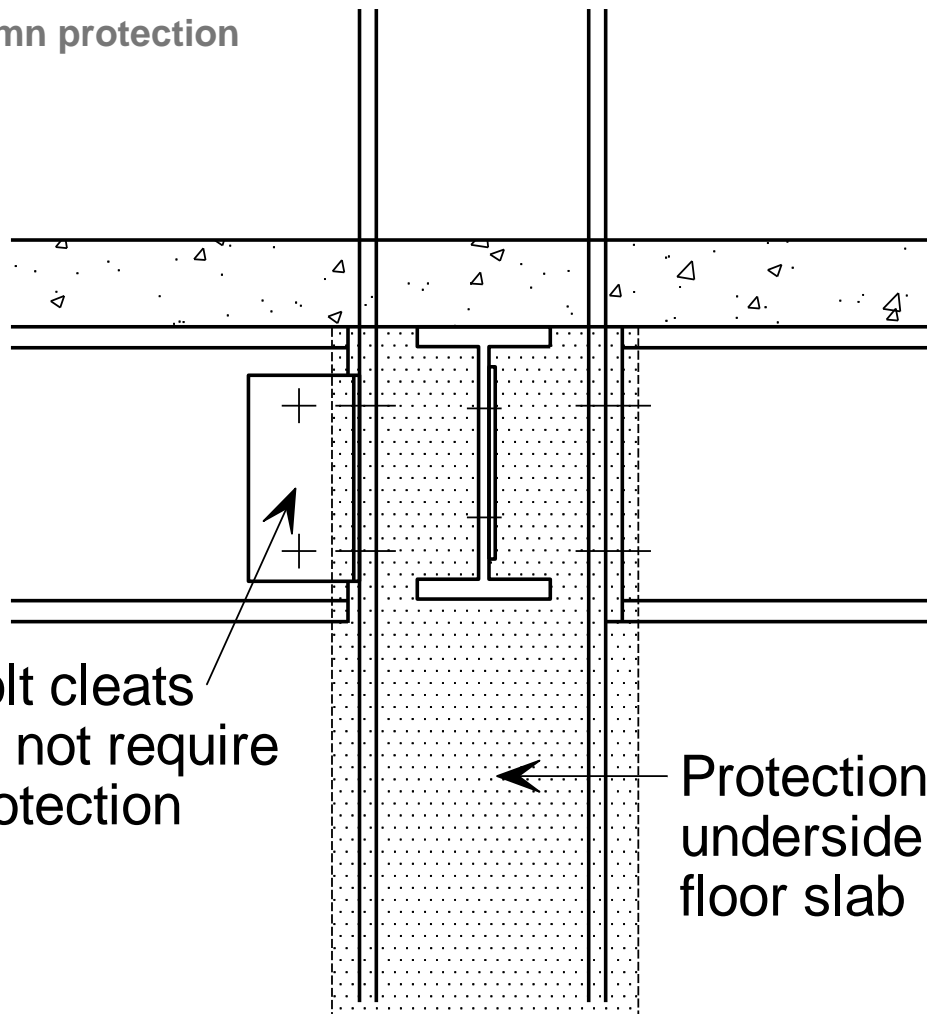
Floor zone B

Floor zone E

Construction
details

Bolt cleats
do not require
protection

Protection to
underside of
floor slab





Demonstration



Demonstration: <C:\Users\Gebruiker\Desktop\MACS+ vbeta 2.06.11.Ink>

Floor zone B

Floor zone E

**Construction
details**