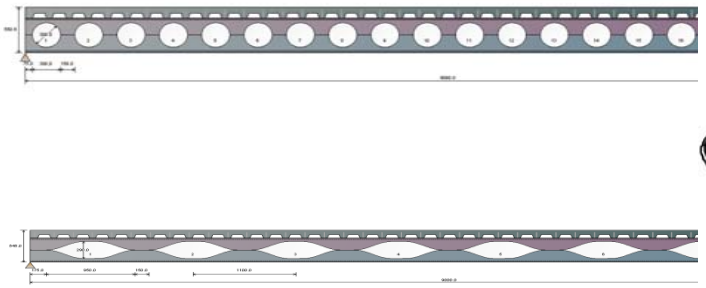
Research Fund for Coal & Steel

Fire Behaviour of Steel and Composite Floor Systems

Worked examples

Table of content

- **Worked examples**
  - Floor layout



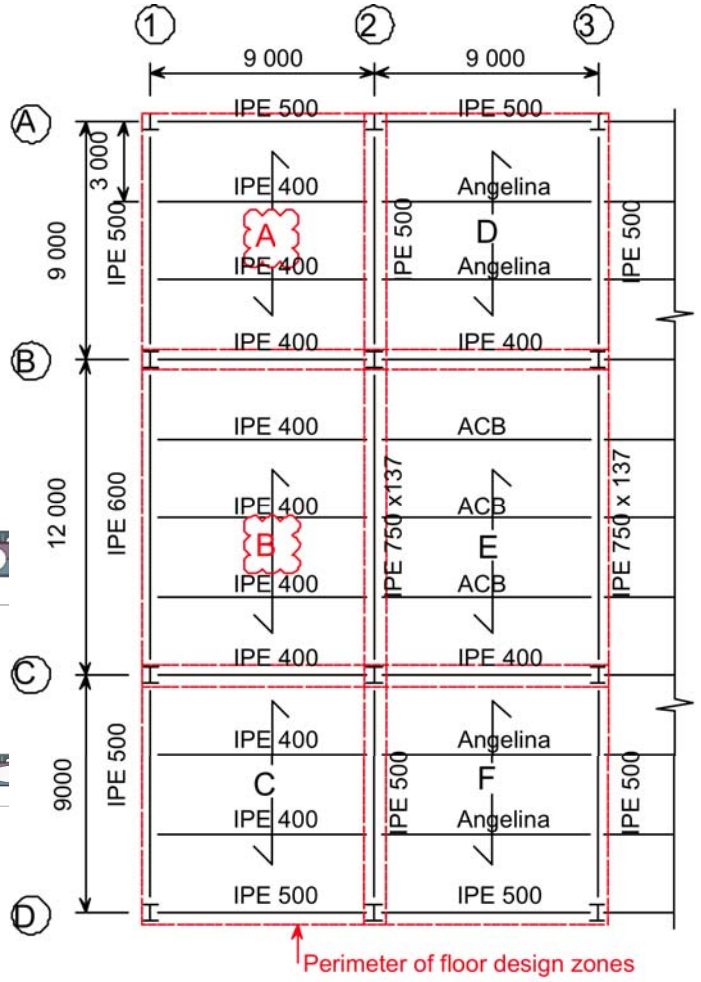
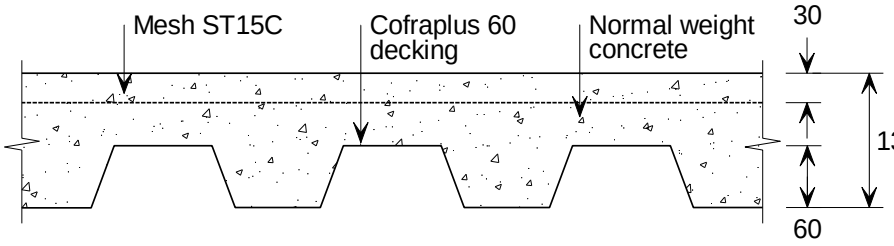


Table of content

- **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 × 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



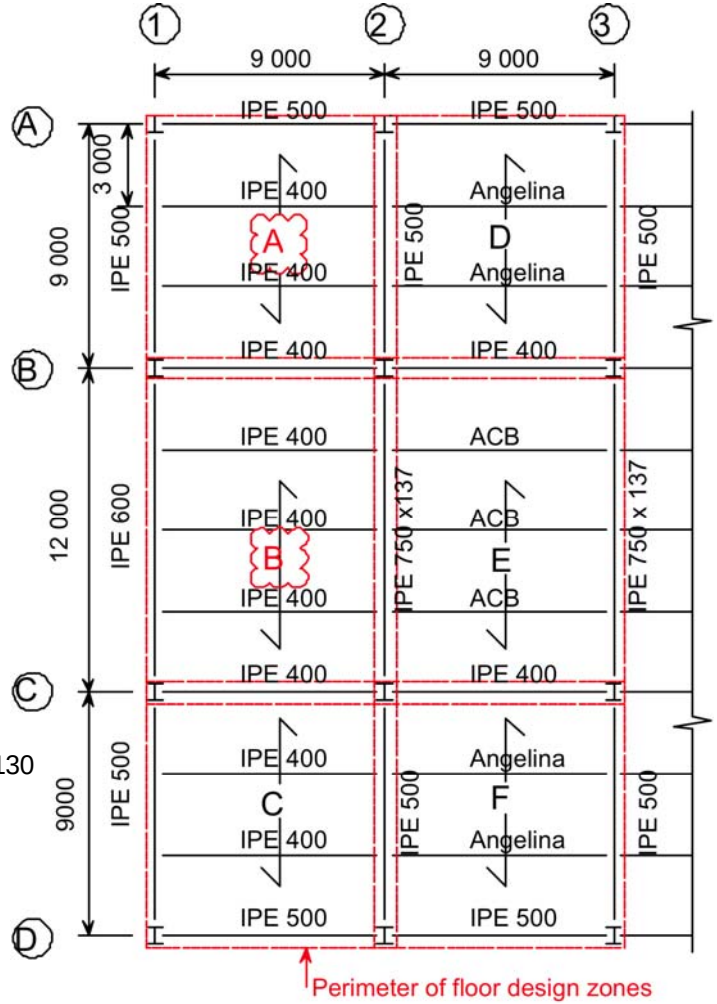
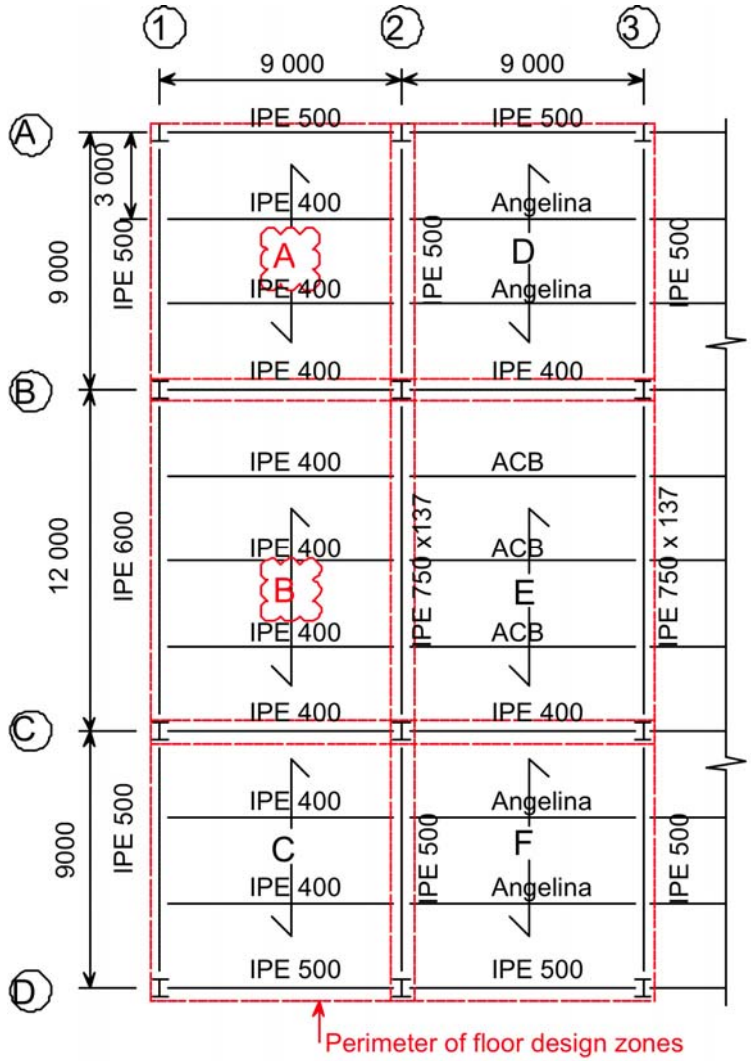


Table of content

- **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 permanente action: 1.0
  - Combination factor for leading variable action: 0.5
  - Combination factor for accompanying variable action: 0.5

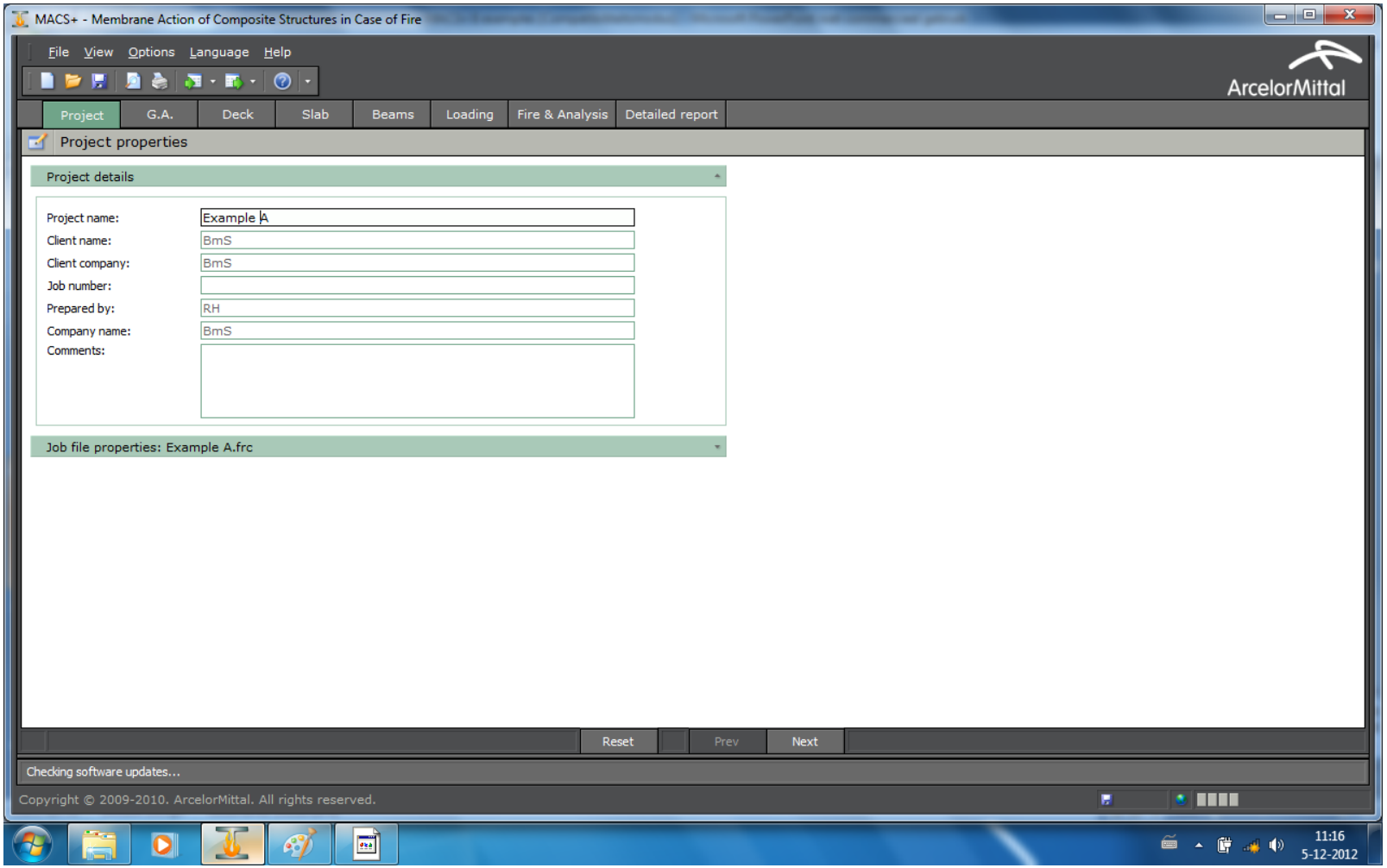
Floor zone B

Floor zone B

Floor zone E

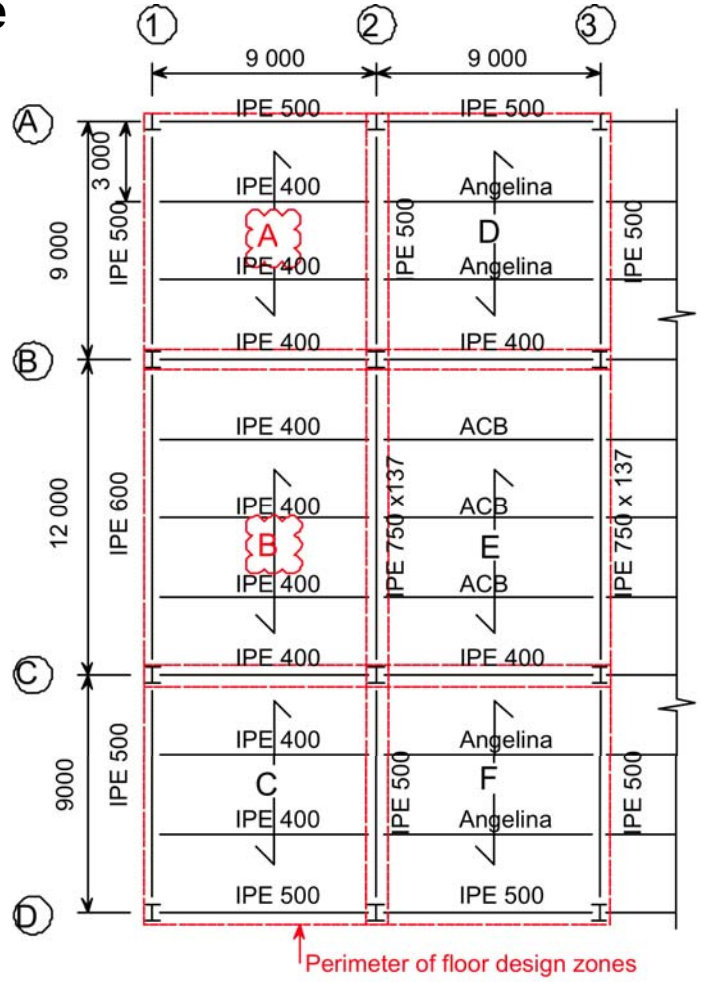
Construction details

- **General data**



Floor zone B

- **9 x 12 m floor design zone**



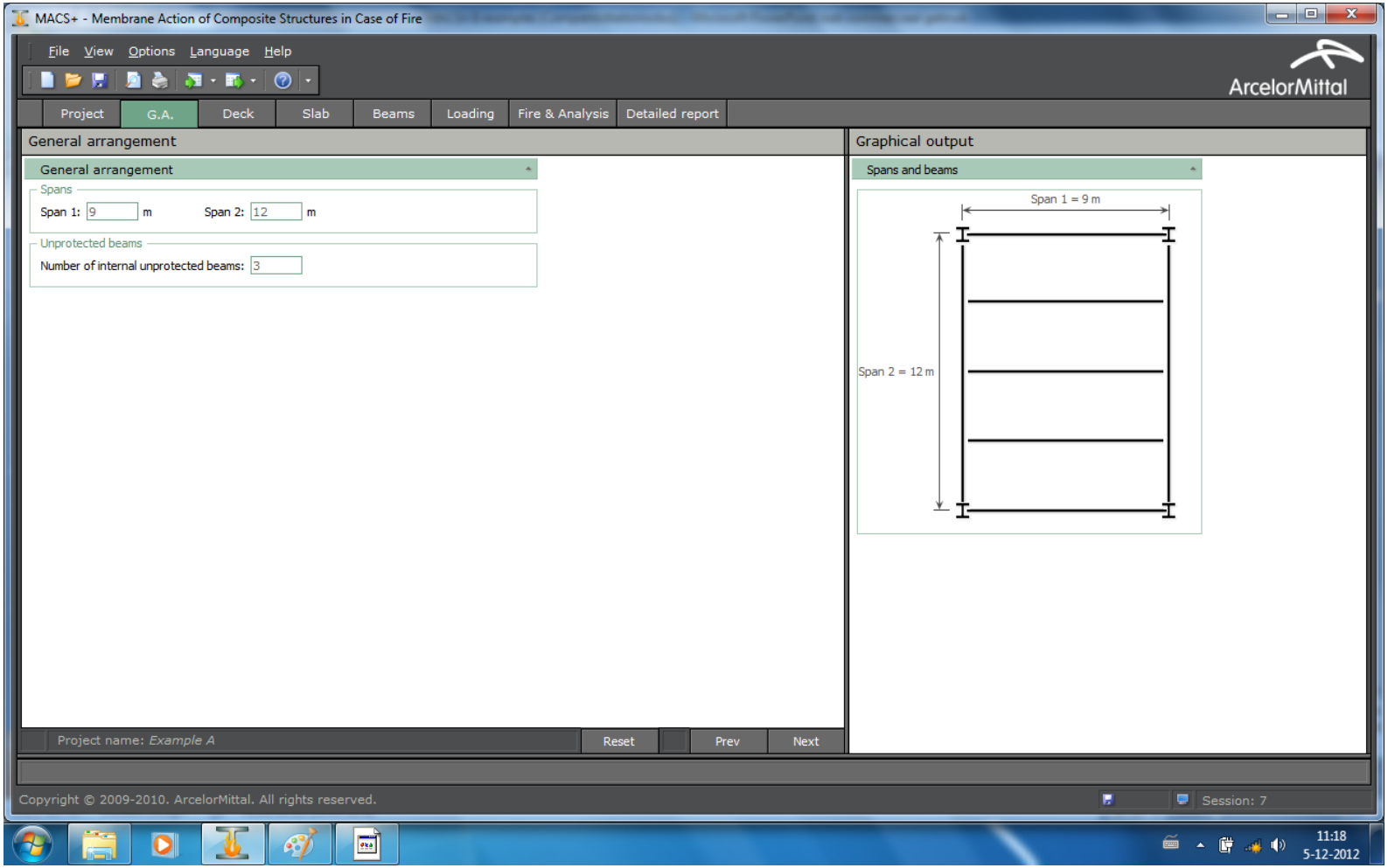
Floor zone B

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

Floor zone B

Floor zone E

Construction details



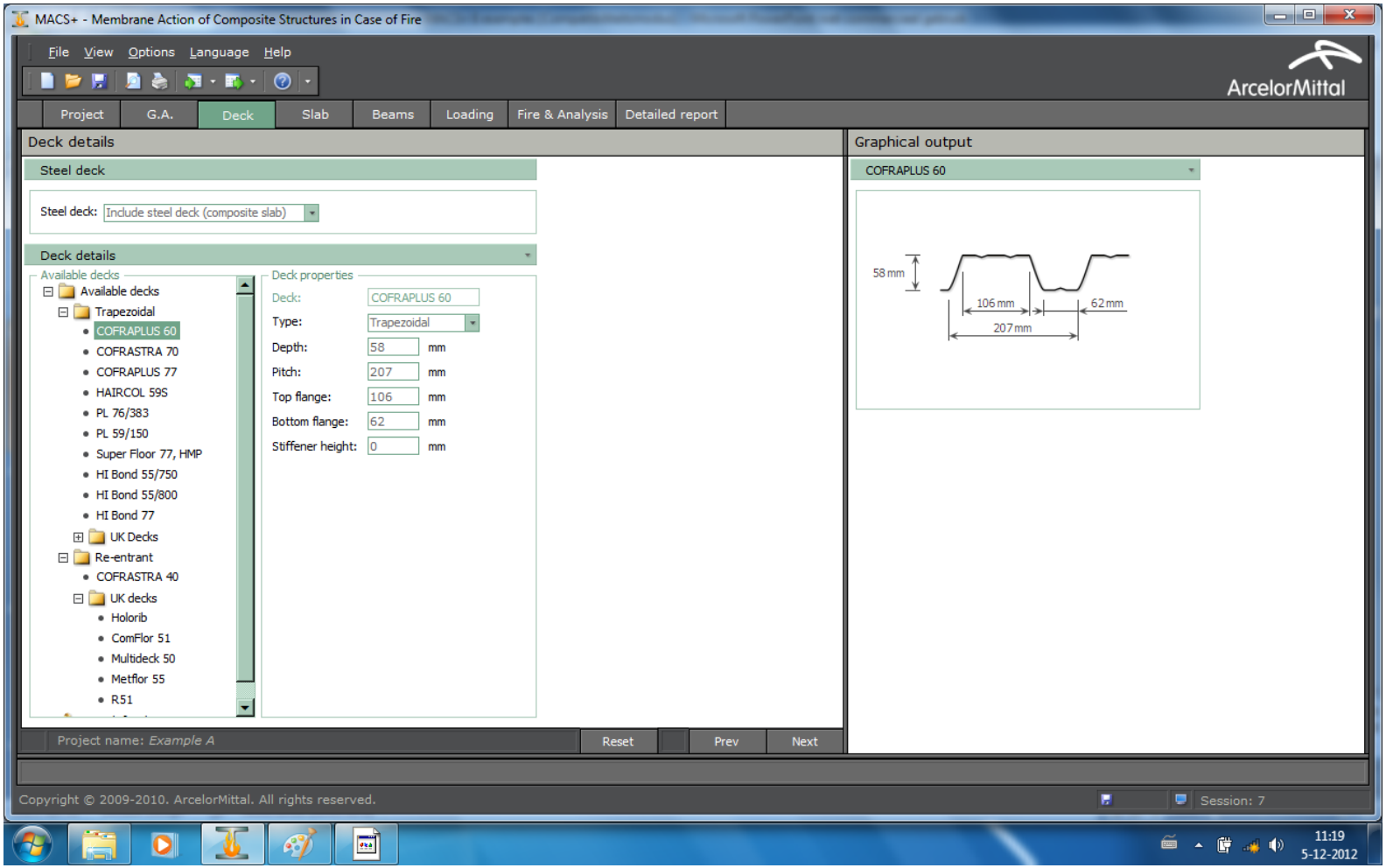
Floor zone B

Floor zone B

Floor zone E

Construction details

- **Input field steel sheet: Cofraplus 60**



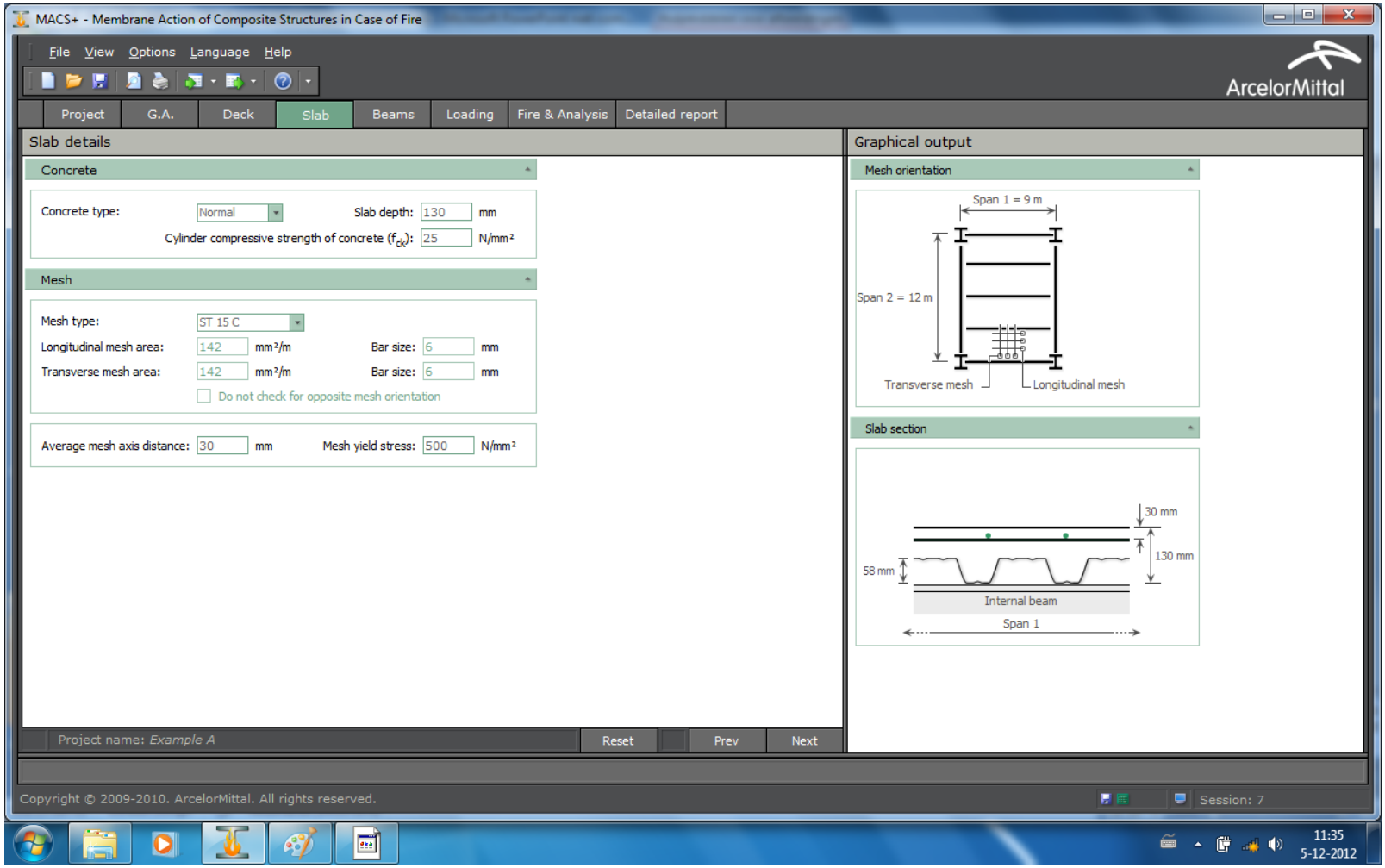
Floor zone B

Floor zone B

Floor zone E

Construction details

- **Input field floor slab**



Floor zone B

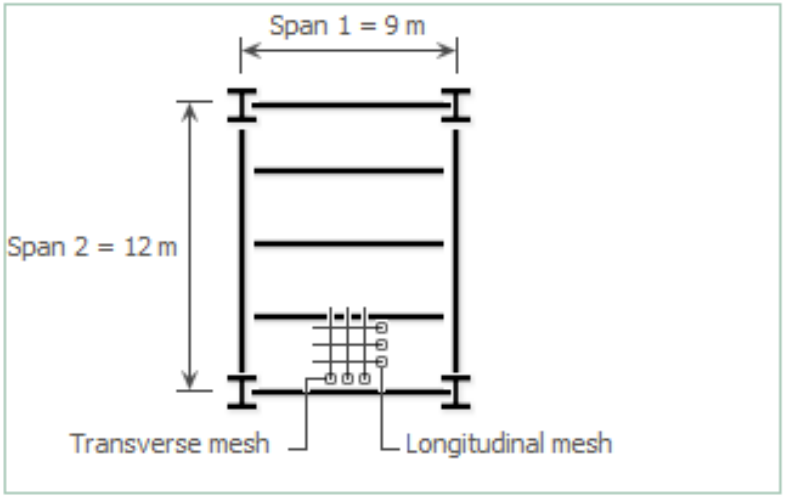
Floor zone B

Floor zone E

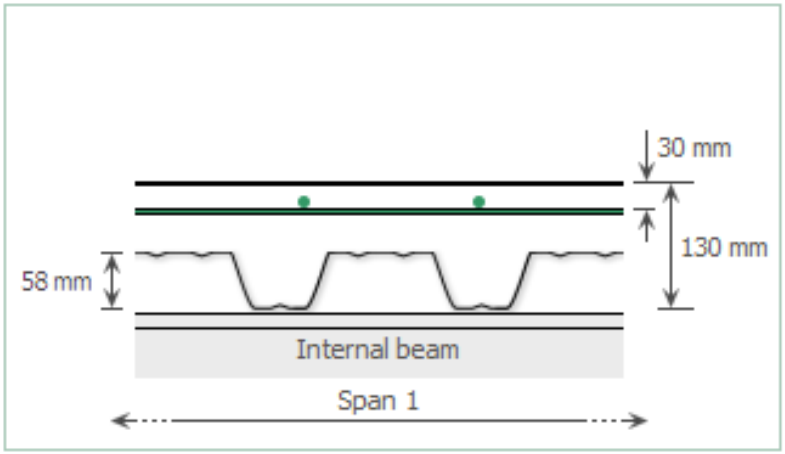
Construction details

- **Input field floor slab**

Mesh orientation



Slab section



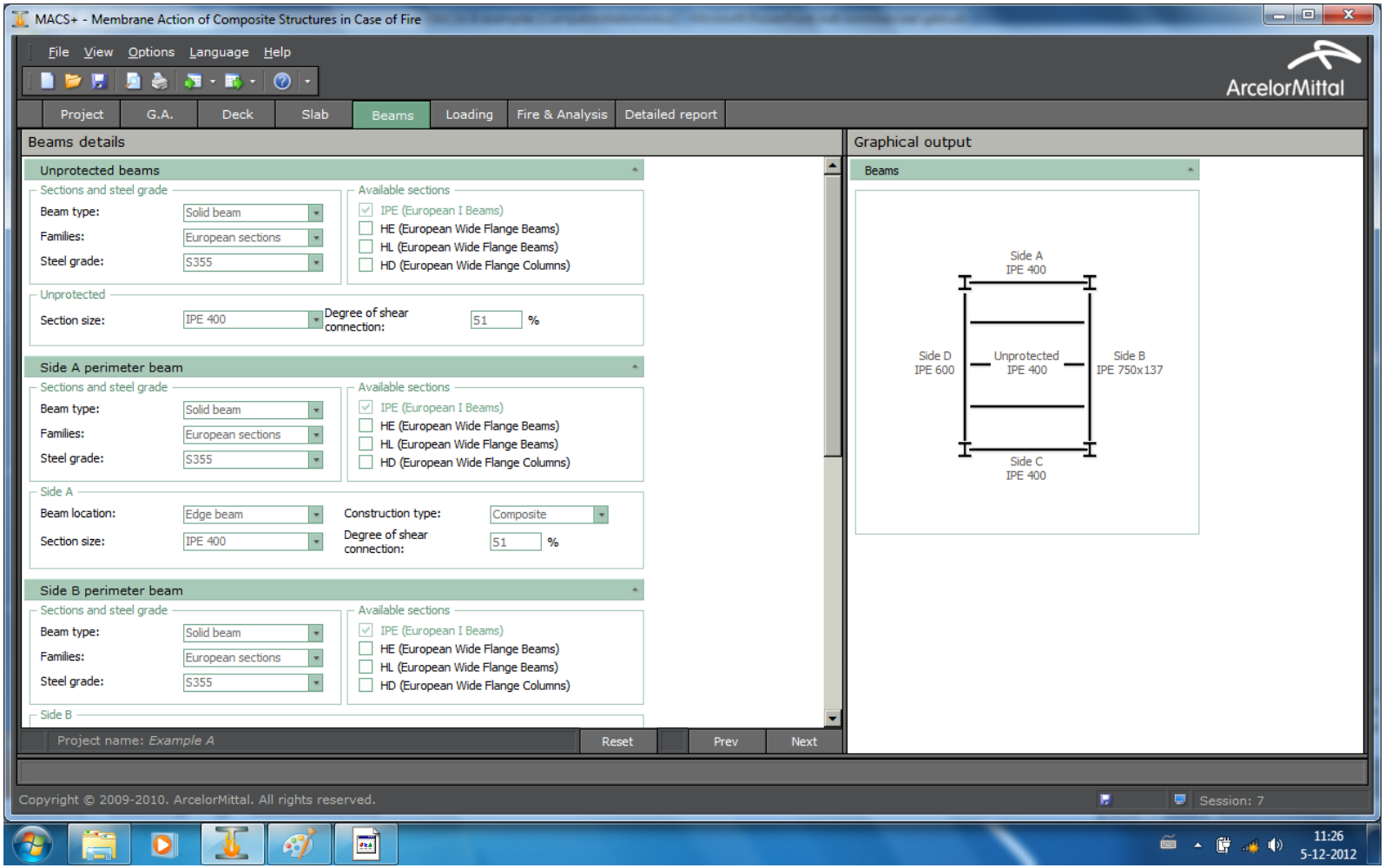
Floor zone B

- **Input field beams**

Floor zone B

Floor zone E

Construction details



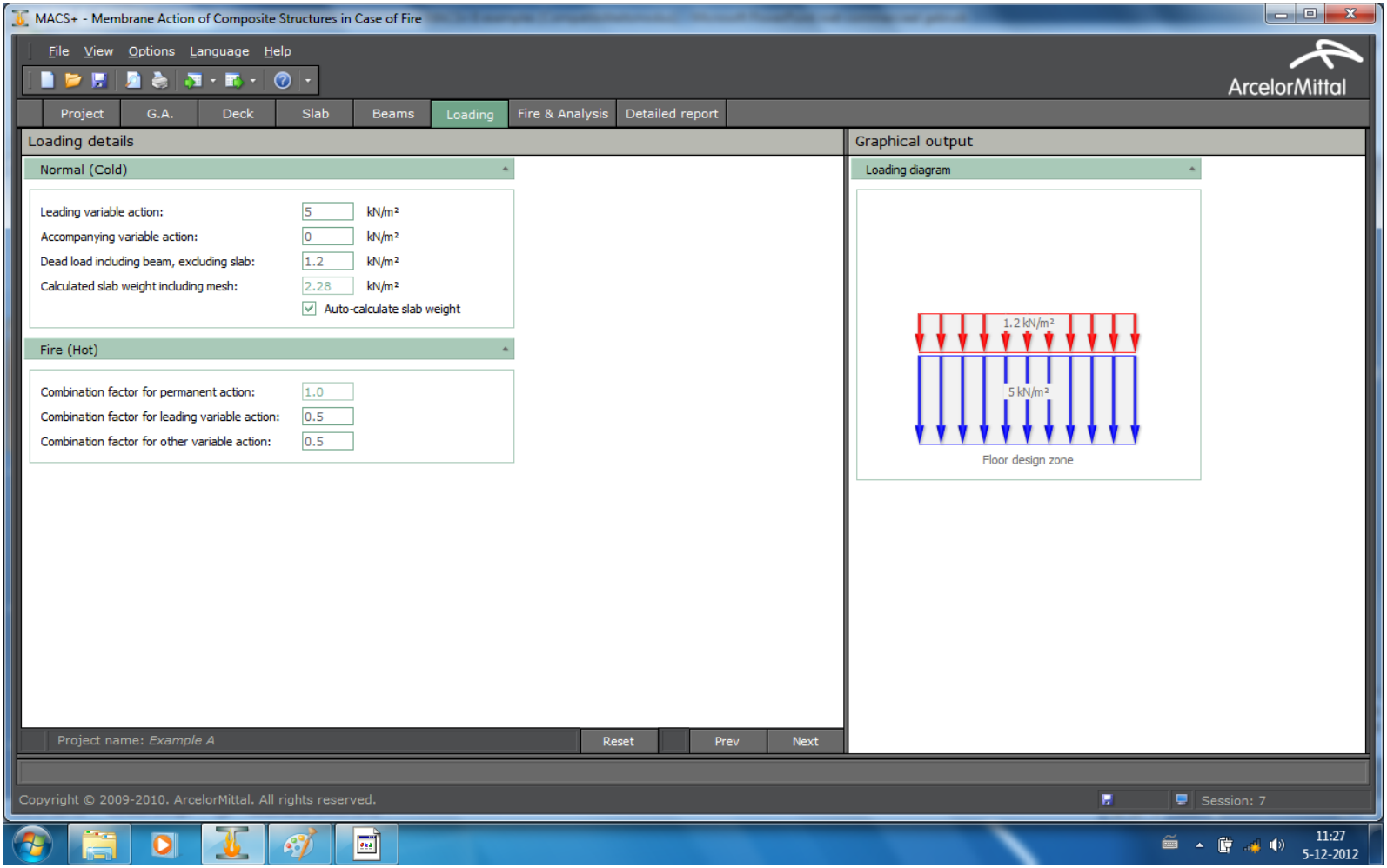
Floor zone B

Floor zone B

Floor zone E

Construction details

- **Input field actions**



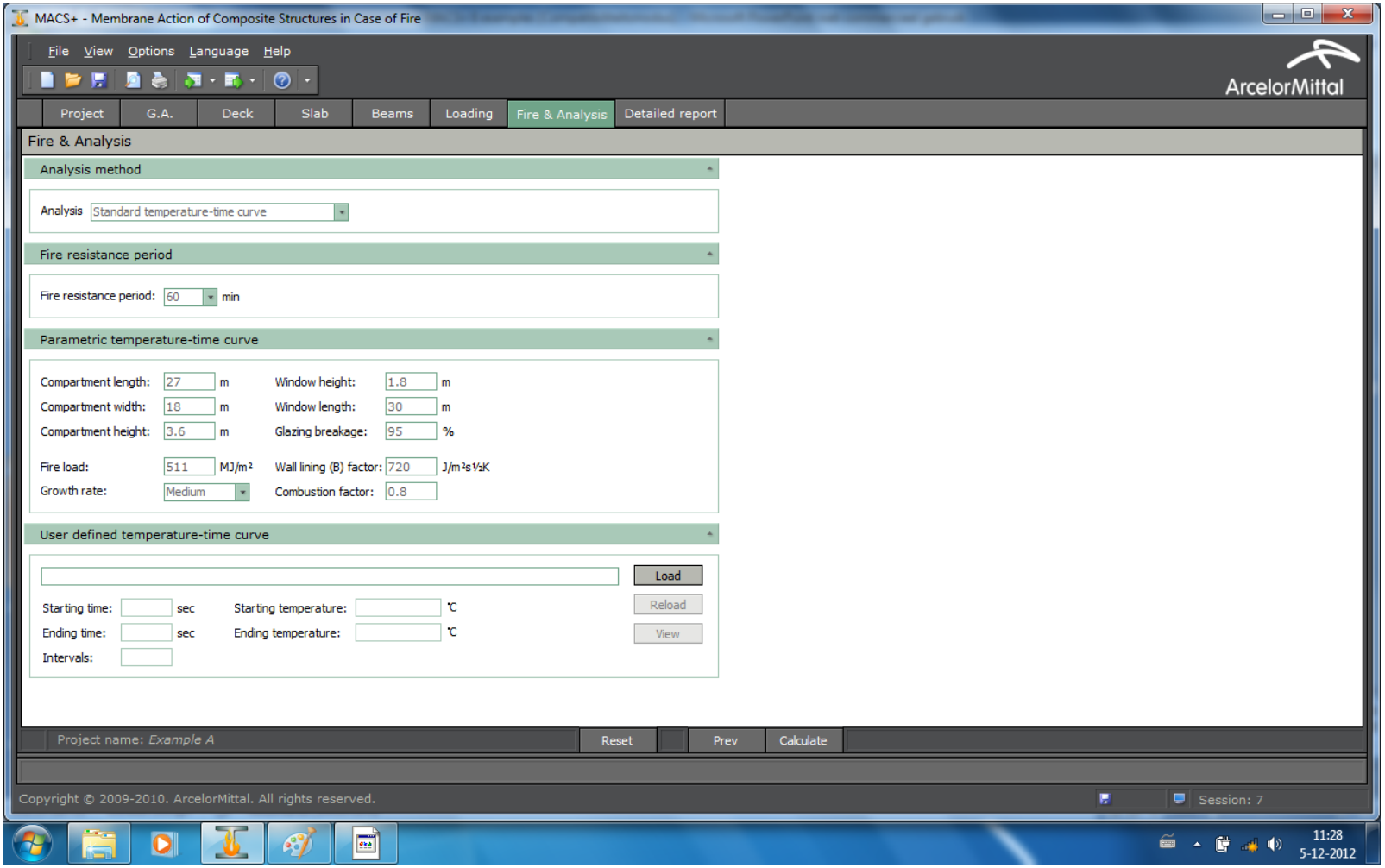
Floor zone B

Floor zone B

Floor zone E

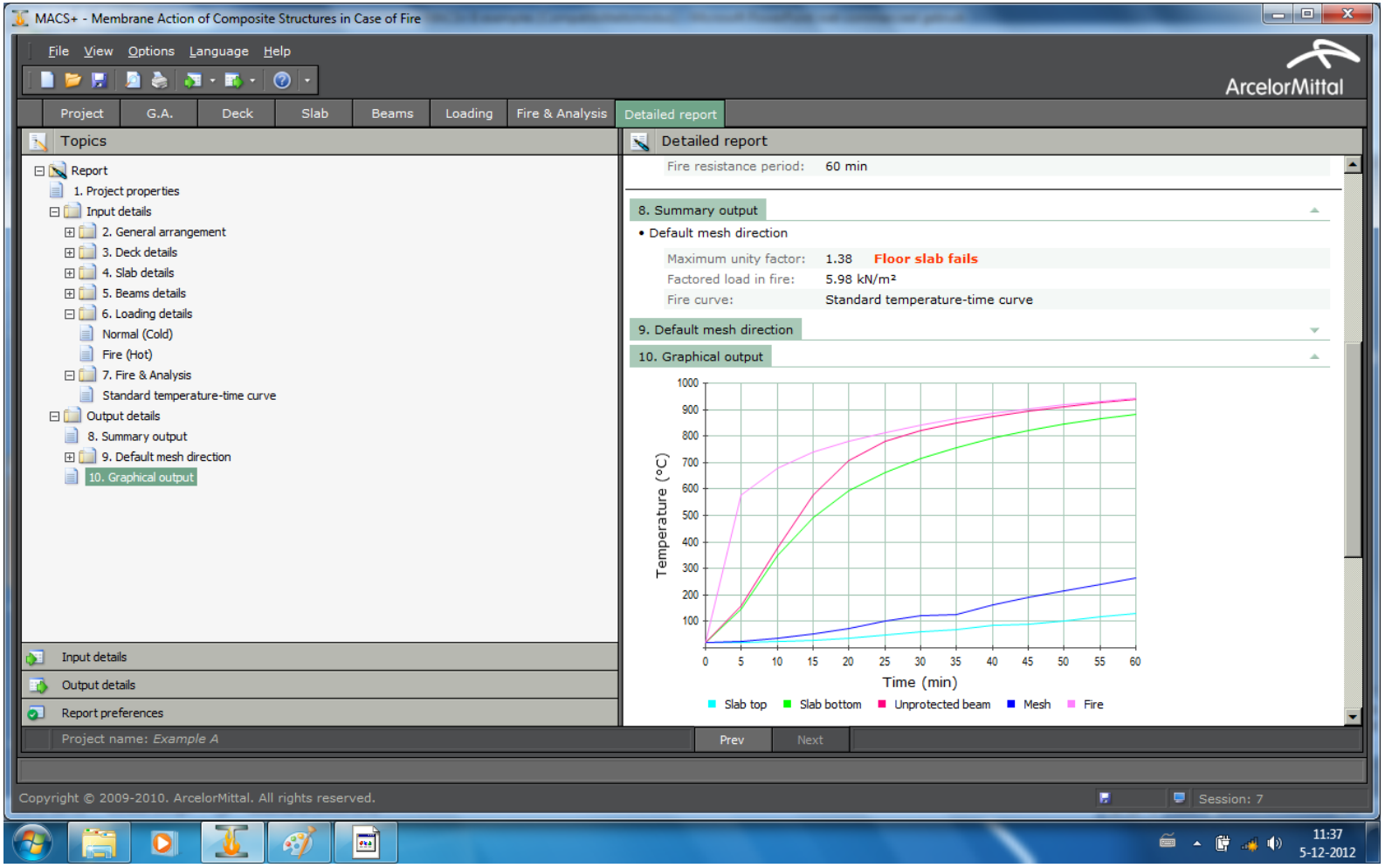
Construction details

- **Input field Fire & Analysis**



Floor zone B

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



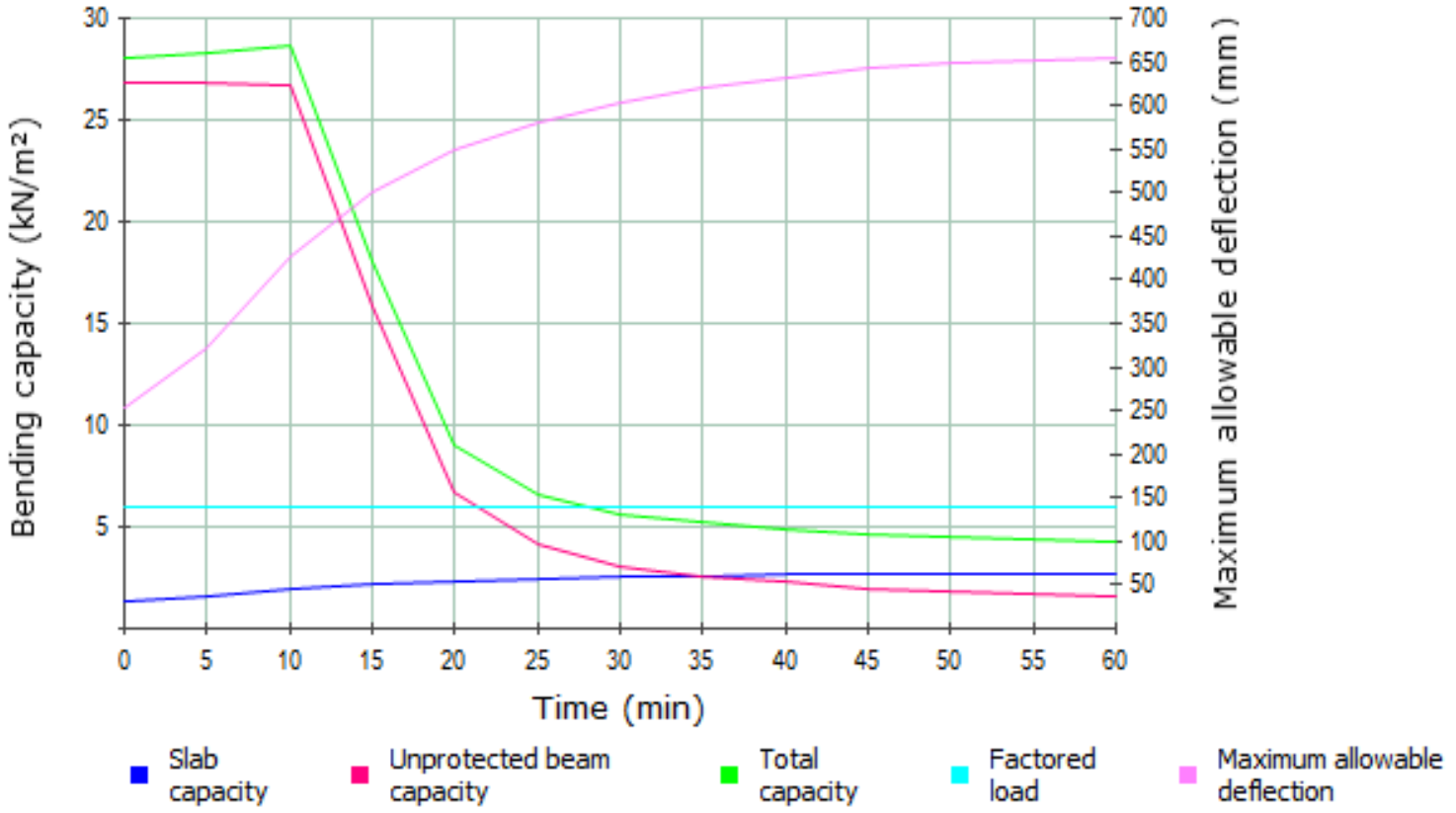
Floor zone B

Floor zone E

Construction details

Floor zone B

- **Results & Output**



Floor zone B

Floor zone B

Floor zone E

Construction details

- **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	Enhance-ment	Slab capacity	Total capacity	Unity factor
mins	°C	°C	°C	°C	kN/m²	mm	kN/m²		kN/m²	kN/m²	
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

- **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

ArcelorMittal

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 A	Beam type:	Solid beam	Composite	Edge 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 %		
	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* Prev Next

Session: 7

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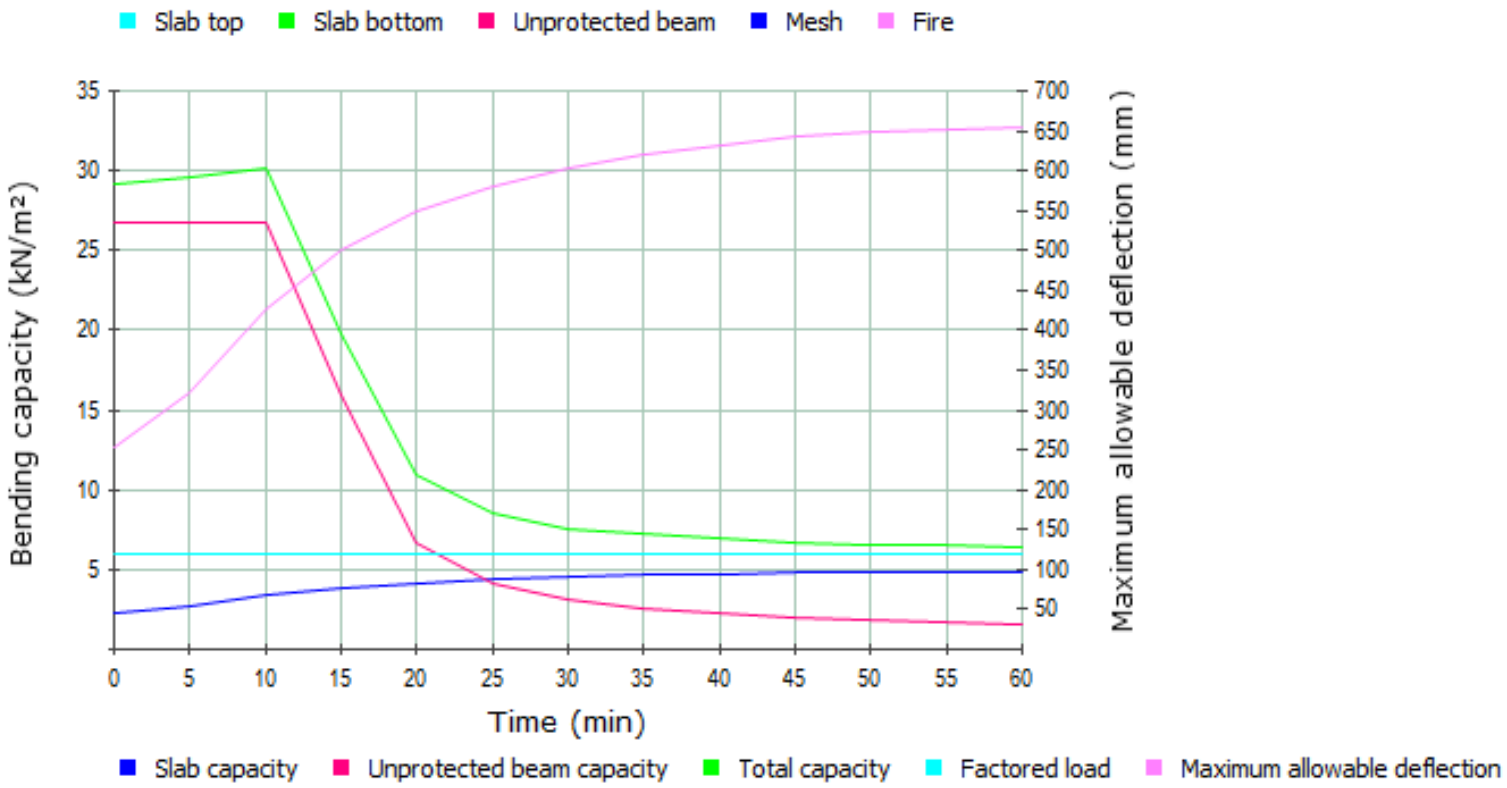
Floor zone B

Floor zone B

Floor zone E

Construction details

- **Results & Output**



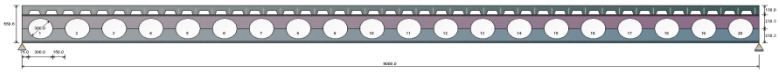
Floor zone E

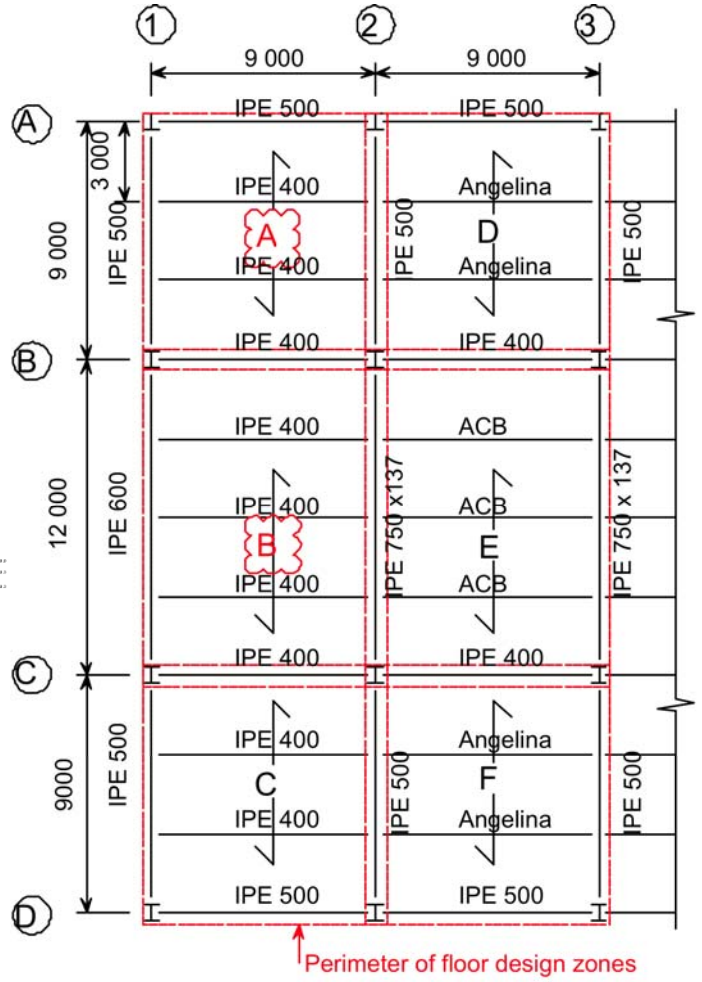
Floor zone B

Floor zone E

Construction details

- **9 x 12 m floor design zone with cellular beams**





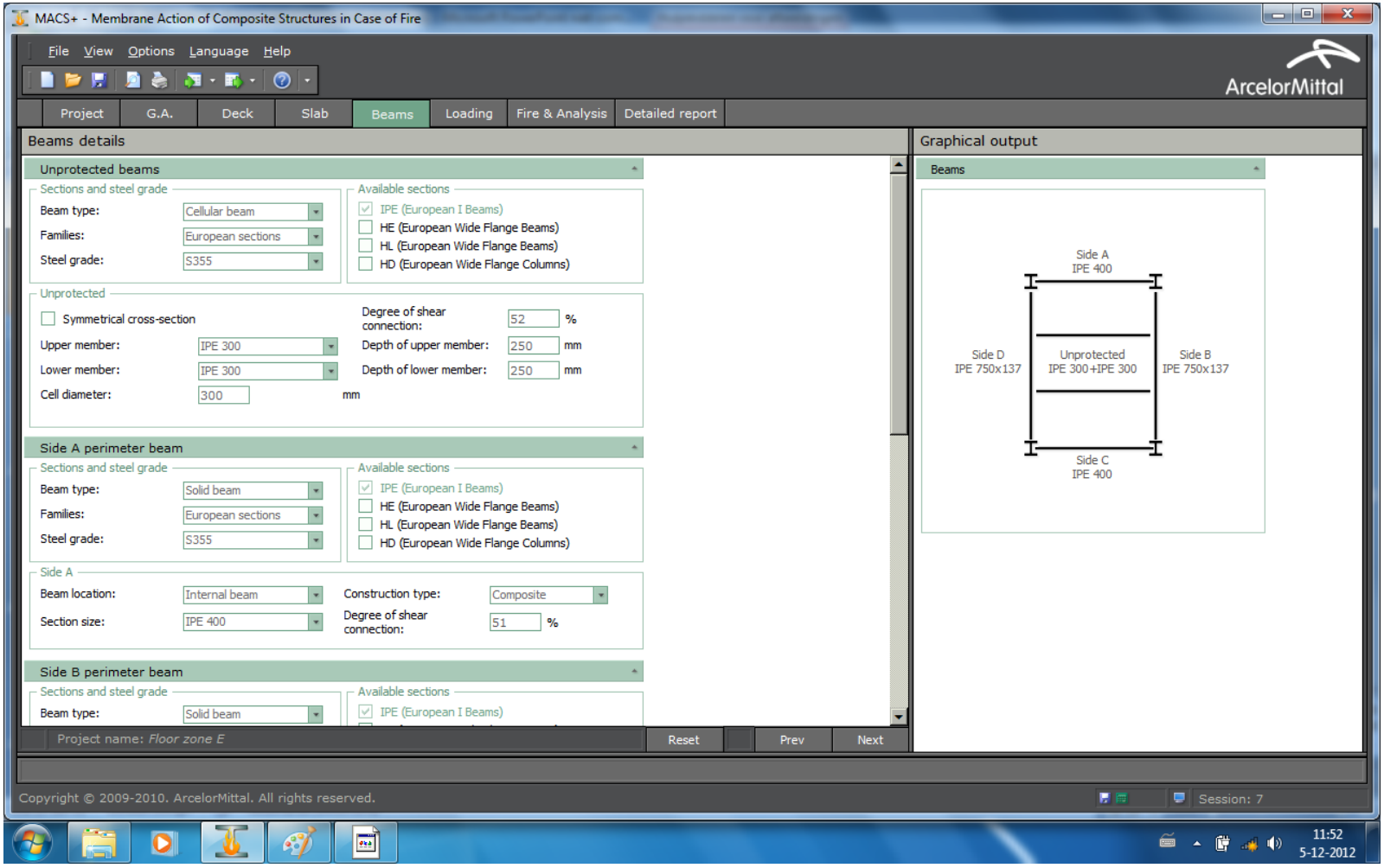
Floor zone E

- **9 x 12 m floor design zone with cellular beams**

Floor zone B

Floor zone E

Construction details



Floor zone E

Floor zone B

Floor zone E

Construction details

- **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		

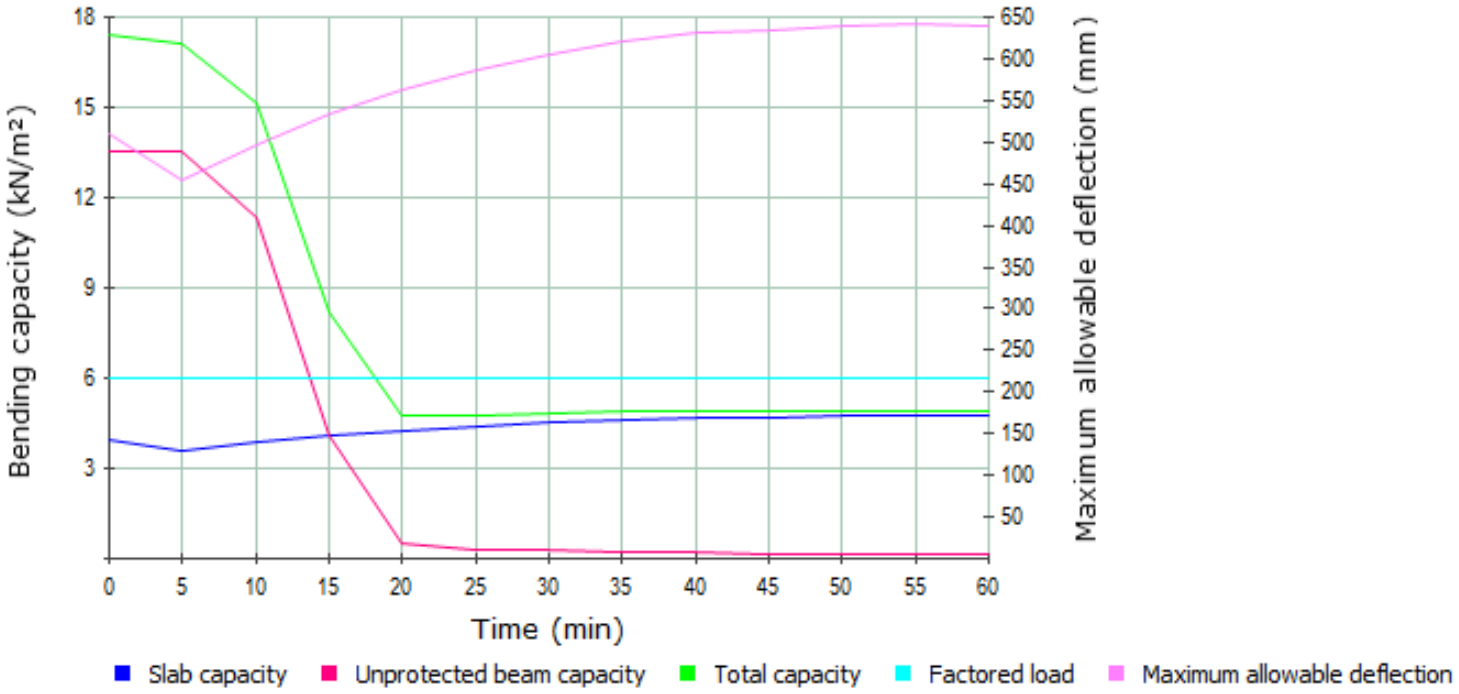
• Tabular results

Time	Beam	Mesh	Slab top	Slab bottom	Beam capacity	Maximum allowable deflection	Slab yield	Enhance-ment	Slab capacity	Total capacity	Unity factor
mins	°C	°C	°C	°C	kN/m²	mm	kN/m²		kN/m²	kN/m²	
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**



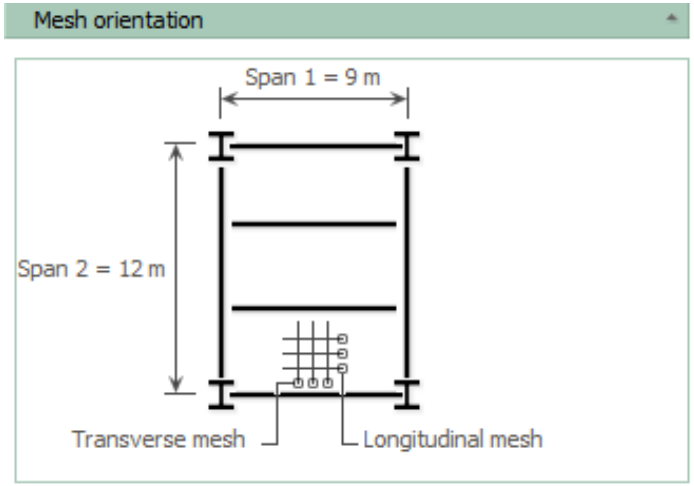
Floor zone B

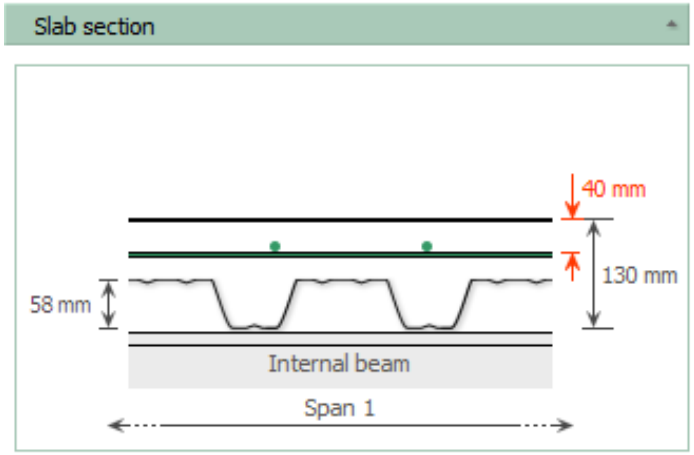
Floor zone E

Construction details

Floor zone E

- **Option 1: axis distance from 30 to 40 mm (temperature just below 400 ° C, so ca. 100% sterngth)**
- **uc of 1.,26 after 25 minutes**
- **improved to**
- **uc of 1.19 after 25 minutes**





Floor zone B

Floor zone E

Construction details

Floor zone E

Floor zone B

Floor zone E

Construction details

- **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	Enhance-ment	Slab capacity	Total capacity	Unity factor
mins	°C	°C	°C	°C	kN/m²	mm	kN/m²		kN/m²	kN/m²	
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**

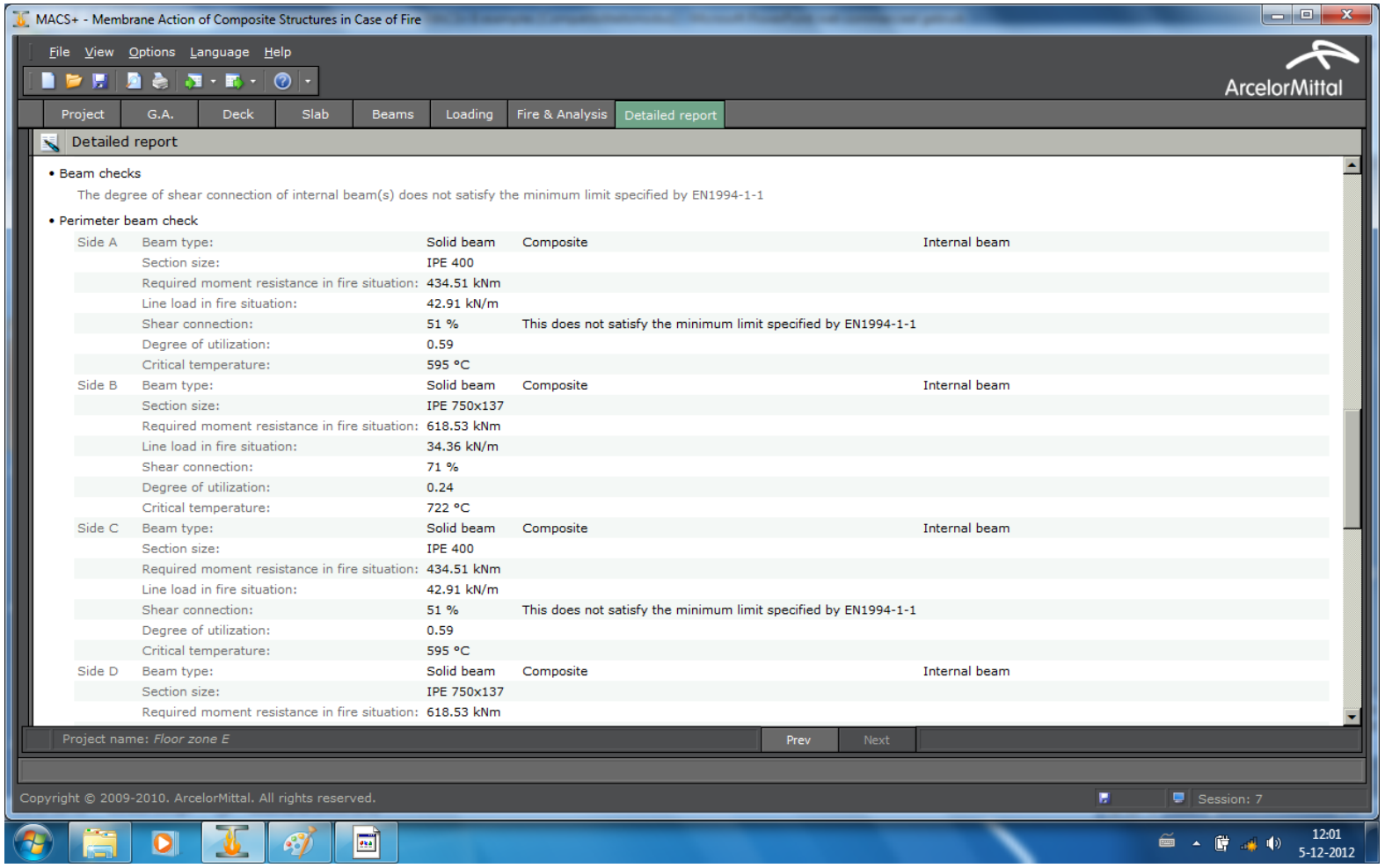
Floor zone E

Floor zone B

Floor zone E

Construction details

- **Results & Output**



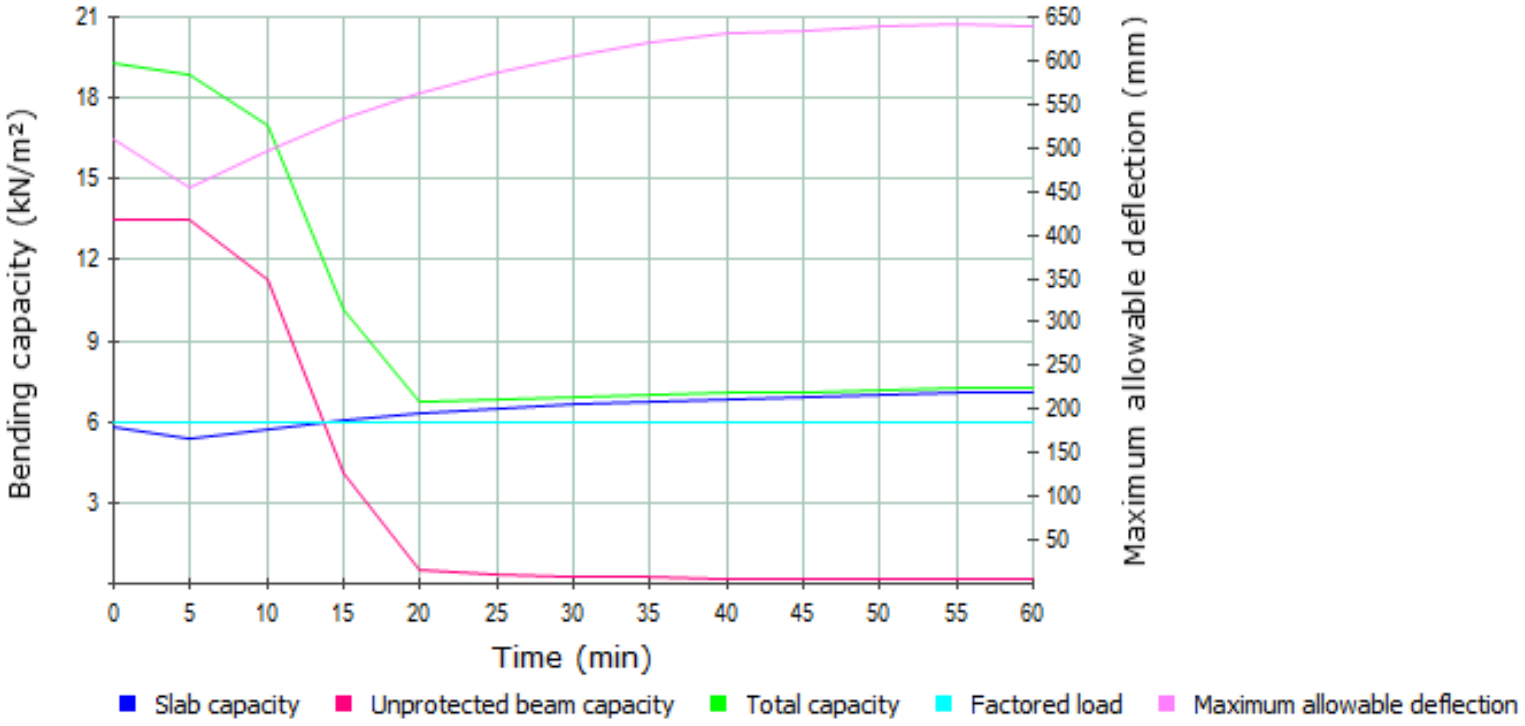
Floor zone E

Floor zone B

Floor zone E

Construction details

- **Results & Output**



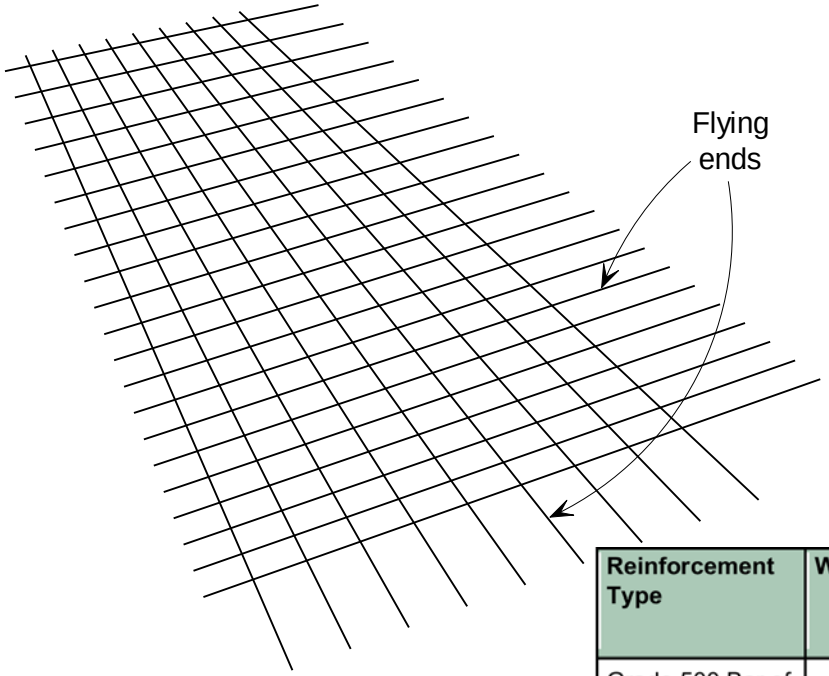
Construction details

Floor zone B

Floor zone E

Construction details

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



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

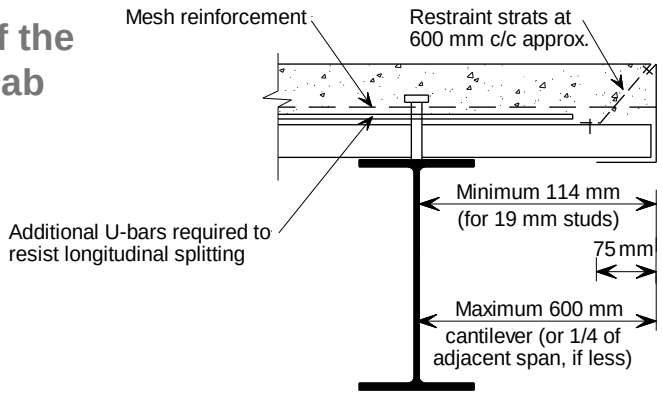
Construction details

Floor zone B

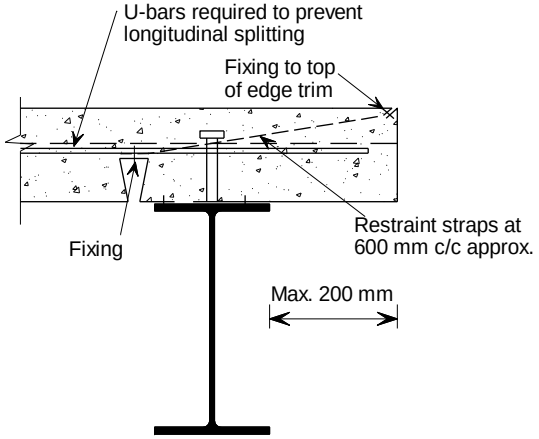
Floor zone E

Construction details

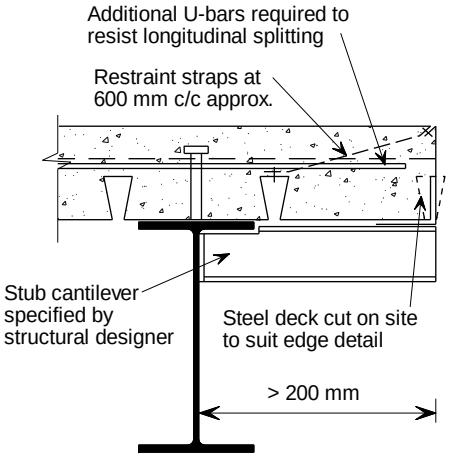
Edge details of the composite slab



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)

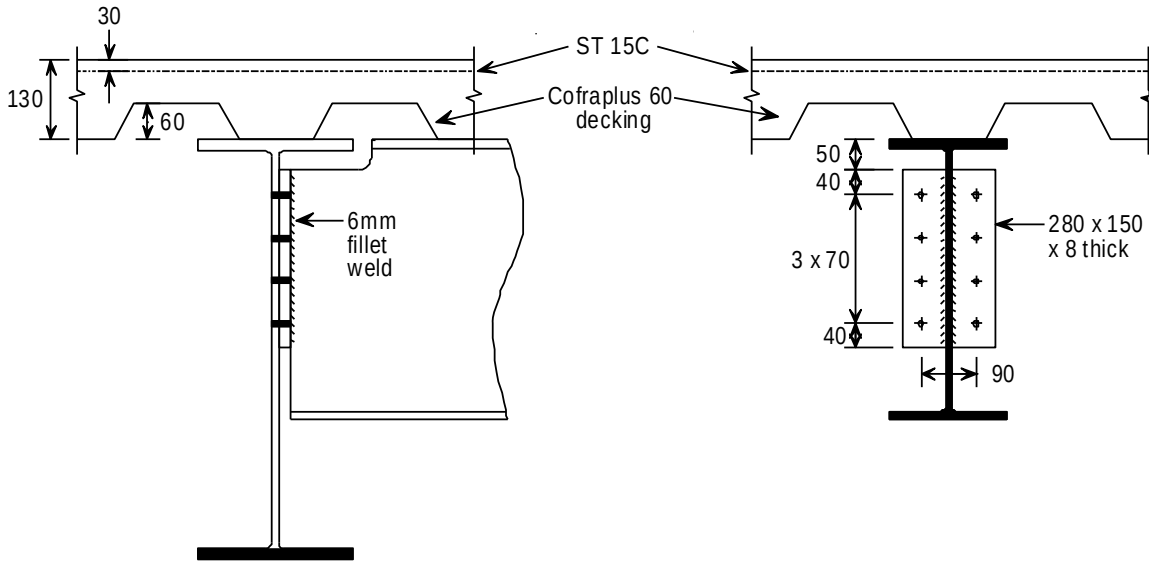
Construction details

Floor zone B

Floor zone E

Construction details

Beam-beam connection



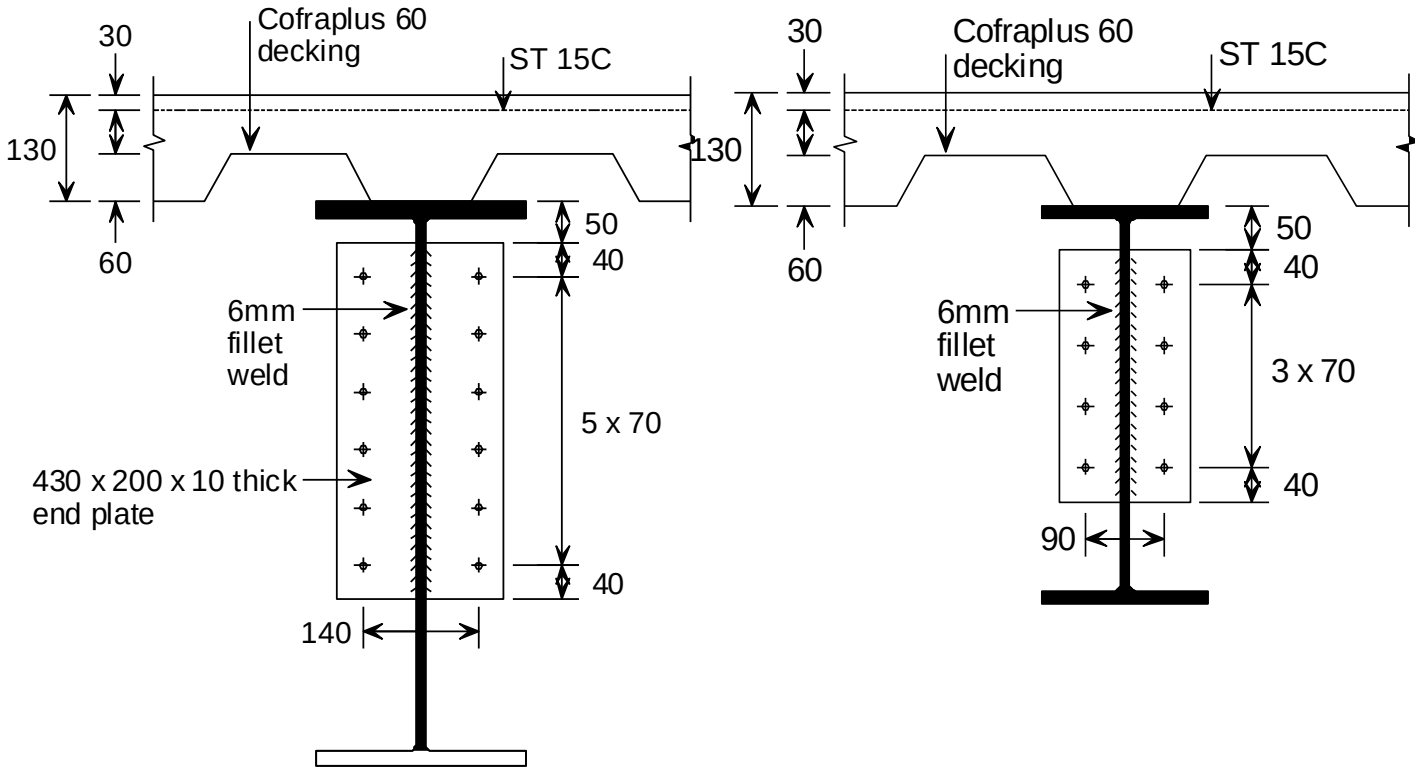
Construction details

Floor zone B

Floor zone E

Construction details

Beam-column connection



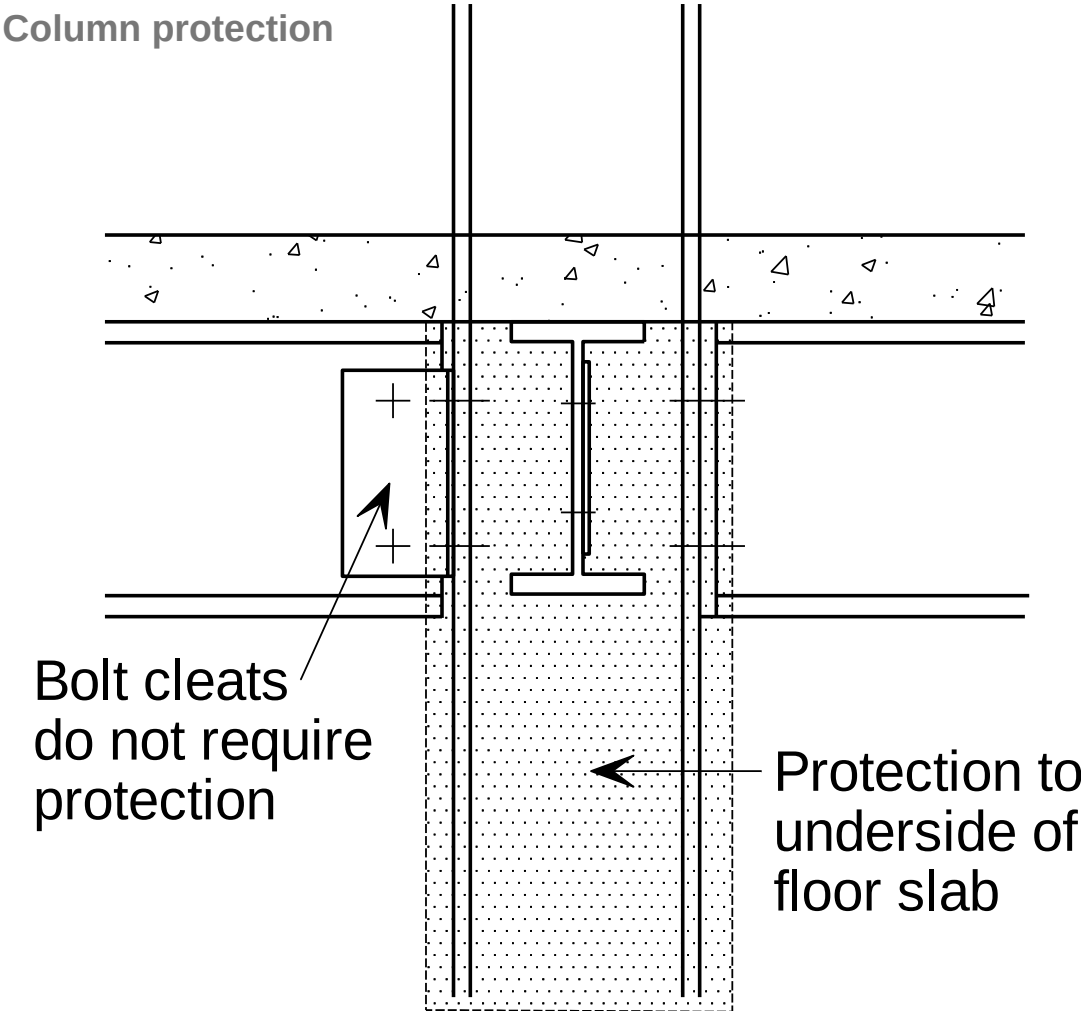
Construction details

Floor zone B

Floor zone E

Construction details

Column protection



Demonstration

Floor zone B

Floor zone E

Construction details

Demonstration: C:\Users\Gebruiker\Desktop\MACS+ vbeta_2.06.11.lnk