OCTOBER 2019

Concrete & Tunnel Structures

FP®-900 / FirePro®

FIRE RESISTING CONSTRUCTIONS
Solutions & Technical Manual

SOBEN INTERNATIONAL
High Performance Building Boards & Solutions for Sustainable Construction

Building With Confidence

A new benchmark for eco-friendly autoclaved cellulose fibre reinforced silicate matrix boards

Few versatile performance building boards offer both architectural envelope and strong technical specification as credible as the Soben International premium product range of eco-friendly autoclaved cellulose fibre reinforced silicate matrix boards. The line includes: fire protection calcium silicate boards, weather resistant fibre-cement boards and prefabricated panels. Since its establishment, Soben International has been a pre-eminent developer and manufacturer of high quality eco-friendly silicate matrix board solutions and has set a new benchmark for comparable products made in Asia.

With extensive product research and testing, our areas of expertise are sophisticated building solutions that tackle fire protection, multi-purpose constructions, façades and claddings where aesthetic finish and quality are of paramount importance.

Soben International high performance boards have been fully tested and certified by first class accredited laboratories and third party certification bodies to testify our commitment to performance, delivery of quality, and health and safety.

STRIVING FOR QUALITY PRODUCTS & PROFESSIONAL EXCELLENCE

FIRE-SAFE

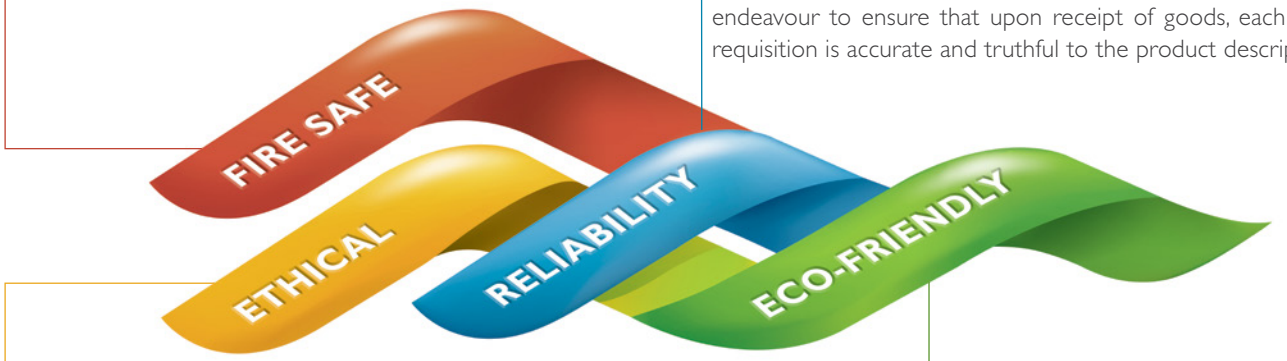
Soben International Boards are prime protectants against fire damage. The range's high levels of fire resistance has been thoroughly tested and certified by official European laboratories.

RELIABILITY

The Soben International team is dedicated to retaining an excellent Client Services department to ensure your needs are adhered to quickly and effectively.

Quality Control and Quality Assurance programmes are in place in all Soben International divisions to guarantee that all orders of our fully tested products and solutions follow their ISO 9001, 14001 and CE Mark standards.

Soben International's customer service team is tasked with the primary goal of providing punctual delivery of shipments and endeavour to ensure that upon receipt of goods, each client's requisition is accurate and truthful to the product description.



ETHICAL

Soben International places great onus on the preservation of good practice and professional conduct at all stages of the supply chain. This is upheld from the manufacturing process to the delivery of goods and throughout all communication with stakeholders and clientele.

ECO-FRIENDLY

Standing at the forefront of environmental innovation, Soben International is committed to sustaining and developing a commendable CSR record. Our solutions for eco building and sustainable development projects have all been certified by the appropriate Green Label authorities.

FP® FIRE RESISTING CONSTRUCTIONS
CONCRETE & TUNNEL STRUCTURES

CONTENTS

FP® Fire Resisting Constructions
Concrete & Tunnel Structures

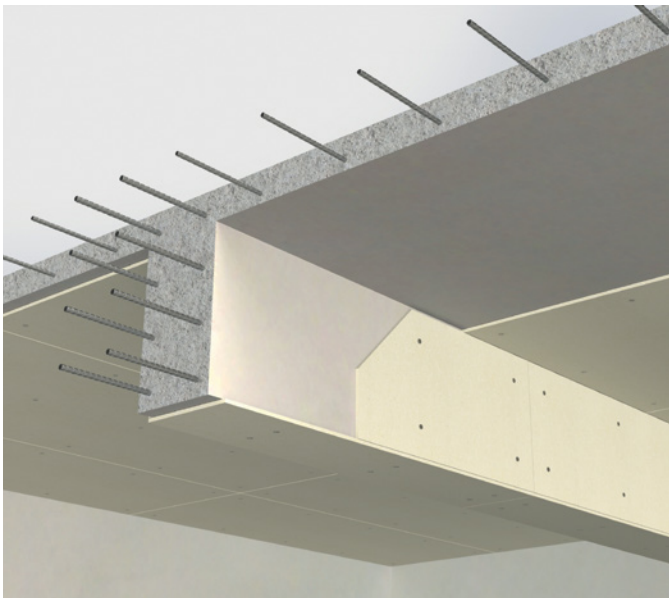
SOBEN INTERNATIONAL

FIRE PROTECTION TO CONCRETE STRUCTURES

Concrete structures attribute a good fire resistance performance and are proven to have high degree of reliability in fire safety. However inferior construction such as insufficient concrete cover to steel reinforcement is detrimental to fire resistance performance of a concrete building structure. Refurbishment or conversion of an existing concrete building to other usage may require higher fire resistance to satisfy its new designated function for a period of time in event of fire so as to comply with building regulations. After all, an appropriate fire resistance upgrade for the concrete structure is needed to maintain fire safe for the building and occupants.

Soben International offers sophisticated solutions for fire resistance upgrade and protection of various concrete or concrete steel composite structural elements in compliance with fire code BS 476: Part 21, and protection to concrete tunnel structures against RWS fire (Rijkswaterstaat) and Eurocode hydrocarbon fire by using FP®-900/FirePro® eco-friendly fire protection calcium silicate matrix board. Installation of FP®-900/FirePro® fire resistance upgrade/protection systems are fast, simple, neat and economical. It generates minimal noise and dust nuisance that minimize disturbance to the job site and surroundings.

By applying FP®-900/FirePro® full-scale loadbearing fire tests on reinforced concrete structures, along with a full engineering appraisal of application performed by Warringtonfire, a world-class independent fire testing consultant. The FP®-900/FirePro® systems have been proven effectively to protect all



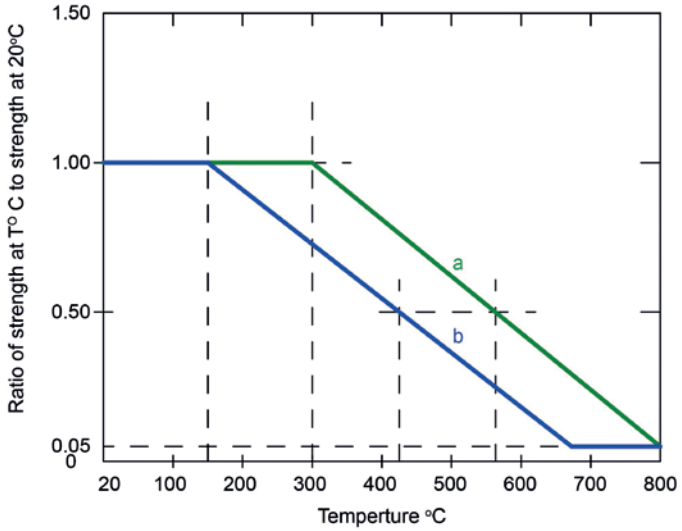
types of concrete structure also feature technical merits, easy installation and cost saving. The protected beam and floor structures effectively maintain their loadbearing fire resistance capacity in terms of both structural safety criteria which do not exceed "maximum allowable deflection" and "limit of rate of deflection" in compliance with BS 476: Part 21. Essentially, strengthening heat "insulation" performance of floor and wall structures that forms fire compartmentation in buildings to control fire spreading.

CONSIDERATIONS FOR FP®-900/FIREPRO® FIRE RESISTANCE UPGRADE/PROTECTION SYSTEMS FOR CONCRETE STRUCTURES

Concrete Structures

FP®-900/FirePro® provides fire resistance upgrading of existing buildings and additional protection to new buildings. These include beams, columns, floors and walls which are constructed with reinforced concrete# and pre-stressed concrete#.

Remark: Design curves for the reduction in strength of concrete at elevated temperatures in accordance with Section 4.5.5 of BS 8110: Part 2.



'a' dense concrete
'b' lightweight aggregate concrete
Design curves for variation of concrete strength with temperature BS 8110: Part 2

Applications

Fire resistance upgrade of any concrete beam, column, floor or wall elements of buildings conform to BS 8110: Part 2 Structure Use of Concrete – Code of Practice for Special Circumstances. The criteria for the original fire resistance duration of various loadbearing structures constructed with reinforced dense concrete, lightweight concrete or prestressed concrete, their minimum dimensions are specified in Table 4.2 to 4.6 of the Code of Practice.

Table 4.2 Reinforced concrete columns
Table 4.3 Concrete beams
Table 4.4 Plain soffit concrete floors
Table 4.5 Ribbed open soffit concrete floors
Table 4.6 Concrete walls with vertical reinforcement

Fire Resistance

The protected concrete structural elements are required to provide fire resisting performance in terms of BS 476: Part 21 specifying the loadbearing capacity, moreover, the integrity and insulation criteria for floor and wall elements in order to maintain appropriate fire compartmentation.

CONSIDERATIONS FOR FP®-900/FIREPRO® FIRE RESISTANCE UPGRADE/PROTECTION SYSTEMS FOR CONCRETE STRUCTURES

Concrete Cover

Cover is expressed the distance between the nearest heated face of the concrete and the surface of the main reinforcement in accordance with Section 4 of BS 8110: Part 2.

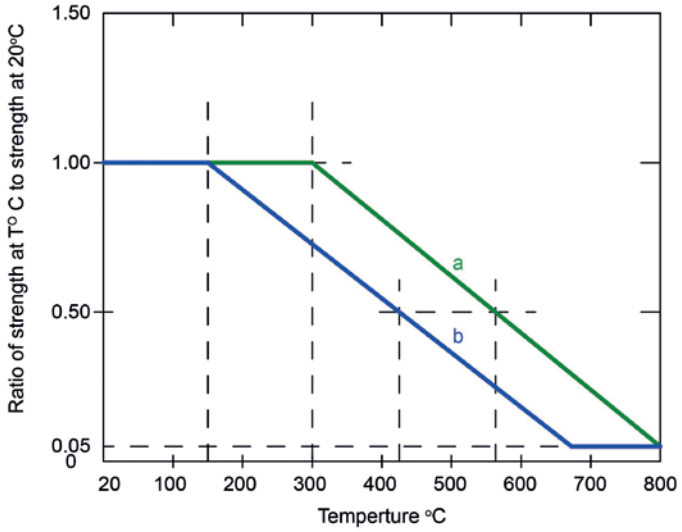
Board Thickness

FP®-900/FirePro® concrete protection systems had been developed for all types of concrete structure constructed by reinforced concrete or prestressed concrete. The required board thickness for protecting existing concrete structures in association with its minimum dimensions and profile specified by BS 8110: Part 2 and BS 476: Part 21, that can be conservatively calculated by the formulas provided below in accordance with fire tests and Warringtonfire assessment report No. 348965.

- Reinforced concrete = 0.43 x concrete thickness at 500°C#
  (applicable for dense concrete & lightweight concrete)
- Prestressed concrete = 0.52 x concrete thickness at 350°C#

#Remark: Design curve for steel was specified in Section 4.5.6 of BS 8110: Part 2 that for the reduction in the strength of reinforcement and prestressing steels was based on 50% of the strength of steel at 20°C being retained by (a) reinforcement steels at 550°C and (b) prestressing tendons at 400°C.

The FP®-900/FirePro® cladding board layer provides heat insulation to maintain the strength of reinforcements for the concrete structure and avoids concrete spalling due to overheating the structure when exposed to fire.



'a' Steel Reinforcement
'b' Prestressing tendons
Design curves for variation of steel strength or yield stress with temperature BS 8110: Part 2

SOBEN INTERNATIONAL

CONSIDERATIONS FOR FP®-900/FIREPRO® FIRE RESISTANCE UPGRADE/PROTECTION SYSTEMS FOR CONCRETE STRUCTURES

Steel Fastener

Size of self-tapping screws for FP®-900/FirePro® boards to the top hat sections should have at least M3.5. The steel screws should be coated for rust resistant. Stainless steel fasteners are recommended at severe humid areas.

Board Thickness

All-steel anchors are M6 expansion type. Bolt anchors or nail anchors can be used. The minimum depth of engagement of the anchors into sound concrete with respective to fire ratings as follows.

Fire rating - minutes	Minimum depth of anchor - mm
30 ~ 120	30mm
180 ~ 240	40mm

Concrete Repair

Before the FP®-900/FirePro® concrete protection system is applied, any locations where concrete is missing or spalling should be repaired with a proprietary concrete product designed for the purpose for fire rated concrete structures.

Movement Joint

A movement joint is needed when a FP®-900/FirePro® board spans a building movement control joint. The movement board joint should be sealed with fire rated sealant. The sealant should be silicone based and tested in accordance with BS 476: Part 20 or equivalent approval.

Fire Rated Sealant

Where FP®-900/FirePro® fire protection boards abutting perimeter wall or floor constructions should be jointed tightly. In case the constructions' surface are uneven, fire rated sealant should be applied to seal up any gaps at the joints. The sealant should be tested in accordance with BS 476: Part 20 or equivalent approval.

Sound Insulation

A structure with cladding of FP®-900/FirePro® boards will enhance sound insulation performance. Please contact Soben International for further information.

TYPES OF ALL-STEEL EXPANSION ANCHOR

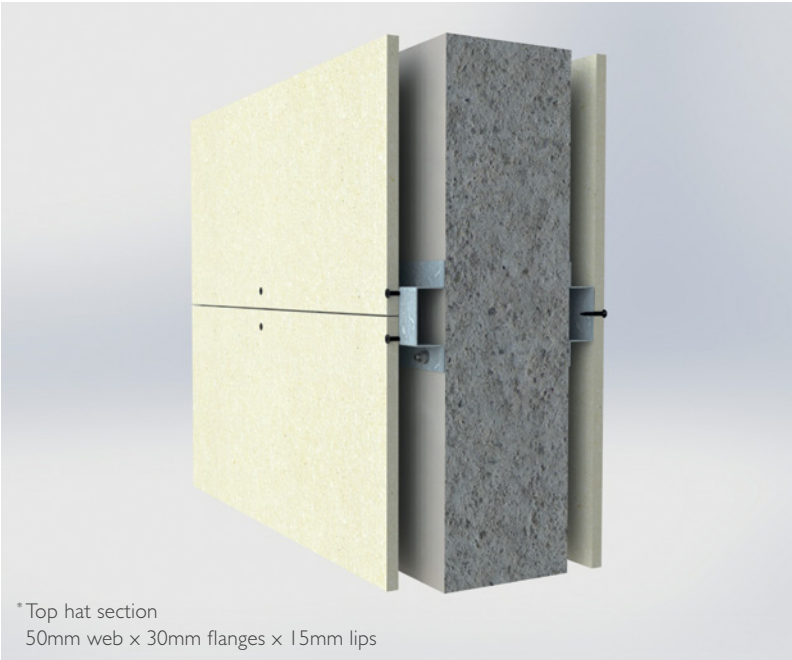
SOBEN INTERNATIONAL

INSTALLATION OF FP®-900/FIREPRO® FIRE RESISTANCE UPGARDE / PROTECTION SYSTEMS FOR CONCRETE STRUCTURES

FP®-900/FirePro® board systems can be installed to all concrete structures with either Direct Fix or Channel Fix method. The two fixing methods allow greater flexibility of receiving various building finishes. Channel Fix uses M4 countersink head screws which are concealed under paint finish on the FP®-900/FirePro® boards. Direct Fix offers a fast and economic installation solution where the boards' surface may be exposed or covered by rendering, tiling or cladding finish.

Direct Fix

FP®-900/FirePro® boards are fixed directly to the concrete face with minimum M6 all-steel masonry/ concrete expansion anchors with pan head diameter at least 13mm or each anchor fitted with a minimum 13mm diameter steel waster under the head. The anchors are located a nominal distance 100mm from the board edge and in a grid with maximum spacing of 500mm. The minimum depth of engagement of the anchors into concrete is 30mm for fire rating up to 120 minutes and 40mm for fire ratings up to 240 minutes. Board joints are tight square butt joint.



*Top hat section
50mm web x 30mm flanges x 15mm lips

Fire rating- minutes	* Minimum thickness of the hat section
30 ~ 90	0.5mm
120	0.6mm
180 ~ 240	0.8mm

Channel Fix

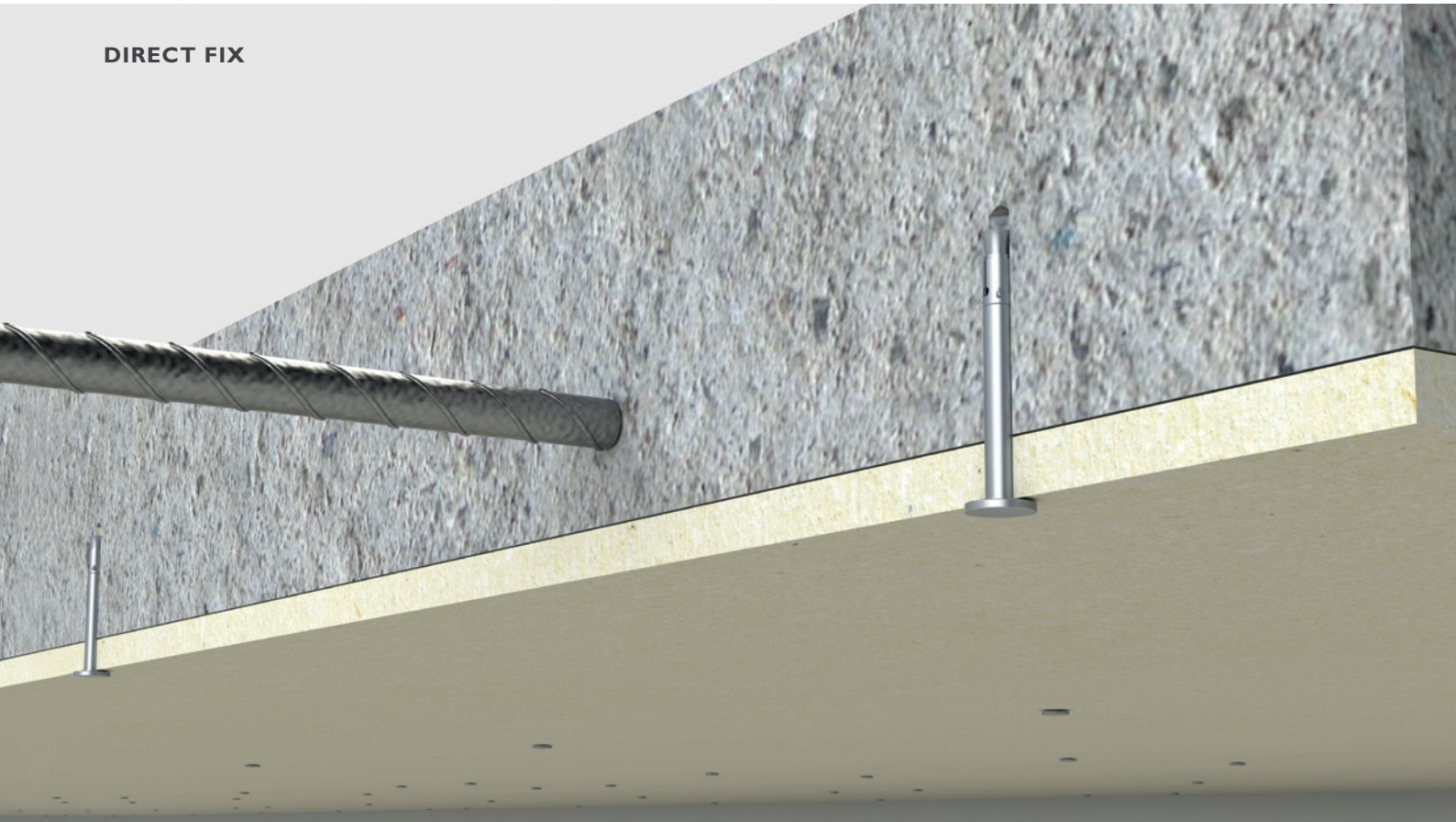
Steel top hat sections are fastened to the concrete at 610mm maximum centres longitudinally and 1220mm maximum centres transversely. The minimum dimensions of the hat section are 50mm web x 30mm flanges x 15mm lips*. The top hat sections are fastened to the concrete with M6 all-steel masonry/concrete expansion anchors at 400mm maximum centres. At the longitudinal corners of beam and column protections the top hat sections are connected with longitudinal steel angles, minimum 30mm x 30mm x 0.5mm thick, which are fastened to the top hat sections with steel rivets or self-tapping screws.

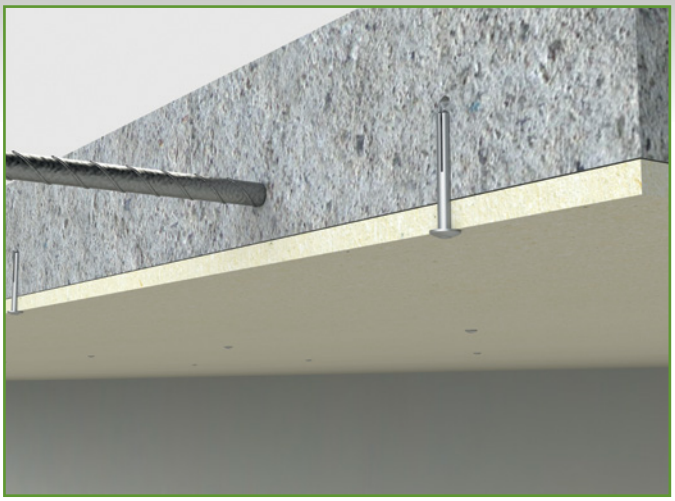
The FP®-900/FirePro® is fastened to the web of the top hat sections and to the angles with M3.5 steel self-tapping screw at 200mm nominal centres. All screws are positioned nominal 12mm from board edges and 40mm from board corners. Board joints parallel with the top hat sections must coincide with the sections. Board joints are tight square butt joints. Where the board is fitted in more than one layer the board joints are staggered between layers.

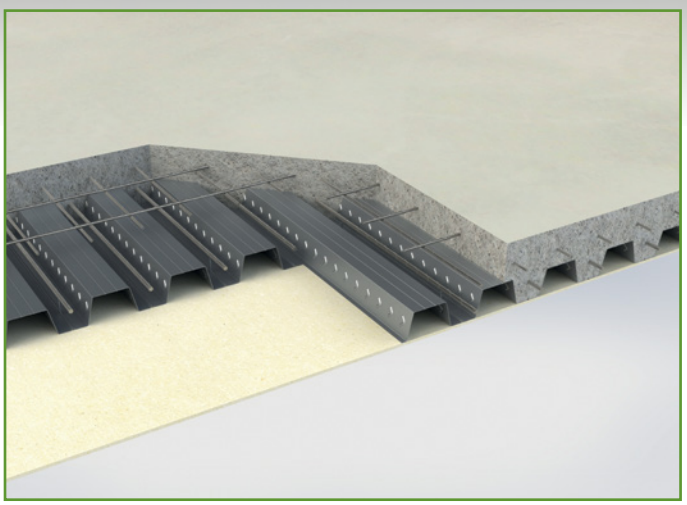
FP®-900/FirePro®
Concrete Structures Upgrade
INSTALLATION

SOBEN INTERNATIONAL

DIRECT FIX



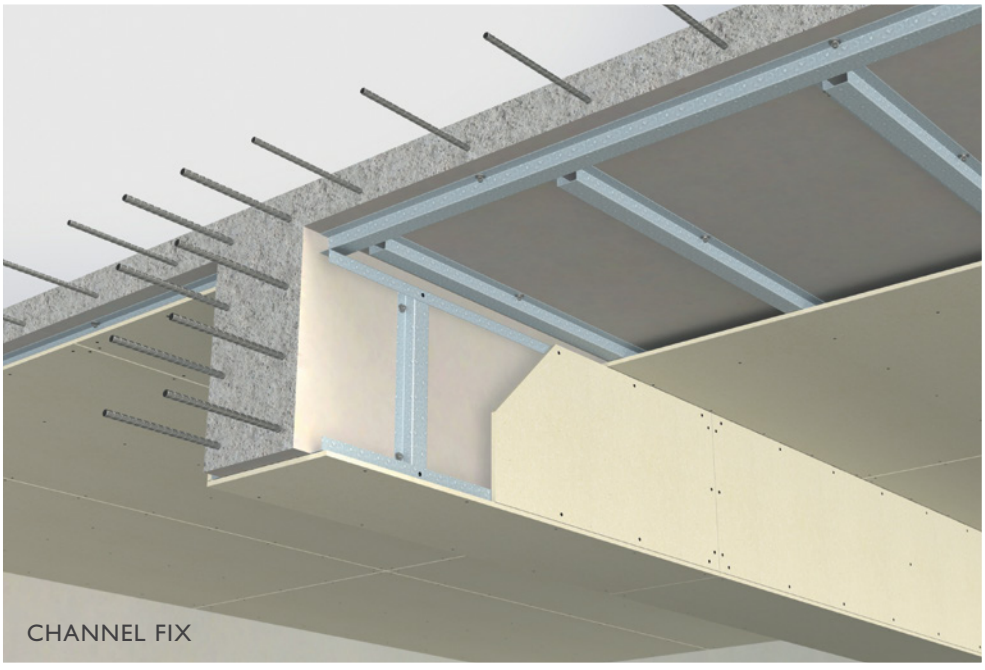




FP®-900/FirePro® fire resistance upgrade and protection systems should be constructed in accordance with the approved specification mentioned in the manufacturer's technical handbook & the local building regulations (if required)

FP®-900/FirePro®
Concrete Structures Upgrade
INSTALLATION

SOBEN INTERNATIONAL



CHANNEL FIX

DIRECT FIX

FP®-900/FirePro®
Concrete Structures Upgrade
CONCRETE COLUMN

SOBEN INTERNATIONAL

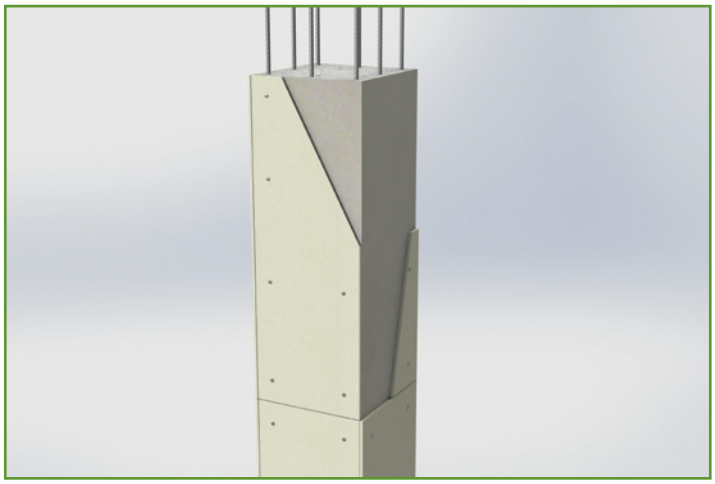
PROTECTION TO CONCRETE COLUMNS

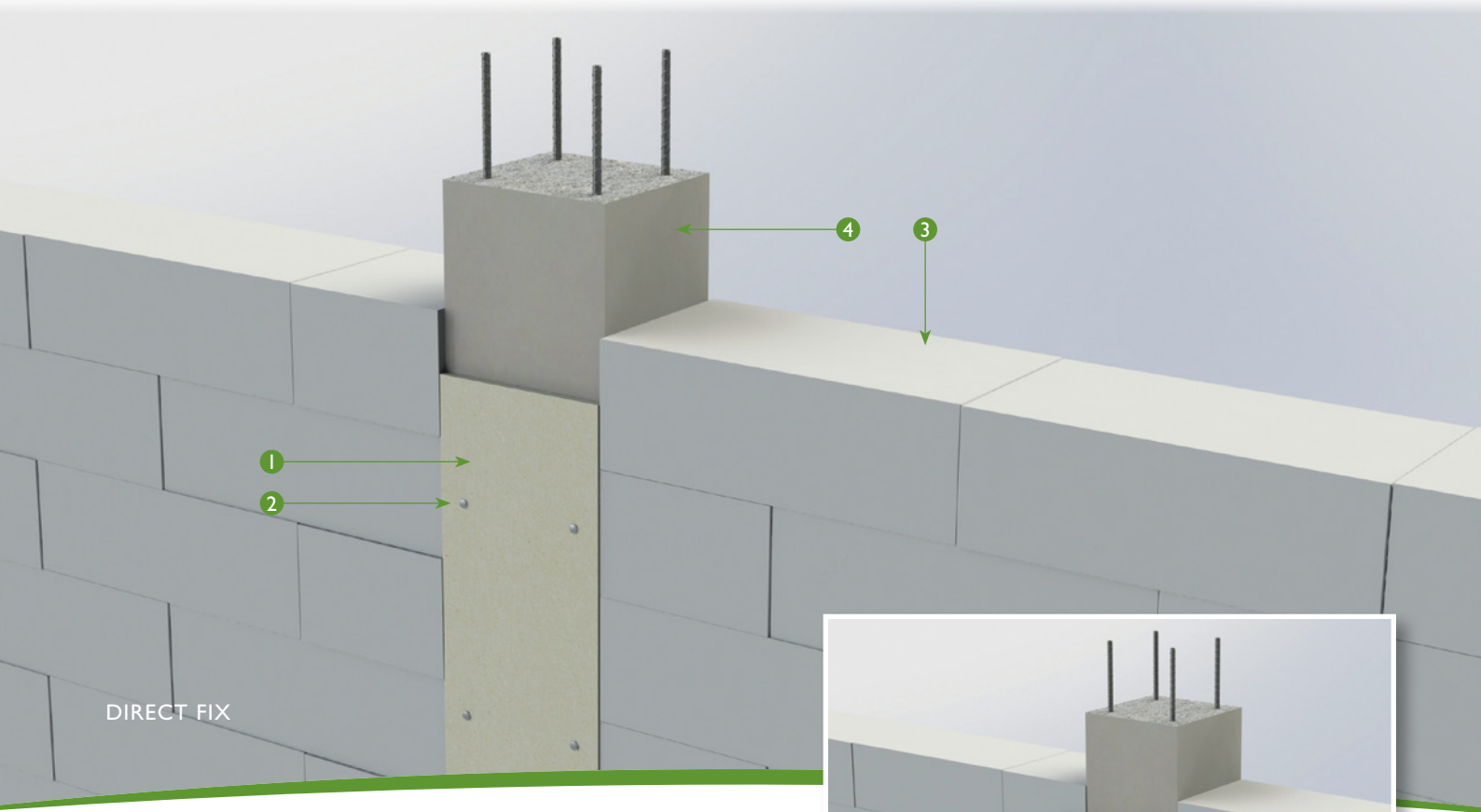
FIRE RATING

FRL	Up to 240 minutes
Standard	BS 476: Part 21 - 1987
	BS 8110: Part 2 - 1997
Approval	FIRES-FR-141-14AUNE
	Warringtonfire WF 348965

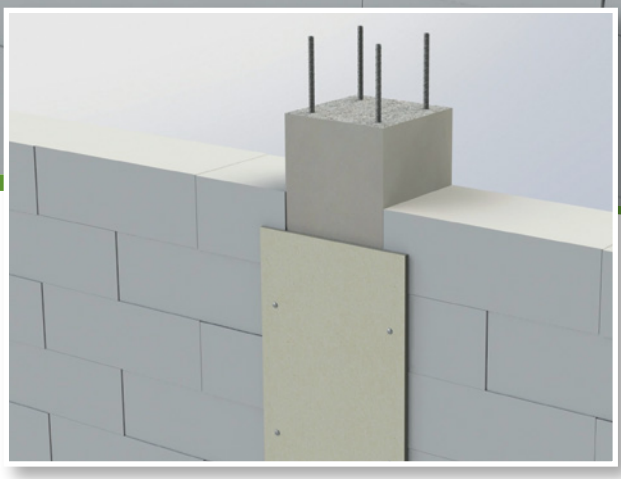
SYSTEM

Installation	Direct Fix / Channel Fix
Column size	Any
Concrete	Dense concrete
	Lightweight concrete
	Prestressed concrete





DIRECT FIX

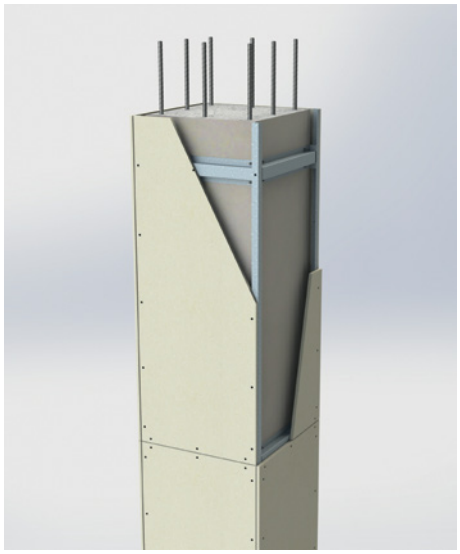


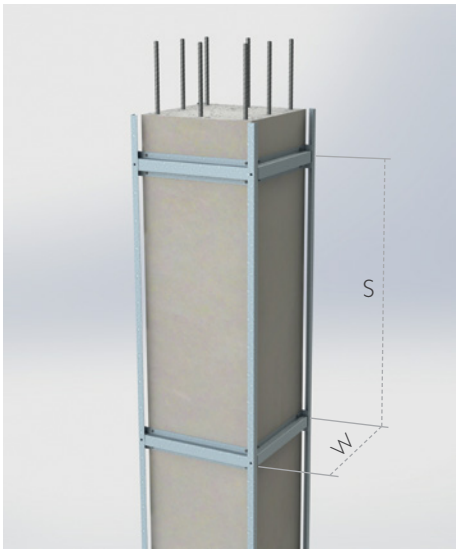
TECHNICAL DATA

1. FP®-900/FirePro® board
2. M6 All-steel anchors at maximum centres of 500mm
3. Fire rated masonry wall / drywall wall
4. Concrete column

SOBEN INTERNATIONAL

CHANNEL FIX TO CONCRETE COLUMNS





Steel frame arrangement

- Column width W ≤ 610mm, top hat sections at spacing S ≤ 1220mm.
- Column width W > 610mm, top hat sections at spacing S ≤ 610mm.

MINIMUM DIMENSIONS OF CONCRETE COLUMN FOR FIRE RESISTANCE

During exposure to a standard fire resistance test in accordance with BS 476: Part 21, a concrete column is exposed to the heating conditions of the test on all sides. The column to be upgraded must be protected on each face that could be exposed to fire with the FP®-900/FirePro® board protection system.

An upgraded column should have maintained minimum concrete column dimensions for respective fire ratings according to BS 8110: Part 2. The minimum dimensions for a concrete member ensure the member having adequate fire resistance capacity in compliance with the criteria of BS 476: Part 21.

BS 8110: PART 2, TABLE 4.2 - REINFORCED CONCRETE COLUMNS

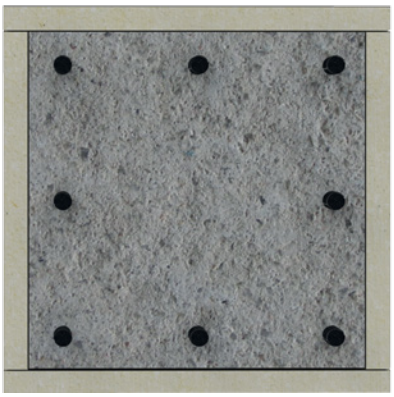
Nature of construction and materials		Minimum dimensions excluding any combustible finish for a fire resistance of:					
		30 min	60 min	90 min	120 min	180 min	240 min
		mm	mm	mm	mm	mm	mm
Fully exposed:							
• dense concrete	Width	150	200	250	300	400	450
	Cover [a]	20	25	30	35	35	35
• lightweight concrete	Width	150	160	200	240	320	360
	Cover [a]	20	20	25	35	35	35
50 % exposed:							
• dense concrete	Width	125	160	200	240	300	350
	Cover [a]	20	25	25	25	30	35
• lightweight concrete	Width	125	130	160	185	250	275
	Cover [a]	20	20	25	25	30	30
One face exposed:							
• dense concrete	Thickness	100	120	140	160	200	240
	Cover [a]	20	25	25	25	25	25
• lightweight concrete	Thickness	100	100	115	130	160	190
	Cover [a]	10	20	20	25	25	25

'a' Cover is expressed here as cover to main reinforcement (see 4.2.3 of BS 8110: Part 2). For practical purposes cover is expressed as nominal cover to all reinforcement and these tabulated values need to be decreased accordingly.

CALCULATION FOR DETERMINING REQUIRED BOARD THICKNESS OF FP-900®/FIREPRO®

CASE C1

A reinforced concrete column size 200mm x 200mm is upgraded from 60 minutes to 120 minutes fire resistance on condition of fully exposed to fire. The concrete cover for main reinforcement of the column is 25mm thick.



Given:

	DENSE CONCRETE COLUMN DIMENSION	
	Existing fire resistance FRL: 60/0/0 Dimensions - mm	Upgrading to fire resistance FRL: 120/0/0 Minimum dimensions - mm
Column width	200	300
Concrete cover for reinforcement	25	35

Checking:

Minimum dimensions of a column for respective fire resistance are required by BS 8110: Part 2: Table 4.2 for reinforced concrete columns. Deficiency of concretes in thickness are:

- Deficiency in concrete cover to steel reinforcement = 35mm - 25mm = 10mm
- Deficiency in column width = 300mm - 200mm = 100mm

Basing on fire tests and Warringtonfire assessment No. WF 348965, the required board thickness to compensate the deficient concrete thickness = 0.43 x deficient concrete thickness.

❶ Deficient concrete cover = 0.43 x 10 = 4.3mm thick

❷ Deficient column width = 0.43 x 100 = 43mm thick, 21.5mm thick at each side

❸ The required FP®-900/FirePro® board for fire resistance upgrade is at least 22mm thick:

- Column width – minimum 22mm thick board fixed at one side and at opposite side ≥ 21.5mm, and
- Concrete cover - 22 mm thick board ≥ 4.3mm are acceptable.

❹ The cladding board can be installed by either Direct Fix or Channel Fix method.

FP®-900/FirePro®
Concrete Structures Upgrade
CONCRETE BEAM

SOBEN INTERNATIONAL

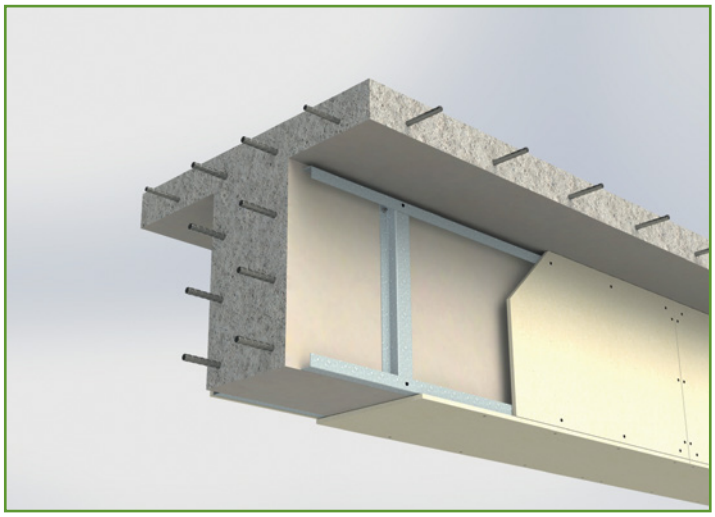
PROTECTION TO CONCRETE BEAMS

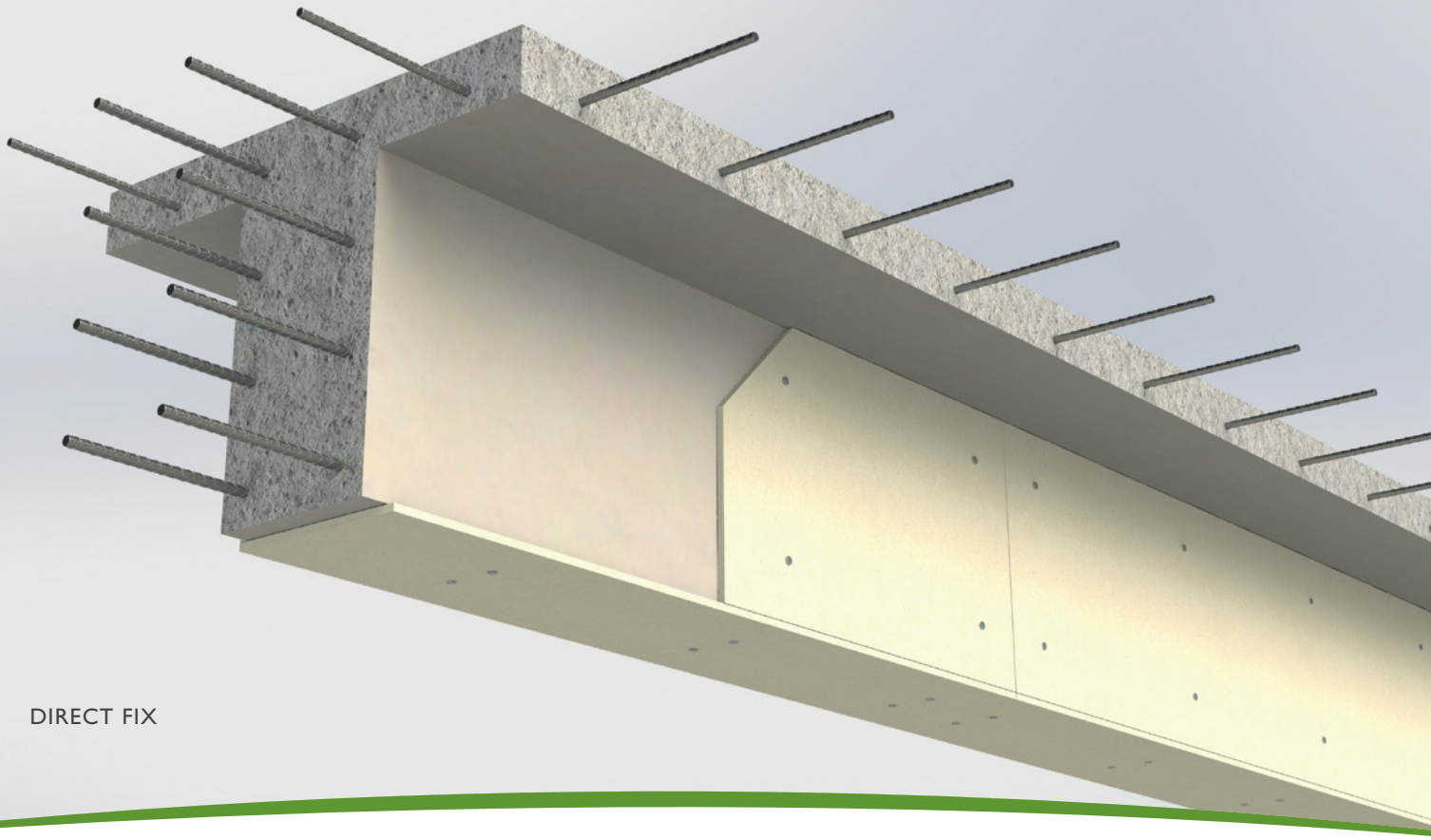
FIRE RATING

FRL	Up to 240 minutes
Standard	BS 476: Part 21 - 1987
	BS 8110: Part 2 - 1997
Approval	FIRES-FR-141-14AUNE
	Warringtonfire WF 348965

SYSTEM

Installation	Direct Fix / Channel Fix
Beam size	Any
Concrete	Dense concrete
	Lightweight concrete
	Prestressed concrete

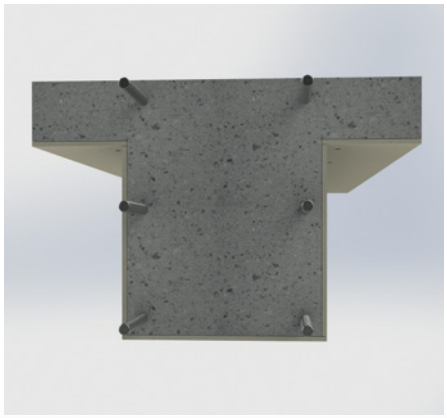


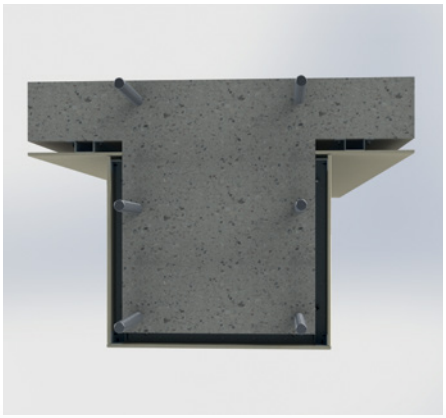


DIRECT FIX

SOBEN INTERNATIONAL

FP®-900/FirePro® boards can be fastened to a beam by Direct Fix, Channel Fix or Combined Fix method.





CHANNEL FIX TO CONCRETE BEAMS

CHANNEL FIX

Steel frame arrangement

- Beam depth D ≤ 610mm, top hat sections at spacing S ≤ 1220mm.
- Beam depth D > 610mm, top hat sections at spacing S ≤ 610mm.

MINIMUM DIMENSIONS OF CONCRETE BEAM FOR FIRE RESISTANCE

During exposure to a standard fire resistance test in accordance with BS 476: Part 21, a concrete beam is exposed to the heating conditions of the test on both sides and soffit. The beam to be upgraded must be protected on each face that could be exposed to fire with the FP®-900/FirePro® board protection system.

An upgraded beam should have maintained minimum concrete beam dimensions for respective fire ratings according to BS 8110: Part 2. The minimum dimensions for a concrete member ensure the member having adequate fire resistance capacity in compliance with the criteria of BS 476: 21.

BS8110: PART 2, TABLE 4.3 - CONCRETE BEAMS

Nature of construction and materials		Minimum dimensions excluding any combustible finish for a fire resistance of:					
		30 min	60 min	90 min	120 min	180 min	240 min
		mm	mm	mm	mm	mm	mm
Reinforced concrete (simply supported)							
• dense concrete	Width	80	120	150	200	240	280
	Cover [a]	20	30	40	50	70	80
• lightweight concrete	Width	80	100	130	160	200	250
	Cover [a]	15	20	35	45	55	65
Reinforced concrete (continuous)							
• dense concrete	Width	80	80	120	150	200	240
	Cover [a]	20	20	35	50	60	70
• lightweight concrete	Width	60	80	90	110	150	200
	Cover [a]	15	20	25	35	45	55
Prestressed concrete (simply supported)							
• dense concrete	Width	100	120	150	200	240	280
	Cover [a]	25	40	55	70	80	90
• lightweight concrete	Width	80	110	130	160	200	250
	Cover [a]	25	30	45	55	65	75
Prestressed concrete (continuous)							
• dense concrete	Width	80	100	120	150	200	240
	Cover [a]	20	30	40	55	70	80
• lightweight concrete	Width	80	90	100	125	150	200
	Cover [a]	20	25	35	45	55	65

'a' Cover is expressed here as cover to main reinforcement (see section 4.2.3 of BS 8110: Part2). For practical purposes cover is expressed as nominal cover to all reinforcement and these tabulated values need to be decreased accordingly.

CALCULATION FOR DETERMINING REQUIRED BOARD THICKNESS OF FP-900®/FIREPRO®

Concrete beams

CASE B1

A reinforced concrete beam with 150mm wide is upgraded to 120 minutes fire resistance with condition of fully exposed to fire. The concrete cover for reinforcement of the beam is 30m thick.

Given:

	DENSE CONCRETE BEAM DIMENSION	
	Existing fire resistance FRL: unknown Dimensions - mm	Upgrading to fire resistance FRL: 120/0/0 Minimum dimensions - mm (Simply support)
Beam width	150	200
Concrete cover for reinforcement	30	50

Checking:

Minimum dimensions of a beam for respective fire resistance are required by BS 8110: Part 2: Table 4.3 for reinforced concrete beams. Deficiency of concretes in thickness are:

- Deficiency in concrete cover to steel reinforcement = 50mm - 30mm = 20mm
- Deficiency in beam width = 200mm - 150mm = 50mm

Basing on fire tests and Warringtonfire assessment No. WF 348965, the required board thickness to compensate the deficient concrete thickness = 0.43 x deficient concrete thickness.

❶ Deficient concrete cover = 0.43 x 20 = 8.6mm thick

❷ Deficient beam width = 0.43 x 50 = 21.5 mm thick, 10.75 mm thick at each side

❸ The required FP®-900/FirePro® board for fire resistance upgrade is 12mm thick:

- Beam width - 12mm thick board at both sides ≥ 10.75mm, and
- Concrete cover - 12mm thick board ≥ 8.6mm are acceptable.

❹ The cladding board can be installed by either Direct Fix or Channel Fix method.

Concrete beams

CASE B2

A reinforced concrete beam with 200mm wide is upgraded from 120 minutes to 240 minutes fire resistance on condition of fully exposed to fire. The concrete cover for main reinforcement of the beam is 50m thick.

Given:

	DENSE CONCRETE BEAM DIMENSION	
	Existing fire resistance FRL: 120/0/0 Dimensions - mm	Upgrading to fire resistance FRL: 240/0/0 Minimum dimensions - mm (Simply support)
Beam width	200	280
Concrete cover for reinforcement	50	80

Checking:

Minimum dimensions of a beam for respective fire resistance are required by BS 8110: Part 2: Table 4.3 for reinforced concrete beams. Deficiency of concretes in thickness are:

- Deficiency in concrete cover to steel reinforcement = 80mm - 50mm = 30m
- Deficiency in beam width = 280mm - 200mm = 80mm

Basing on fire tests and Warringtonfire assessment No. WF 348965, the required board thickness to compensate the deficient concrete thickness = 0.43 x deficient concrete thickness.

❶ Deficient concrete cover = 0.43 x 30= 12.9mm thick

❷ Deficient beam width = 0.43 x 80 = 34.4mm thick, 17.2mm thick at each side

❸ The required FP®-900/FirePro® board for fire resistance upgrade is 18mm thick:

- Beam width – 18mm thick board at both sides ≥ 12.9mm, and
- Concrete cover - 18m thick board ≥ 12.9mm are acceptable.

❹ The cladding board can be installed by either Direct Fix or Channel Fix method.

Concrete beams

CASE B3

A prestressed dense concrete beam with 200mm wide is upgraded from 120 minutes to 240 minutes fire resistance with condition of fully exposed to fire. The concrete cover for main reinforcement of the beam is 70m thick.

Given:

	PRESTRESSED DENSE CONCRETE BEAM DIMENSION	
	Existing fire resistance FRL: 120/0/0 Dimensions - mm	Upgrading to fire resistance FRL: 240/0/0 Minimum dimensions - mm (Simply support)
Beam width	200	280
Concrete cover for reinforcement	70	90

Checking:

Minimum dimensions of a beam for respective fire resistance are required by BS 8110: Part 2: Table 4.3 for reinforced concrete beams. Deficiency of concretes in thickness are:

- Deficiency in concrete cover to steel reinforcement = 90mm - 70mm = 20mm
- Deficiency in beam width = 280mm - 200mm = 80mm

Basing on fire tests and Warringtonfire assessment No 348965, the required board thickness to compensate the deficient pre-stressed concrete thickness = 0.52 x deficient concrete thickness.

❶ Deficient concrete cover = 0.52 x 20 = 10.4mm thick

❷ Deficient beam width = 0.52 x 80 = 41.6mm thick, 20.8mm thick at each side

❸ The required FP®-900/FirePro® board for fire resistance upgrade is 21mm thick:

- Beam width - 21mm thick board at both sides ≥ 20.8mm, and
- Concrete cover - 21mm thick board ≥ 10.4mm are acceptable.

❹ The cladding board can be installed by either Direct Fix or Channel Fix method.

FP®-900/FirePro®
Concrete Structures Upgrade
CONCRETE FLOOR

SOBEN INTERNATIONAL

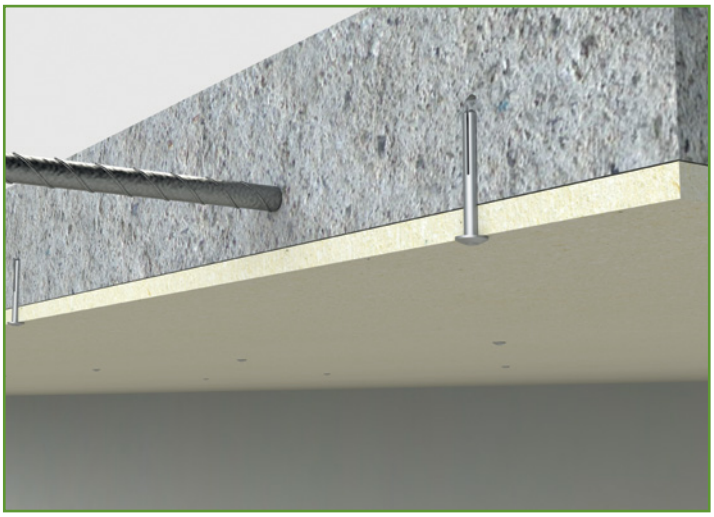
PROTECTION TO PLAIN SOFFIT CONCRETE FLOORS

FIRE RATING

FRL	Up to 240/240/240
Standard	BS 476: Part 21 - 1987
	BS 8110: Part 2 - 1997
Approval	FIRES-FR-141-14-AUNE
	Warringtonfire WF 348965

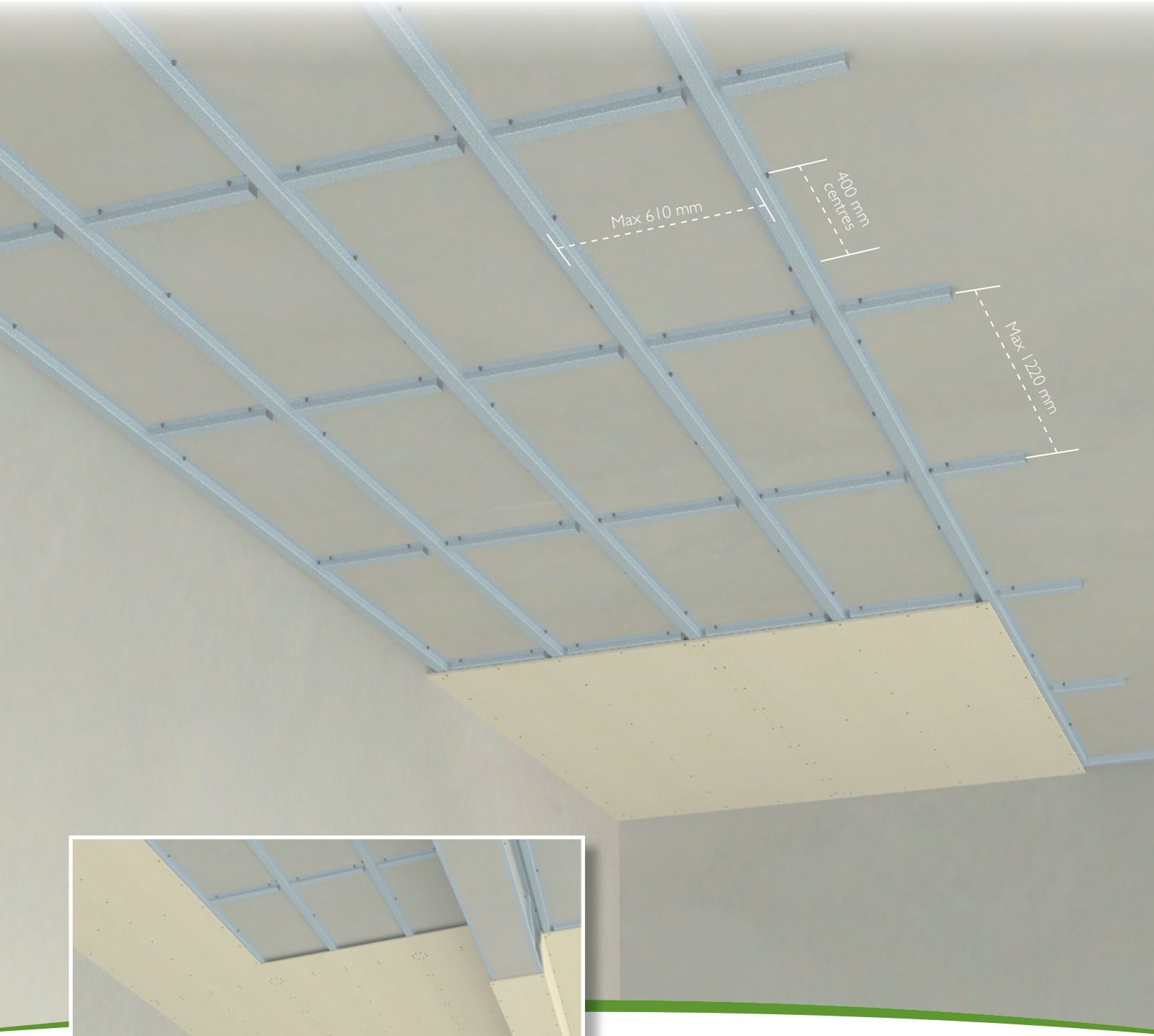
SYSTEM

Installation	Direct Fix / Channel Fix
Floor thickness	Any
Concrete	Dense concrete
	Lightweight concrete
	Prestressed concrete



SOBEN INTERNATIONAL

CHANNEL FIX TO PLAIN SOFFIT CONCRETE FLOORS



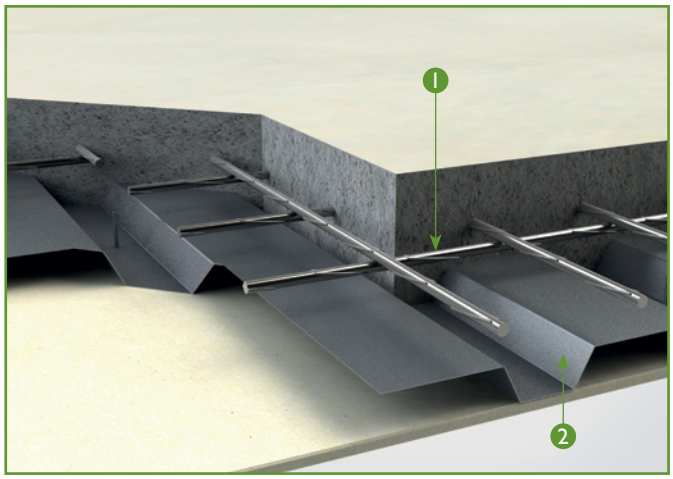
SOBEN INTERNATIONAL

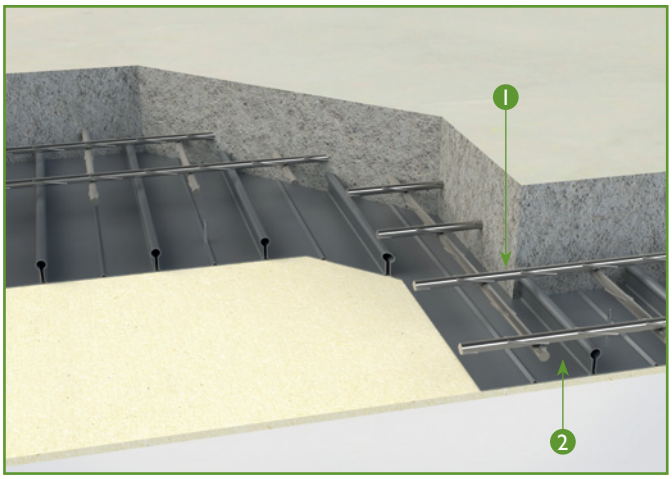
PLAIN SOFFIT CONCRETE FLOORS

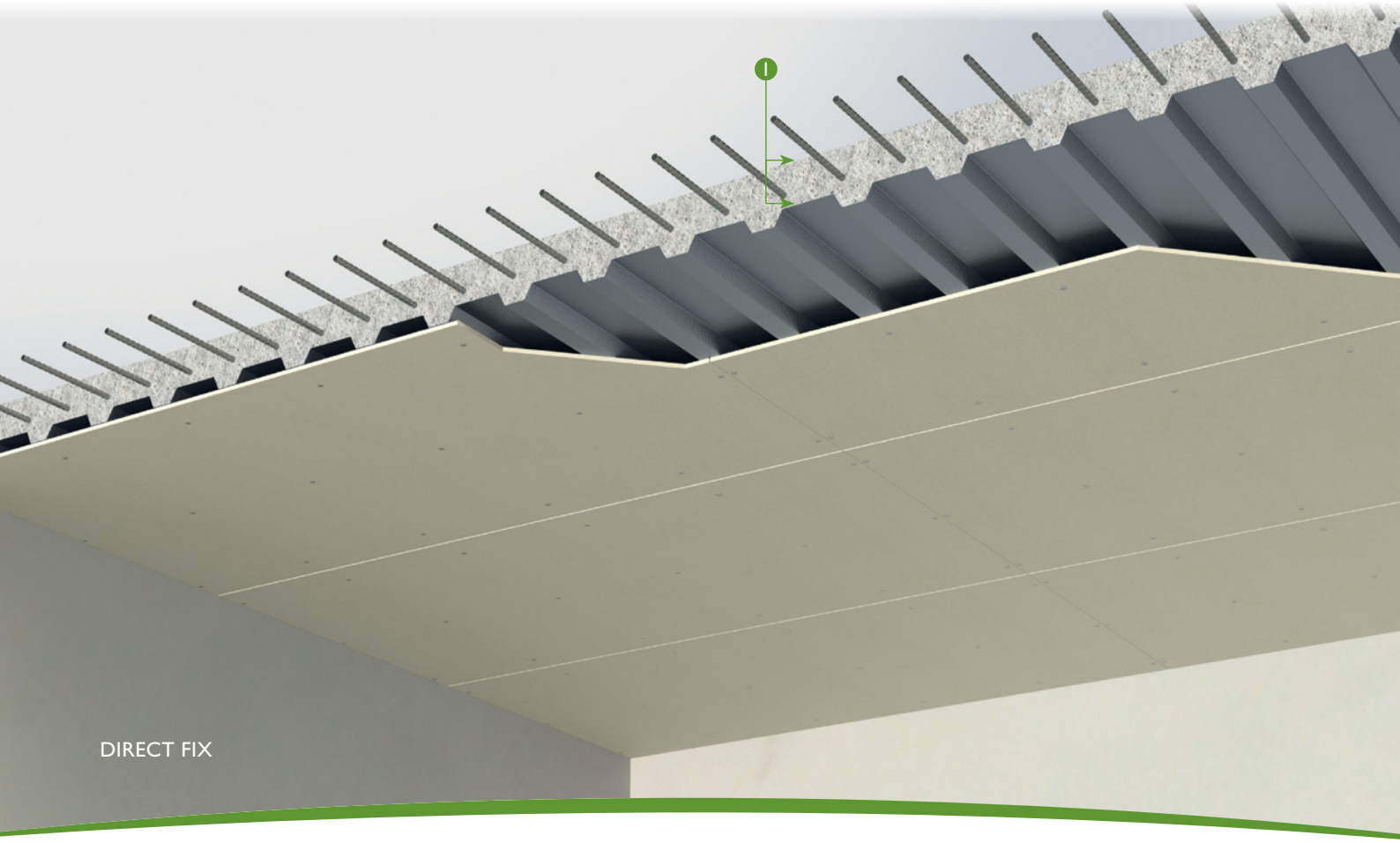
A floor construction incorporating a corrugated metal deck form can be considered as a plain soffit concrete floor when protected with a FP®-900/FirePro® fire resistance upgrade system. The floor is subjected to the criteria below.

1. Where steel reinforcement is provided within the thinnest floor thickness only, and
2. The metal deck is not considered to take any loads.

Remark: Should the metal deck require fire protection, please refer to Technical Manual for FP®-900/FirePro® Structural Steel protection.







DIRECT FIX

MINIMUM DIMENSIONS OF PLAIN SOFFIT CONCRETE FLOOR FOR FIRE RESISTANCE

During exposure to a standard fire resistance test in accordance with BS 476: Part 21, a plain soffit concrete floor is exposed to the heating conditions of the test on the underside and the fire exposure assumed to be from below. The floor to be upgraded must be protected underside that could be exposed to fire with the FP®-900/FirePro® board protection system. However, fire protection may be required on top of the upgraded floor where concrete cover to steel reinforcement is inadequate to provide fire resistance, if fire risk is known at both sides of the floor.

An upgraded floor should have maintained minimum concrete floor dimensions for respective fire ratings according to BS 8110: Part 2. The minimum floor thickness not only aim for fire resistance of the member itself, but also provide sufficient heat insulation for fire compartmentation in compliance with the criteria of BS 476: Part 20, 21 & 22.

BS 8110: PART 2, TABLE 4.4 - PLAIN SOFFIT CONCRETE FLOORS

Nature of construction and materials		Minimum dimensions excluding any combustible finish for a fire resistance of:					
		30 min	60 min	90 min	120 min	180 min	240 min
		mm	mm	mm	mm	mm	mm
Reinforced concrete (simply supported)							
• dense concrete	Thickness	75	95	110	125	150	170
	Cover [a]	15	20	25	35	45	55
• lightweight concrete	Thickness	70	90	105	115	135	150
	Cover [a]	15	15	20	25	35	45
Reinforced concrete (continuous)							
• dense concrete	Thickness	75	95	110	125	150	170
	Cover [a]	15	20	20	25	35	45
• lightweight concrete	Thickness	70	90	105	115	135	150
	Cover [a]	15	15	20	20	25	35
Prestressed concrete (simply supported)							
• dense concrete	Thickness	75	95	110	125	150	170
	Cover [a]	20	25	30	40	55	65
• lightweight concrete	Thickness	70	90	105	115	135	150
	Cover [a]	20	20	30	35	45	60
Prestressed concrete (continuous)							
• dense concrete	Thickness	75	95	110	125	150	170
	Cover [a]	20	20	25	35	45	55
• lightweight concrete	Thickness	70	90	105	115	135	150
	Cover [a]	20	20	25	30	35	45

'a' Cover is expressed here as cover to main reinforcement (see 4.2.3 of BS 8110: Part 2). For practical purposes cover is expressed as nominal cover to all reinforcement and these tabulated values need to be decreased accordingly.

CALCULATION FOR DETERMINING REQUIRED BOARD THICKNESS OF FP-900®/FIREPRO®

Plain soffit concrete floors

CASE F1

A reinforced dense concrete floor with 125mm thick is upgraded from 120 minutes to 240 minutes fire resistance of both sides of the floor slab. The concrete cover for reinforcement of the floor is 35m thick.

Given:

	DENSE CONCRETE PLAIN SOFFIT FLOOR DIMENSION	
	Existing fire resistance FRL: 120/120/120 Dimensions - mm	Upgrading to fire resistance FRL: 240/240/240 Minimum dimensions - mm (Simply support)
Floor thickness	125	170
Concrete cover for reinforcement	35	55

Checking:

Minimum dimensions of a plain soffit floor for respective fire resistance are required by BS 8110: Part 2: Table 4.4 for plain soffit concrete floors. Deficiency of concretes in thickness are:

- Deficiency in concrete cover to steel reinforcement = 55mm - 35mm = 20mm
- Deficiency in floor thickness = 170mm - 125 = 45mm

Basing on fire tests and Warringtonfire assessment No. WF 348965, the required board thickness to compensate the deficient concrete thickness = 0.43 x deficient concrete thickness.

❶ Deficient concrete cover = 0.43 x 20 = 8.6mm thick

❷ Deficient floor thickness = 0.43 x 45 = 19.35mm thick, total minimum board thickness at top and soffit sides is 19.35mm

❸ The required FP®-900/FirePro® boards for fire resistance upgrade are:

- Floor thickness - 12mm thick board at soffit & 9mm thick board at top, total 21mm ≥ 19.35mm, and
- Concrete cover – minimum 9mm thick board ≥ 8.6mm are acceptable.

❹ The cladding board can be installed by either Direct Fix or Channel Fix method.

Plain soffit concrete floors

CASE F2

A reinforced lightweight concrete floor with 100mm thick is upgraded from 60 minutes to 120 minutes of fire resistance required for fire attack from below only. The concrete cover for reinforcement of the floor is 20mm thick.

Given:

	LIGHTWEIGHT CONCRETE PLAIN SOFFIT FLOOR DIMENSION	
	Existing fire resistance FRL: 60/60/60 Dimensions - mm	Upgrading to fire resistance FRL: 120/120/120 Minimum dimensions - mm (Simply support)
Floor thickness	100	115
Concrete cover for reinforcement	20	25

Checking:

Minimum dimensions of a plain soffit floor for respective fire resistance are required by BS 8110: Part 2: Table 4.4 for plain soffit concrete floors. Deficiency of concretes in thickness are:

- Deficiency in concrete cover to steel reinforcement = 25mm - 20mm = 5mm
- Deficiency in floor thickness = 115mm - 100mm = 15mm

Basing on fire tests and Warringtonfire assessment No. WF 348965, the required board thickness to compensate the deficient concrete thickness = 0.43 x deficient concrete thickness.

❶ Deficient concrete cover = 0.43 x 5 = 2.15mm thick

❷ Deficient floor thickness = 0.43 x 15 = 6.45mm thick, total minimum board thickness at soffit side is 6.45mm

❸ The required FP®-900/FirePro® boards for fire resistance upgrade is 9mm thick.

- Floor thickness - 9mm thick board ≥ 6.45mm, and
- Concrete cover – 9mm thick board ≥ 2.15mm are acceptable.

❹ The cladding board can be installed by either Direct Fix or Channel Fix method.

FP®-900/FirePro®
Concrete Structures Upgrade
CONCRETE FLOOR

SOBEN INTERNATIONAL

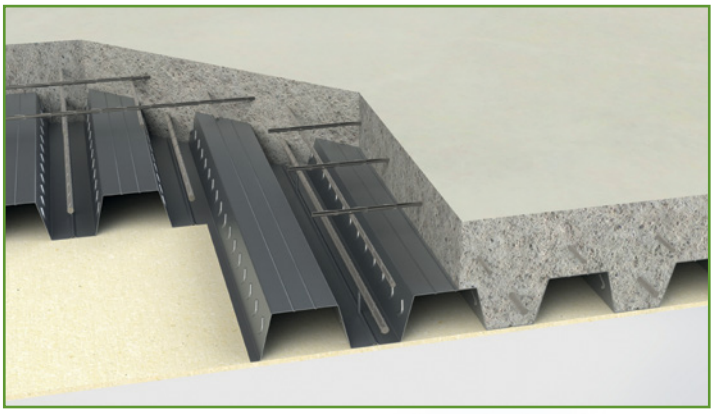
PROTECTION TO RIBBED OPEN SOFFIT CONCRETE FLOORS

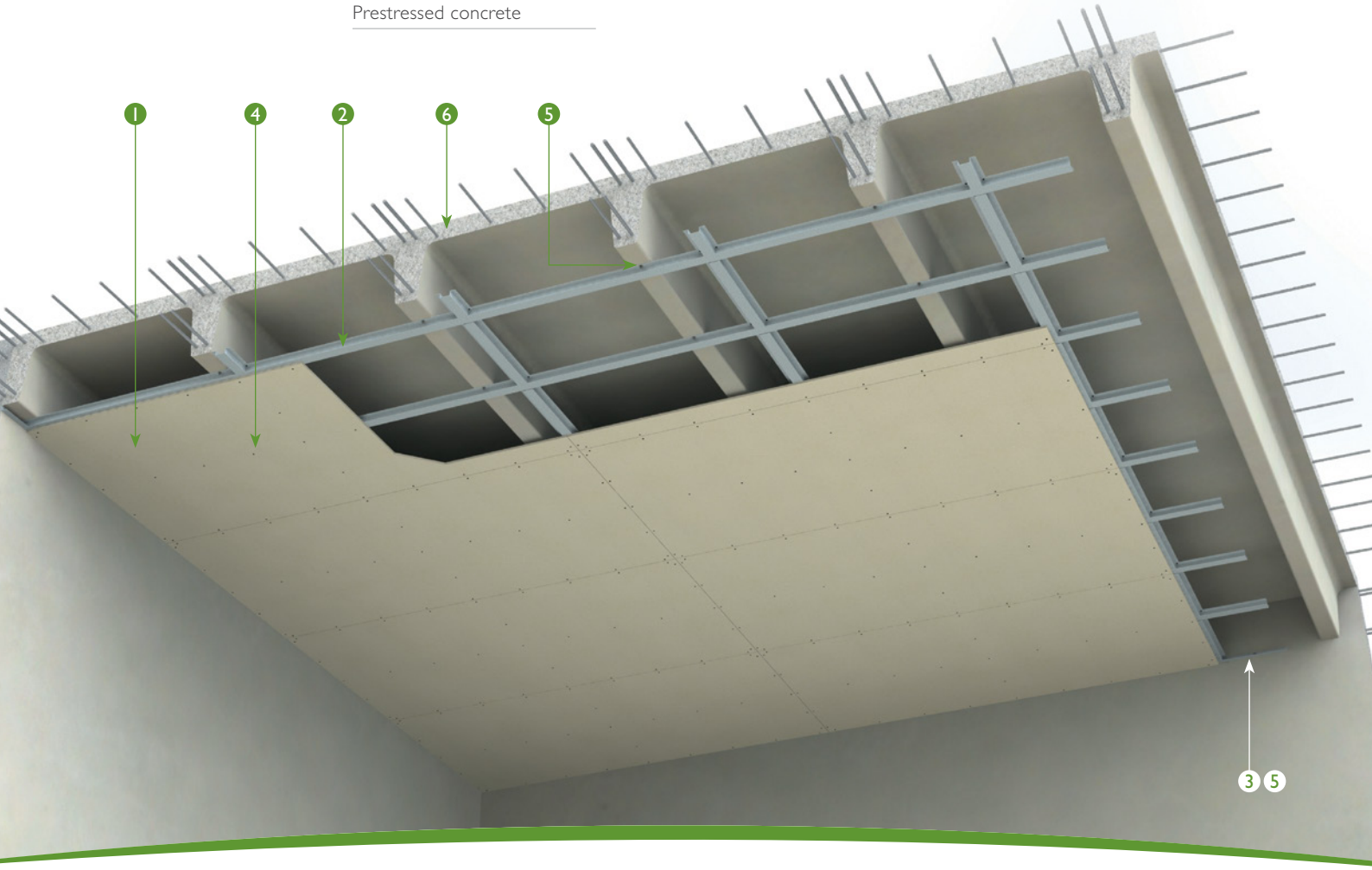
FIRE RATING

FRL	Up to 240/240/240
Standard	BS 476: Part 21 - 1987
	BS 8110: Part 2 - 1997
Approval	FIRES-FR-141-14-AUNE
	Warringtonfire WF 348965

SYSTEM

Installation	Direct Fix / Channel Fix
Floor thickness	Any
Concrete	Dense concrete
	Lightweight concrete
	Prestressed concrete





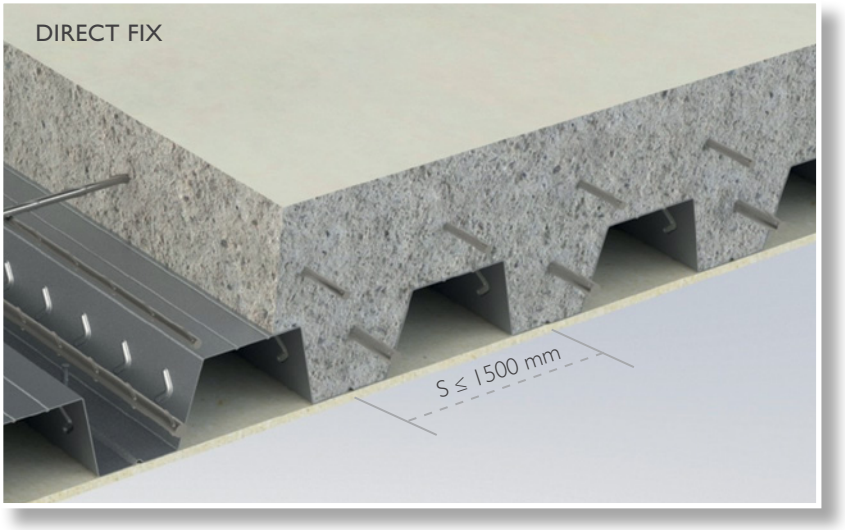
TECHNICAL DATA

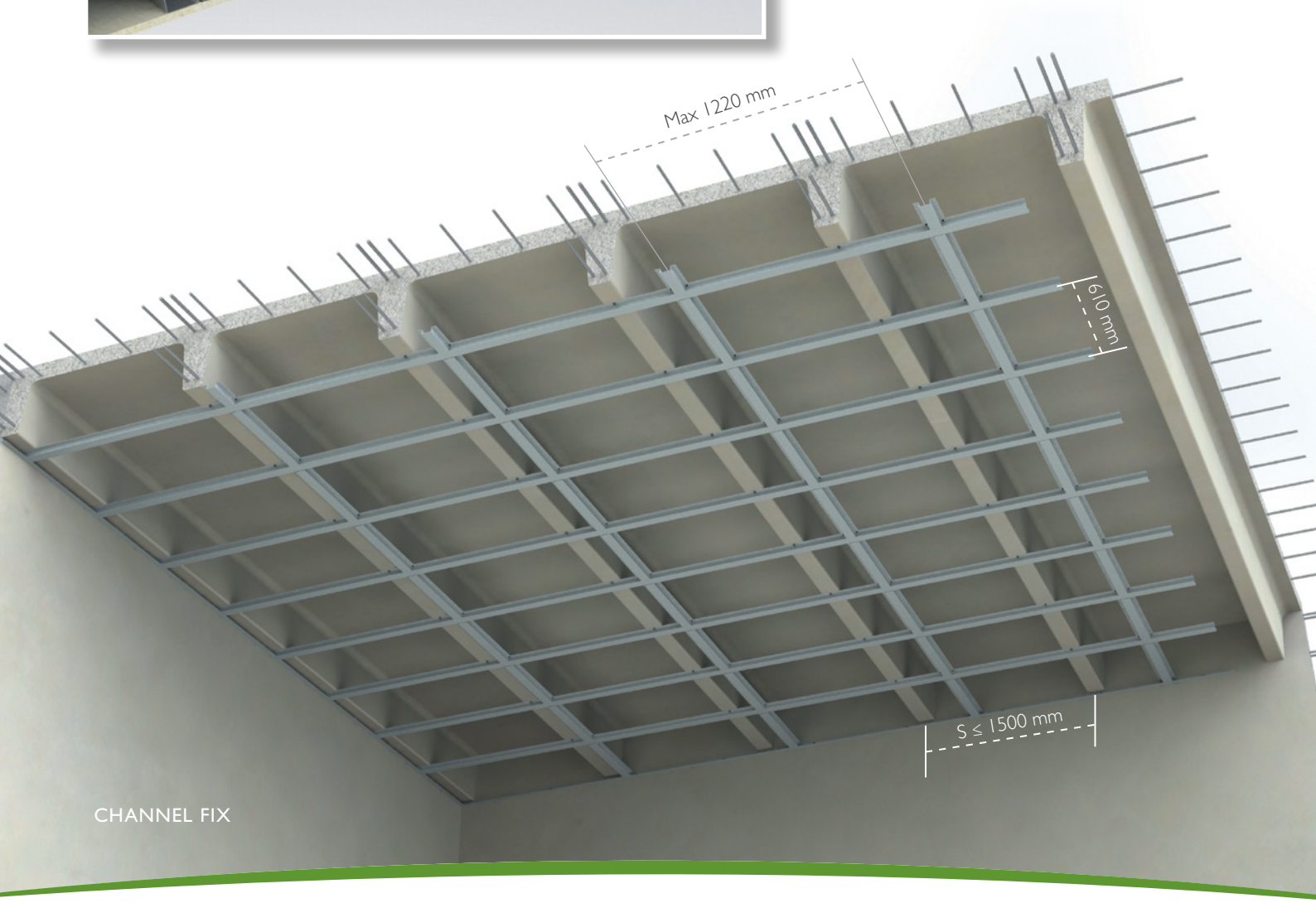
1. FP®-900/FirePro® boards
2. Top hat sections – minimum 50mm web x 30mm flanges x 15mm lips x 0.5mm thick
   - Main members at 610mm maximum centres
   - Cross members at 1220mm maximum centres.
3. Perimeter angle 30 x 30x 0.5mm
4. M4 self-tapping screws at 200mm centres
5. M6 all-steel anchors
6. Floor

SOBEN INTERNATIONAL

RIBBED OPEN SOFFIT CONCRETE FLOORS

A ribbed floor which ribs should be spaced at (S) maximum 1.5m centres. Exceeding the spacing a rib is treated as a beam in accordance with section 4.2.7 of BS 8110: Part 2.





SOBEN INTERNATIONAL

MINIMUM DIMENSIONS OF RIBBED OPEN SOFFIT CONCRETE FLOOR FOR FIRE RESISTANCE

During exposure to a standard fire resistance test in accordance with BS 476: Part 21, a ribbed open soffit concrete floor is exposed to the heating conditions of the test on the underside and the fire exposure assumed to be from below. The floor to be upgraded must be protected underside that could be exposed to fire with the FP®-900/FirePro® board protection system. However, fire protection may be required on top of the upgraded floor where concrete cover to steel reinforcement is inadequate to provide fire resistance, if fire risk is known at both sides of the floor.

An upgraded ribbed floor should have maintained minimum concrete ribbed floor dimensions for respective fire ratings according to BS 8110: Part 2. The minimum floor thickness not only aim for fire resistance of the member itself, but also provide sufficient heat insulation for fire compartmentation in compliance with the criteria of BS 476: Part 21 & 22.

BS 8110: PART 2, TABLE 4.5 - RIBBED OPEN SOFFIT CONCRETE FLOORS

Nature of construction and materials		Minimum dimensions excluding any combustible finish for a fire resistance of:					
		0.5 h	1 h	1.5 h	2 h	3 h	4 h
		mm	mm	mm	mm	mm	mm
Reinforced concrete (simply supported)							
• dense concrete	Thickness	70	90	105	115	135	150
	Width	75	90	110	125	150	175
	Cover [a]	15	25	35	45	55	65
• lightweight concrete	Thickness	70	85	95	100	115	130
	Width	60	75	85	100	125	150
	Cover [a]	15	25	30	35	45	55
Reinforced concrete (continuous)							
• dense concrete	Thickness	70	90	105	115	135	150
	Width	75	80	90	110	125	150
	Cover [a]	15	20	25	35	45	55
• lightweight concrete	Thickness	70	85	95	100	115	130
	Width	70	75	80	90	100	125
	Cover [a]	15	20	25	30	35	45
Prestressed concrete (simply supported)							
• dense concrete	Thickness	70	90	105	115	135	150
	Width	80	110	135	150	175	200
	Cover [a]	25	35	45	55	65	75
• lightweight concrete	Thickness	70	85	95	100	115	130
	Width	75	90	110	125	150	175
	Cover [a]	20	30	35	45	55	65
Prestressed concrete (continuous)							
• dense concrete	Thickness	70	90	105	115	135	150
	Width	70	75	110	125	150	175
	Cover [a]	20	25	35	45	55	65
• lightweight concrete	Thickness	70	85	95	100	115	130
	Width	70	75	90	110	125	150
	Cover [a]	20	25	30	35	45	55

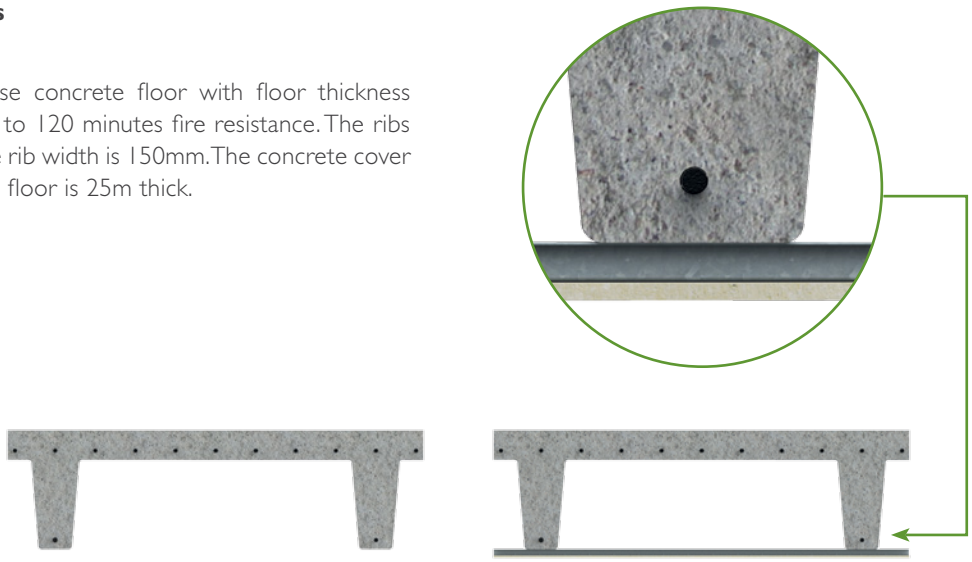
'a' Cover is expressed here as cover to main reinforcement (see 4.2.3 of BS 8110: Part 2). For practical purposes cover is expressed as nominal cover to all reinforcement and these tabulated values need to be decreased accordingly.

CALCULATION FOR DETERMINING REQUIRED BOARD THICKNESS OF FP-900®/FIREPRO®

Ribbed open soffit concrete floors

CASE RF1

A ribbed open soffit reinforced dense concrete floor with floor thickness 120mm is upgraded from 60 minutes to 120 minutes fire resistance. The ribs are spaced at 1000mm centres and the rib width is 150mm. The concrete cover for steel reinforcement of the ribs and floor is 25m thick.



Given:

	DENSE CONCRETE RIBBED OPEN SOFFIT FLOOR DIMENSION	
	Existing fire resistance FRL: 60/60/60 Dimensions - mm	Upgrading to fire resistance FRL: 120/120/120 Minimum dimensions - mm (Simply support)
Rib width	150	125
Floor thickness	120	115
Concrete cover for reinforcement	25	45

Checking:

Minimum dimensions of a ribbed floor for respective fire resistance are required by BS 8110: Part 2: Table 4.5 for ribbed open soffit concrete floors. Deficiency of concretes in thickness are:

- Deficiency in concrete cover to steel reinforcement
  - rib = 45mm - 25mm = 20mm
  - floor exposed to fire from below = 45mm - 25mm = 20mm
    - floor exposed to fire from above = 120mm (floor thickness) – Ø 12mm (reinforcement) - 25mm (concrete cover) = 83mm ≥ 45mm is acceptable.
- Deficiency in floor thickness = 0 (exceed the minimum)
- Deficiency in rib width = 0 (exceed the minimum)

Basing on fire tests and Warringtonfire assessment No. WF 348965, the required board thickness to compensate the deficient concrete thickness = 0.43 x deficient concrete thickness.

❶ Deficient concrete cover
- Rib = 0.43 x 20 = 0.86mm thick
- Floor exposed to fire from below = 0.43 x 20 = 8.6mm thick

❷ The required FP®-900/FirePro® board for fire resistance upgrade is 9mm thick fixed to the underneath of ribs.
- Concrete cover - 9mm thick board ≥ 8.6mm are acceptable.

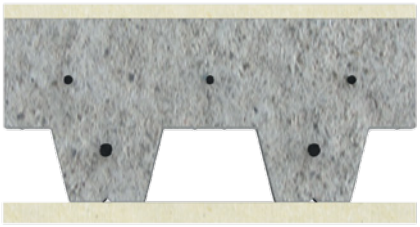
❸ The cladding board is installed by Channel Fix method.

Ribbed open soffit concrete floors

CASE RF2

A corrugated metal form/reinforced dense concrete floor is upgraded to 240 minutes fire resistance. The rib width and floor thickness are 75mm. The floor slab and ribs are reinforced with a layer of A252 steel mesh and Ø 8mm steel bars respectively. The concrete cover for all reinforcements is 35mm thick.

Assumption: The corrugated metal form as a left-in formwork is not designed to take any loadings.



Given:

	DENSE CONCRETE RIBBED OPEN SOFFIT FLOOR DIMENSION	
	Existing fire resistance Unknown Dimensions - mm	Upgrading to fire resistance FRL: 240/240/240 Minimum dimensions - mm (Simply support)
Rib width	75	175
Floor thickness	75	150
Concrete cover for reinforcement	35	65

Checking:

Minimum dimensions of a plain soffit floor for respective fire resistance are required by BS 8110: Part 2: Table 4.5 for ribbed open soffit concrete floors. Deficiency of concretes in thickness are:

- Deficiency in concrete cover to steel reinforcement
  - rib = 65mm - 35mm = 30mm thick
  - floor exposed to fire from below = 65mm - 35mm = 30mm
  - floor exposed to fire from above = 75mm (floor thickness) - Ø 8mm (reinforcement) - 35mm (concrete cover) = 32mm, so 65mm - 32mm = 33mm
- Deficiency in floor thickness = 150mm - 75mm = 75mm
- Deficiency in rib width = 175mm - 75mm = 100mm

Basing on fire tests and Warringtonfire assessment No. WF 348965, the required board thickness to compensate the deficient concrete thickness = 0.43 x deficient concrete thickness.

❶ Deficient concrete cover
- Rib =0.43 x 30mm = 12.9mm thick
- Floor exposed to fire from below = 0.43 x 30 = 12.9mm thick
- Floor exposed to fire from above = 0.43 x 33 = 14.19mm thick

❷ Deficient floor thickness = 0.43 x 75 = 32.25mm thick.

❸ Deficient rib width = 0.43 x 100 = 43mm, minimum 21.5mm board thickness at each side

❹ The required FP®-900/FirePro® boards for fire resistance upgrade are 24mm board at soffit and 15mm board at top.
- Floor thickness – 24mm + 15mm = 39mm thick board ≥ 32.25mm, and
- Concrete cover at top - 15mm thick board ≥ 14.19mm, and
- Concrete cover at ribs and bottom - 24mm thick board ≥ 12.9mm are acceptable.

❺ The cladding board at soffit can be installed by either Direct Fix or Channel Fix method.

Remark:
In case of fire resistance upgrade is required on soffit side of the floor only, FP®-900/FirePro® boards are needed to just protect the underside of ribbed floor and the required board thickness should be at least 33mm.

FP®-900/FirePro®
Concrete Structures Upgrade
CONCRETE WALL

SOBEN INTERNATIONAL

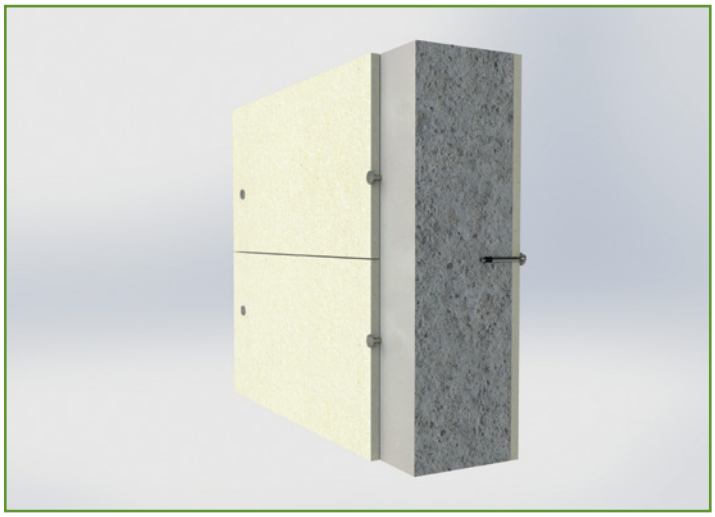
PROTECTION TO CONCRETE WALLS

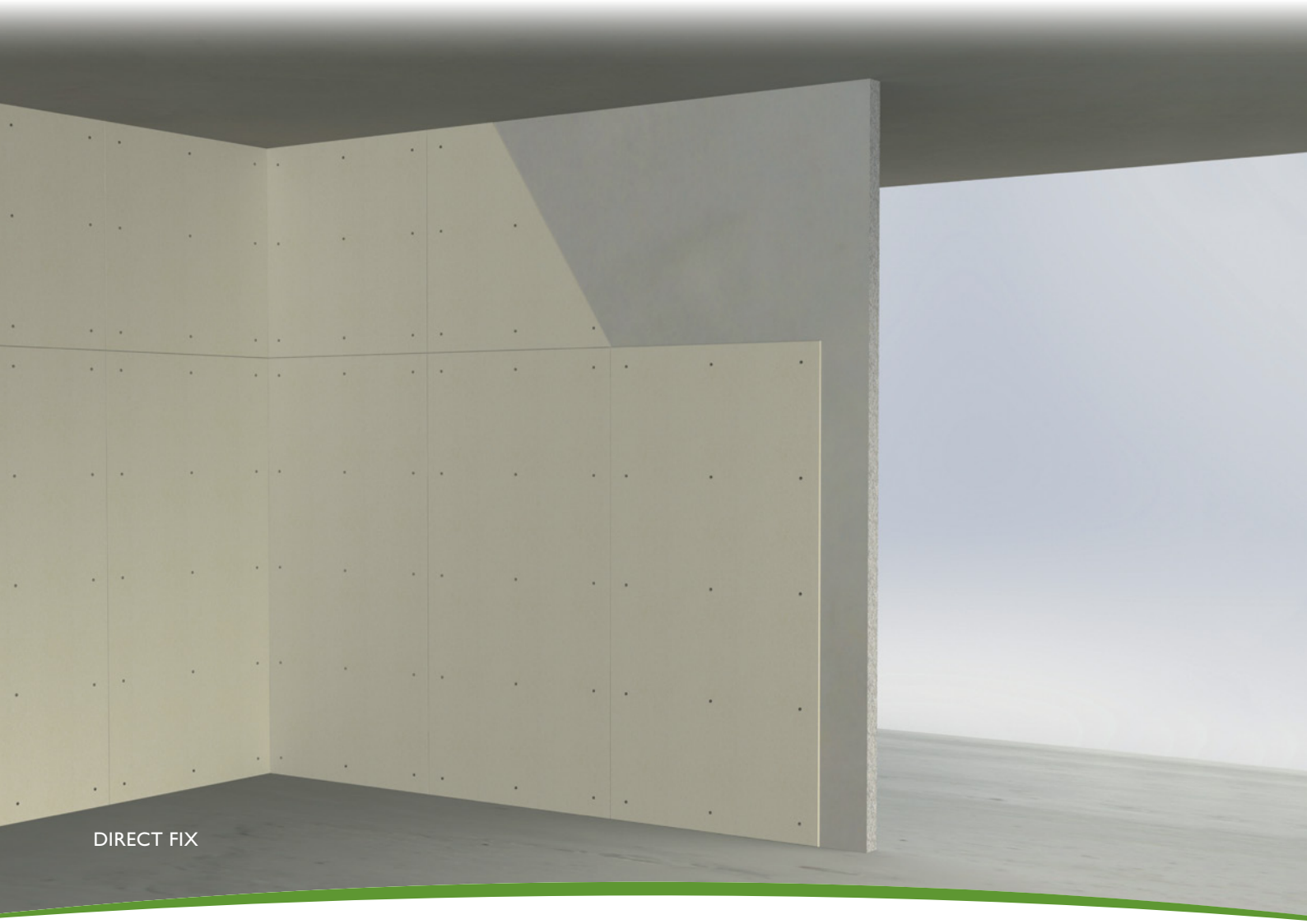
FIRE RATING

FRL	Up to 240/240/240
Standard	BS 476: Part 21 & Part 22 - 1987
	BS 8110: Part 2 - 1997
Approval	FIRES-FR-141-14-AUNE
	Warringtonfire WF 348965

SYSTEM

Installation	Direct Fix / Channel Fix
Column size	Any
Concrete	Dense concrete
	Lightweight concrete
	Prestressed concrete

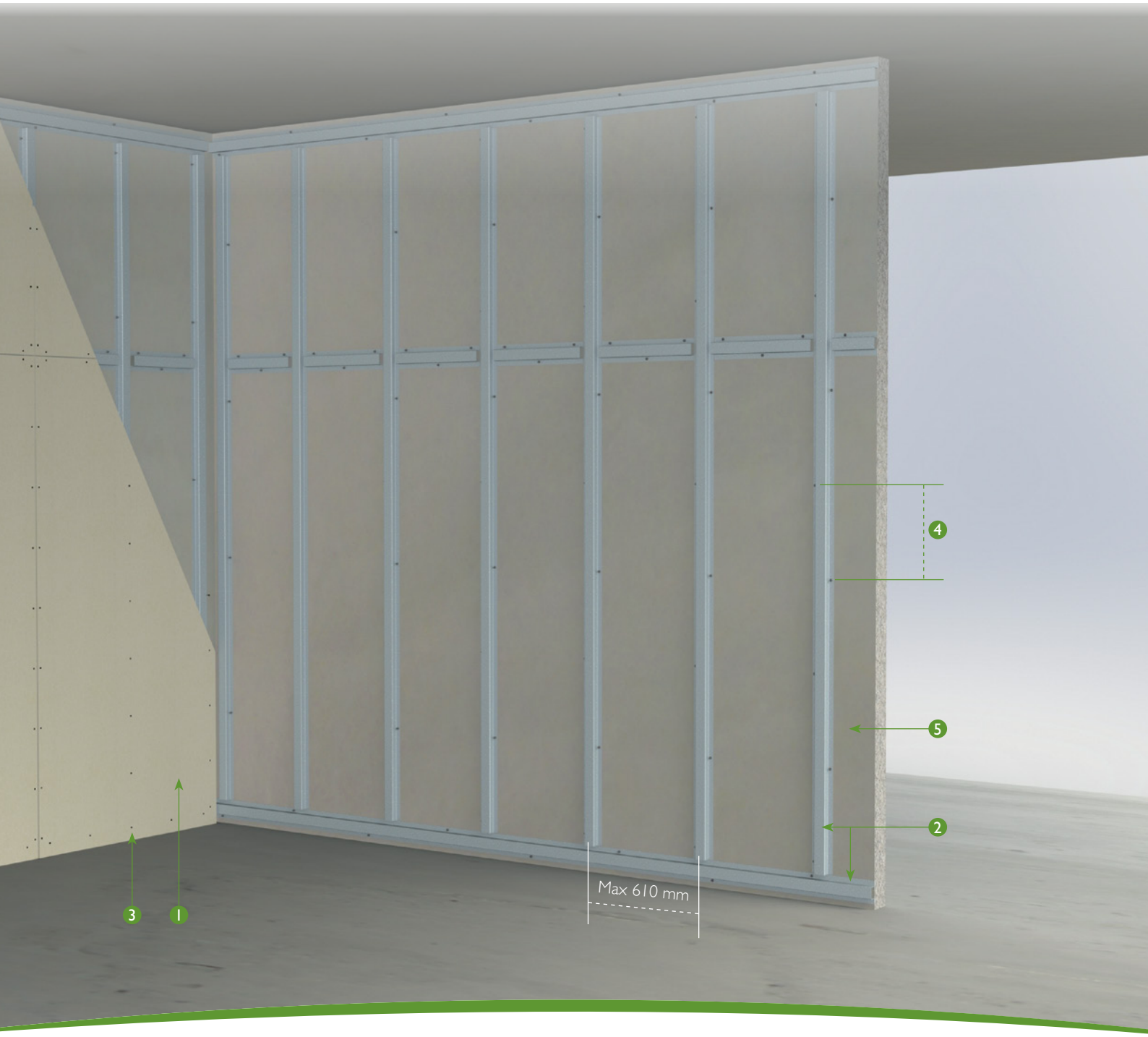




DIRECT FIX

SOBEN INTERNATIONAL

CHANNEL FIX TO CONCRETE WALL



TECHNICAL DATA

1. FP®-900/FirePro® boards
2. Top hat sections
   - Vertical members at maximum 610mm centres
   - Horizontal member at maximum 2440mm centres.
3. M4 self-tapping screws at 200mm centres
4. M6 all-steel anchors at 400mm centres
5. Concrete wall

MINIMUM DIMENSIONS OF CONCRETE WALL FOR FIRE RESISTANCE

An upgraded wall should have maintained minimum concrete wall dimensions for respective fire ratings according to BS 8110: Part 2. The minimum wall thickness not only aim for fire resistance of the member itself, but also provide sufficient heat insulation for fire compartmentation in compliance with the criteria of BS 476: Part 20, 21 & 22.

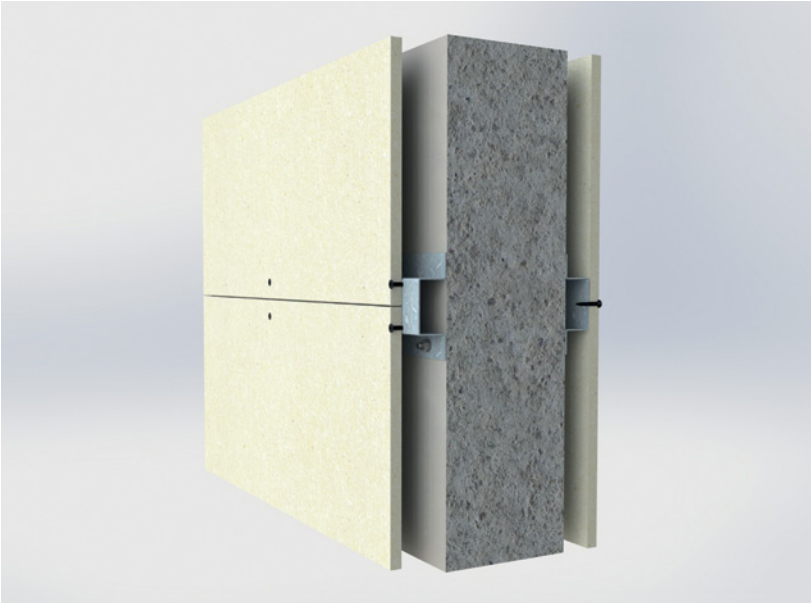
BS 8110: PART 2, TABLE 4.6 - CONCRETE WALLS WITH VERTICAL REINFORCEMENT

Nature of construction and materials		Minimum dimensions excluding any combustible finish for a fire resistance of:					
		30 min	60 min	90 min	120 min	180 min	240 min
		mm	mm	mm	mm	mm	mm
Walls with less than 0.4 % reinforcement made from dense aggregate	Thickness	150	150	175	–	–	–
Walls with 0.4 % to 1.0 % reinforcement made from dense aggregate (concrete density up to 2.4 t/m³)	Width	100	120	140	160	200	240
	Cover [a]	25	25	25	25	30	35
Walls made from lightweight aggregate (concrete density 1.2 t/m³) [b]	Thickness	100	100	115	130	160	190
	Cover [a]	10	10	10	25	25	25
Walls with over 1.0 % reinforcement	Thickness	(See note)	(See note)	100	100	150	180
	Cover [a]	15	15	25	25	25	25

'a' Cover is expressed here as cover to main reinforcement (see 4.2.3 of BS 8110: Part 2). For practical purposes cover is expressed as nominal cover to all reinforcement and these tabulated values need to be decreased accordingly

'b' For concrete of densities between 1.2 t/m³ and 2.4 t/m³ the value of wall thickness may be interpolated.

'NOTE' Use the minimum practical dimension but not less than 75 mm.



Walls are usually symmetrical and if the fire risk side of the wall is not known, then both sides of the wall must be protected with the relevant thickness of board for the required period of fire resistance.

In condition that an existing wall with sufficient concrete cover to vertical reinforcement satisfies the minimum cover criterion for the upgraded fire resistance, so FP®-900/FirePro® boards are allowed to be fastened on either side of the wall that provide the minimum wall thickness for sufficient heat insulation.

CALCULATION FOR DETERMINING REQUIRED BOARD THICKNESS OF FP-900®/FIREPRO®

Concrete walls

CASE W1

A reinforced dense concrete wall with 75mm thick is upgraded from 60 minutes to 120 minutes fire resistance of both sides of the wall. The concrete cover for vertical reinforcements is 15mm thick.

Given:

	DENSE CONCRETE WALL DIMENSION	
	Existing fire resistance FRL: 60/60/60 Dimensions - mm	Upgrading to fire resistance FRL: 120/120/120 Minimum dimensions - mm
Wall thickness	75	100
Concrete cover for vertical reinforcement ≥ 1%	15	25

Checking:

Minimum dimensions of a wall for respective fire resistance are required by BS 8110: Part 2: Table 4.6 for concrete walls. Deficiency of concretes in thickness are:

- Deficiency in concrete cover to steel reinforcement = 25mm - 15mm = 10mm
- Deficiency in wall thickness = 100mm - 75mm = 25mm

Basing on fire tests and Warringtonfire assessment No. WF 348965, the required board thickness to compensate the deficient concrete thickness = 0.43 x deficient concrete thickness.

❶ Deficient concrete cover = 0.43 x 10 = 4.3mm thick

❷ Deficient wall thickness = 0.43 x 25 = 10.75mm thick, total minimum board thickness at both sides of the wall is 10.75mm

❸ The required FP®-900/FirePro® boards for fire resistance upgrade are:
- Wall thickness - 9mm thick board at each side, total 18mm ≥ 10.75mm, and
- Concrete cover – minimum 9mm thick board ≥ 4.3mm are acceptable.

❹ The cladding board can be installed by either Direct Fix or Channel Fix method.

Concrete walls

CASE W2

A reinforced dense concrete wall with 120mm thick is upgraded from 60 minutes to 120 minutes fire resistance of both sides of the wall. The concrete cover for vertical reinforcement is 25mm thick.

Given:

	DENSE CONCRETE WALL DIMENSION	
	Existing fire resistance FRL: 60/60/60 Dimensions - mm	Upgrading to fire resistance FRL: 120/120/120 Minimum dimensions - mm
Wall thickness	120	160
Concrete cover for vertical reinforcement = 0.4 % to 1%	25	25

Checking:

Minimum dimensions of wall for respective fire resistance are required by BS 8110: Part 2: Table 4.6 for concrete walls. Deficiency of concretes in thickness are:

- Deficiency in concrete cover to steel reinforcement = 25mm - 25mm = 0
- Deficiency in wall thickness = 160mm - 120mm = 40mm

Basing on fire tests and Warringtonfire assessment No. WF 348965, the required board thickness to compensate the deficient concrete thickness = 0.43 x deficient concrete thickness.

❶ Deficient concrete cover = 0 (satisfy the minimum)

❷ Deficient wall thickness = 0.43 x 40 = 17.2mm thick, total minimum board thickness either at one side or both sides of the wall is 17.2mm

❸ The required FP®-900/FirePro® boards for fire resistance upgrade are

- Wall thickness – either 18mm thick board at one side or 9mm thick board at each side, total 18mm ≥ 10.75mm is acceptable.

❹ The cladding board can be installed by either Direct Fix or Channel Fix method.

Concrete walls

CASE W3

A reinforced lightweight concrete wall with 100mm thick is upgraded from 60 minutes to 120 minutes fire resistance of both sides of the wall. The concrete cover for vertical reinforcement is 20mm thick.

Given:

	LIGHTWEIGHT CONCRETE WALL DIMENSION	
	Existing fire resistance FRL: 60/60/60 Dimensions - mm	Upgrading to fire resistance FRL: 120/120/120 Minimum dimensions - mm
Wall thickness	100	130
Concrete cover for vertical reinforcement	20	25

Checking:

Minimum dimensions of a lightweight wall for respective fire resistance are required by BS 8110: Part 2: Table 4.6 for concrete walls. Deficiency of concretes in thickness are:

- Deficiency in concrete cover to steel reinforcement = 25mm - 20mm = 5mm
- Deficiency in wall thickness = 130mm - 100mm = 30mm

Basing on fire tests and Warringtonfire assessment No. WF 348965, the required board thickness to compensate the deficient concrete thickness = 0.43 x deficient concrete thickness.

❶ Deficient concrete cover = 0.43 x 5 = 2.15mm thick

❷ Deficient wall thickness = 0.43 x 30 = 12.9mm thick, total minimum board thickness at both sides of the wall is 12.9mm

❸ The required FP®-900/FirePro® boards for fire resistance upgrade are:

- Wall thickness - 9mm thick board at each side, total 18mm ≥ 12.9mm, and
- Concrete cover – minimum 9mm thick board ≥ 2.15mm are acceptable.

❹ The cladding board can be installed by either Direct Fix or Channel Fix method. .

FP®-900/FirePro®
Tunnel Concrete Structures

SOBEN INTERNATIONAL

FP® SYSTEMS FOR FIRE PROTECTION TO TUNNELS

Fires in tunnels or underground motorways where are confined spaces extremely hazardous to human life. Fires might jeopardise the tunnel structure and incur subsequent costly reinstatement. Fire protection measures to tunnels are crucial for life escape, fireman's safety and prevention of tunnel structure damage and collapse in event of fire.

Most road tunnel fires are caused by fuels which generate very high intensive of fire and heat flux. Within a few minutes of fire, elevated temperatures in a confined tunnel space can reach over 1000°C. An unprotected reinforced concrete tunnel could be severely damaged or even collapse due to loss of steel reinforcement's strength and concrete spalling whilst the fire heat temperature continuously increases. Installation of a passive fire and thermal resistant barrier to a tunnel structure is a need for tunnel construction to maintain its structural stability. The barrier not only effectively protects the concrete structure safely, but also avoids tunnel fires causing costly damage to surrounding of infrastructure.

A few researches on hydrocarbon fire nature in tunnels have been taken place internationally. These are Eurocode *Hydrocarbon (HC), Modified Hydrocarbon (HCM), Rijkwaterstaat (RWS) and RABT* fire curves with attributes of time-temperature change. The Eurocode HC and RWS standards are mostly applied for fire safety of tunnels in many countries. In cope with tunnel fire safety, Soben International offers sophisticated fire protection solutions for tunnel concrete structures against Rijkswaterstaat (RWS) fire and Eurocode Hydrocarbon (HC) fire by using FP®-900/FirePro® high performance fire protection calcium silicate matrix board in terms of cost saving and performance. The eco-friendly FP®-900/FirePro® board withstand the highest temperature of 1350°C and truly suits for installation in tunnels or underground spaces where are humid and damp. FP®-900/FirePro® is high quality calcium silicate matrix and does not contain wood chips infill. The installed fire boards will not be warped or deteriorated in tunnels. It has been tested to prove its high dimensional stability and durability when exposed to extreme warm water, soak-dry, freeze-flaw cycle tests and water impermeability in compliance with European Standard.

SOBEN INTERNATIONAL

CONSIDERATIONS FOR FP®-900/FIREPRO® FIRE RESISTANCE UPGRADE/PROTECTION SYSTEMS FOR CONCRETE STRUCTURES

Normal strength concrete is commonly used in tunnel construction. Lots of fire research and testing on the behaviour of concrete have been done. It is known that fire heat temperature above 400°C the normal strength concrete begins to loss its strength and increases risk of concrete spalling. Continuous temperature rise at steel reinforcement within the concrete will lose its strength. Installation of FP®-900/FirePro® protective board system can prevent temperature rapidly rise affecting the tunnel structural safety in terms of concrete spalling and collapse of tunnel soffits.

In keeping the tunnel structural safety when a tunnel exposed to fire, the FP®-900/FirePro® protective board system is able to provide good insulation of high temperature heat from hydrocarbon fires. It effectively maintains the stability of tunnel structure where requires the temperature not exceed 380°C on the concrete surface behind the fire protective board layer and 250 °C on the steel reinforcement within the concrete. The protective board system should be installed properly with the requirements as mentioned below.

Applications	FP®-900/FirePro® tunnel fire protection systems were designed to tackle the severe fire risk with respect to RWS and European hydrocarbon fire curve.
Tunnel Concrete	A tunnel may be designed with normal or high compressive strength concrete. The minimum required concrete strength class for a standard RWS tunnel fire resistance test is C28/35 in accordance with Eurocode 2A.
Concrete cover	Concrete cover should have minimum 25mm thick for a tunnel concrete structure. The concrete cover for steel reinforcement provides fire protection a certain length of time and hence to maintain the loadbearing capacity of the structure. Thicker concrete cover can extend the time of fire protection.
Steel Anchors	FP®-900/FirePro® boards are fixed onto the concrete structure or lining of the tunnel by M6 all-steel nail anchors. Each anchor is installed in combination with a steel washer minimum Ø29mm x 1.2mm thick to support the board. Depth of engagement of the anchors into sound concrete should be at least 30mm. The anchors and washers should be zinc coated mild steel or stainless steel for rust resistance.
Concrete Repair	Before the FP®-900/FirePro® concrete protection system is applied, any locations where concrete is missing or spalling should be repaired with a proprietary concrete product designed for the purpose of fire rated concrete structures.
Movement Joint	A movement joint is needed when a FP®-900/FirePro® board spans a movement control joint of concrete structure. The movement board joint should be sealed with fire rated sealant. The sealant should be silicone based and tested in accordance with BS 476: Part 20 or equivalent approval.

SOBEN INTERNATIONAL

Fire Rated Sealant	Where FP®-900/FirePro® fire protection boards abutting perimeter wall or floor constructions should be jointed tightly. In case the construction surface is uneven, fire rated sealant should be applied to seal up any gaps at the joints. The sealant should be tested in accordance with BS 476: Part 20 or equivalent approval.
Board joints	All FP®-900/FirePro® boards are tightly butt jointed. If the cut edge-joint is not tight or rough where the gap should be sealed with fire rated sealant.
Box-out	Where box-out at FP®-900/FirePro® boards is left for installation of devices, for instance a ventilation fan is installed directly on the concrete lining, a gap not greater than 10mm between the box-out and the device should be provided and filled with fire rated sealant.
Building Services Installed in Tunnels	Power cabling, fire service piping and ducting run along in the tunnel. They may cause fire risk or require fire protection to the services in order to maintain their functions in event of fire. FP®-900/FirePro® fire rated building services enclosure and ductwork systems provide fire protection in tunnels. Further information, please contact Soben International.

FP®-900/FirePro®
Tunnel Concrete Structures
RWS & HYDROCARBON FIRE PROTECTION SYSTEMS

SOBEN INTERNATIONAL

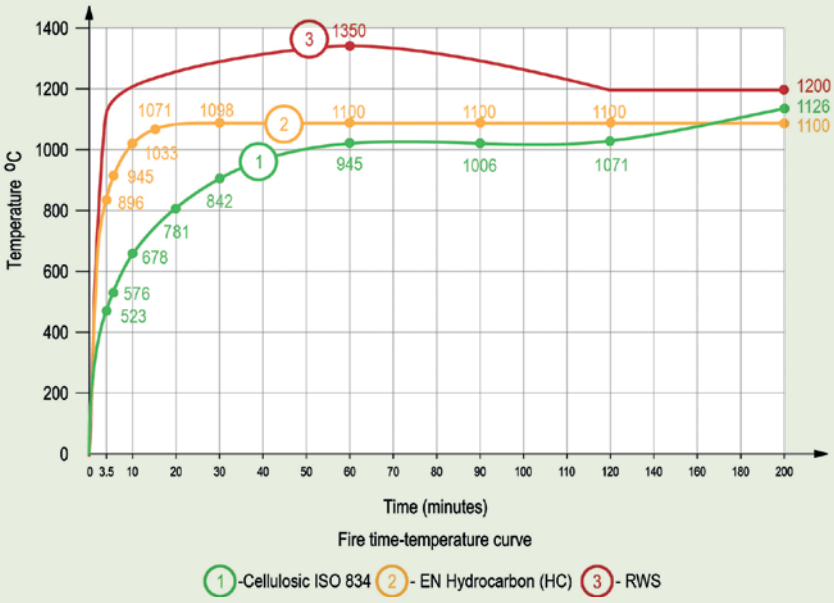
FIRE RATING

FRL	Up to 180 minutes	Up to 240 minutes
Standard	**RWS Fire** 2008-Efectis-R0695	**Hydrocarbon Fire** EN 1363-2 & EN 1992-1-2
Approval	Efectis-000711 & 000712 Efectis-R001500, 1550 & 1608 Warrington Certifire CF5546	Efectis-000713 & 000714 Efectis-R001500 & 1608

SYSTEM

Durability	BS EN 12467	BS EN 12467

Eurocode Hydrocarbon and RWS have been established to tackle tunnel fires fuelled by oil spills or gas clouds that characterise faster fire heating and higher heat fluxes. The EN Hydrocarbon Fire is the most popular national standard for fire protection to concrete tunnels or underground vehicular subways in many countries. The highest temperature of EN Hydrocarbon fire reaches 1100°C based on the fire testing standard EN 1363-2 and Eurocode 2 for fire resisting concrete structures. RWS provides resistance to extreme high temperature up to 1350°C. RWS was advocated by TNO Netherland and based on the testing procedures of 2008-Efectis-R0695.



The diagram exhibits the elevated temperature of Eurocode Hydrocarbon (HC) and Rijkswaterstaat (RWS) fire loads in tunnels and the standard cellulose fire load in buildings

FP®-900/FIREPRO® TUNNEL FIRE PROTECTIVE BOARD

FP®-900/FirePro® tunnel fire protective board systems can be installed to walls and soffit of a concrete tunnel. The required thickness of board with respect to fire rating and the type of fire risk given in the tables below.

Minimum required FP®-900/FirePro® board thickness for Eurocode Hydrocarbon (HC) fire protection

TABLE TC 1	Eurocode Hydrocarbon Fire	
Fire rating - minutes	Required thickness of board - mm	Minimum concrete cover - mm
60	14	25
90	14	25
120	17	25
180	20	25
240	23	25

The FP®-900/FirePro® tunnel HC fire protection systems had been designed in compliance with Eurocode Hydrocarbon fire risk up to 240 minutes fire rating.

Minimum required FP®-900/FirePro® board thickness for RWS fire protection

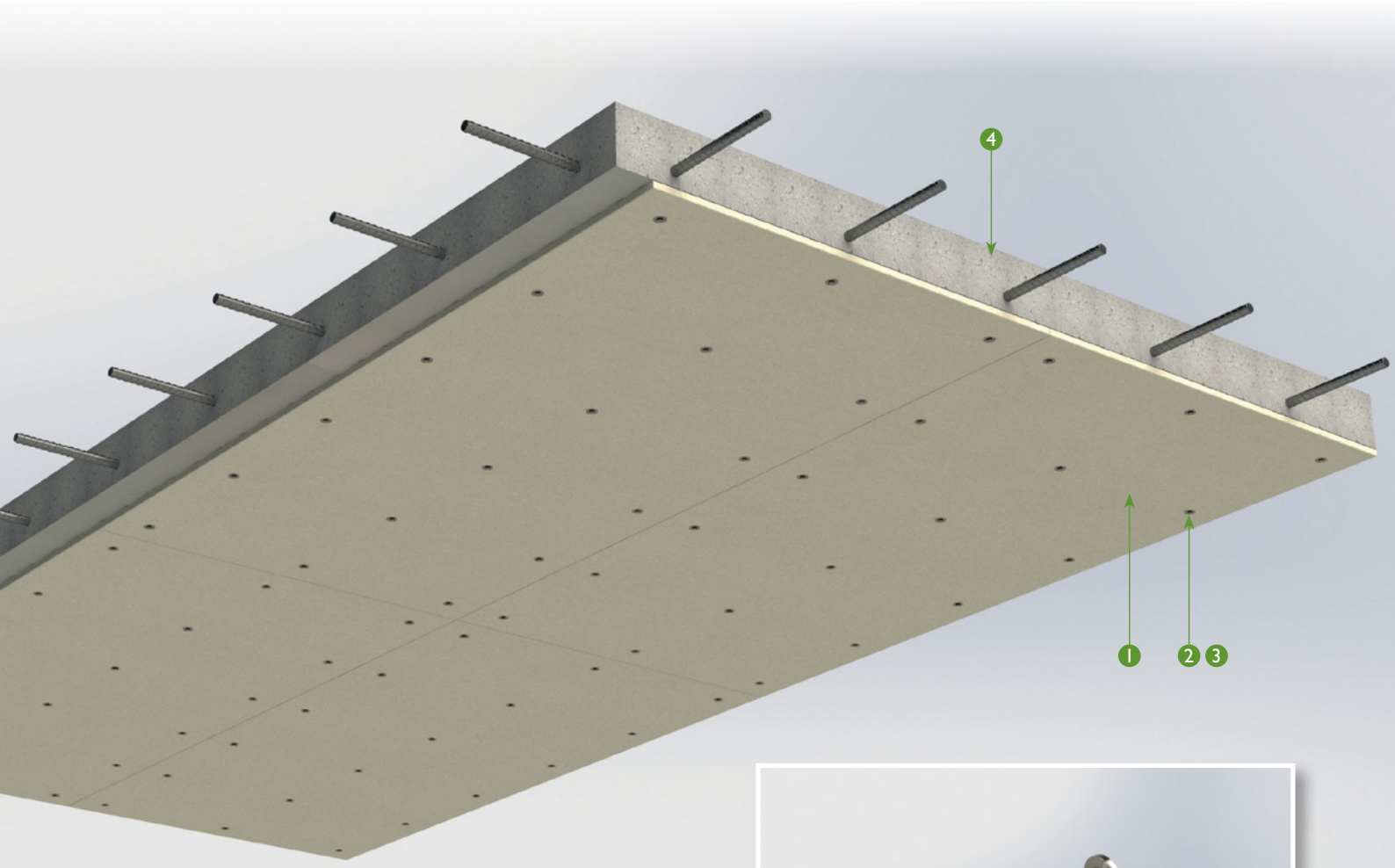
TABLE TC 2	RWS Fire	
Fire rating - minutes	Required thickness of board - mm	Minimum concrete cover - mm
60	20	25
90	29	25
120	36	25
180#	36	25

The FP®-900/FirePro® tunnel RWS fire protection systems for concrete tunnels had been designed for up to 120 minutes fire rating. The 180 minutes fire protection represents the protective board system ensuring the safety of the concrete tunnel structure continuously exposed to fire till 180 minutes without collapse and spalling.

SOBEN INTERNATIONAL

INSTALLATION OF FP®-900/FIREPRO® TUNNEL FIRE PROTECTION SYSTEMS

FP®-900/FirePro® protective board systems are applied to tunnel ceiling and wall. The boards can be installed to concrete tunnel structures with either **Post Fixed** or **Lost Formwork Fixing** method. The two fixing methods allow ease of installation to suit various off-site and in-situ constructions. Post Fixed method is regarded as the most convenient installation method to bored or open-cut tunnel construction. FP®-900/FirePro® protective boards are fastened to the concrete tunnel on site or pre-casted concrete units in the casting yard. Alternatively, Lost Formwork Fixing benefits to open-cut tunnel constructions. Making use of FP®-900/FirePro® board layer as a left-in formwork after concreting. It greatly speeds up the in-situ construction and reduces the cost of formwork and labour deployed.



TECHNICAL DATA

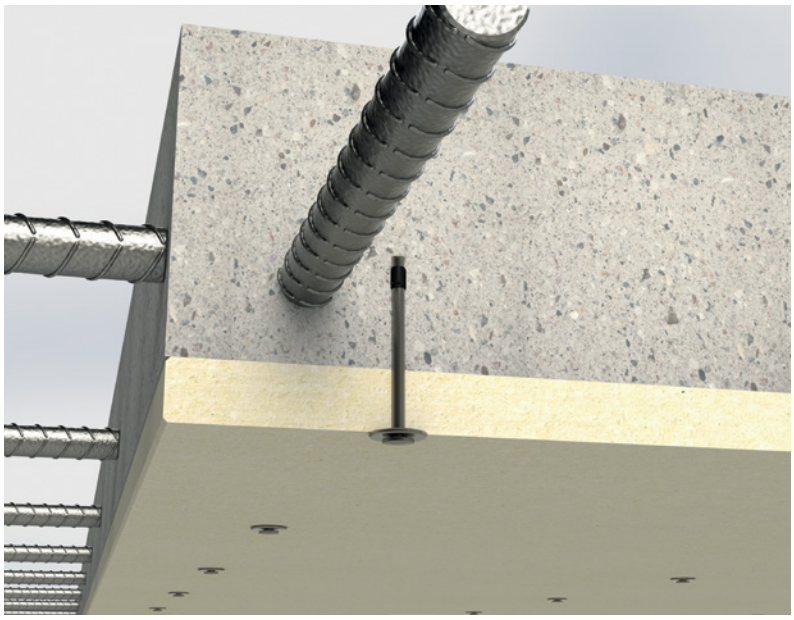
1. FP®-900/FirePro® board#
2. M6 all-steel or stainless steel nail anchor
3. Steel or stainless steel washer
4. Concrete tunnel structure

Thickness of the board refers to Table TC1 & TC2

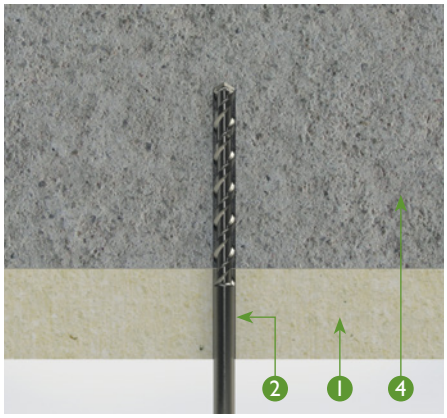
SOBEN INTERNATIONAL

Post Fixed

FP®-900/FirePro® boards are fixed onto the concrete face with M6 all-steel nail anchors. Each nail anchor is installed in combination with a circular steel washer 29mm diameter x 1.2mm thick to support the board. The steel anchors and washers should be either zinc coated rust resistance or grade A2/A4 stainless steel. The anchors are located at 500mm maximum centres longitudinally and 450mm maximum centres transversely. The nominal board edge distance for anchors is 100mm to 150mm. The minimum depth of engagement of the anchors into concrete is at least 30mm. The boards are installed next to each other with butt joints. If two-layer of FP®-900/FirePro® board uses, both staggered and straight joints can be applied.



Fast & easy way of nail anchor fixing



Step 1

Step 2

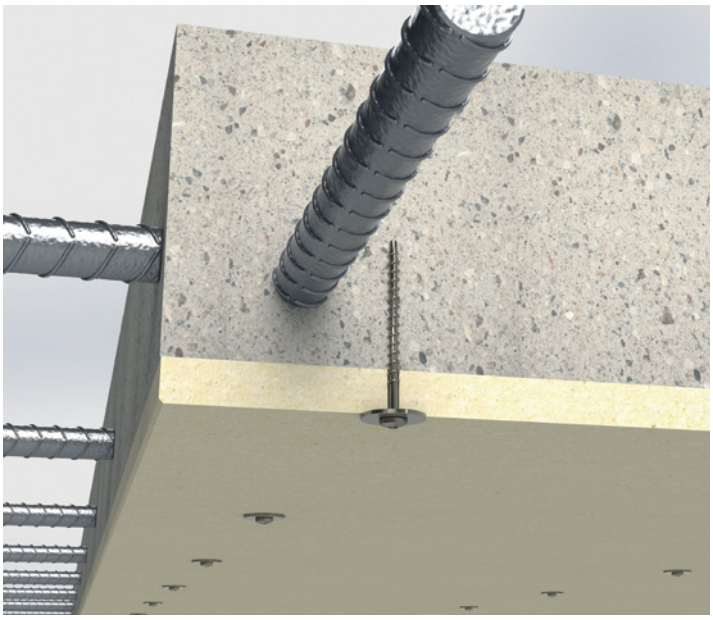
Step 3

TECHNICAL DATA

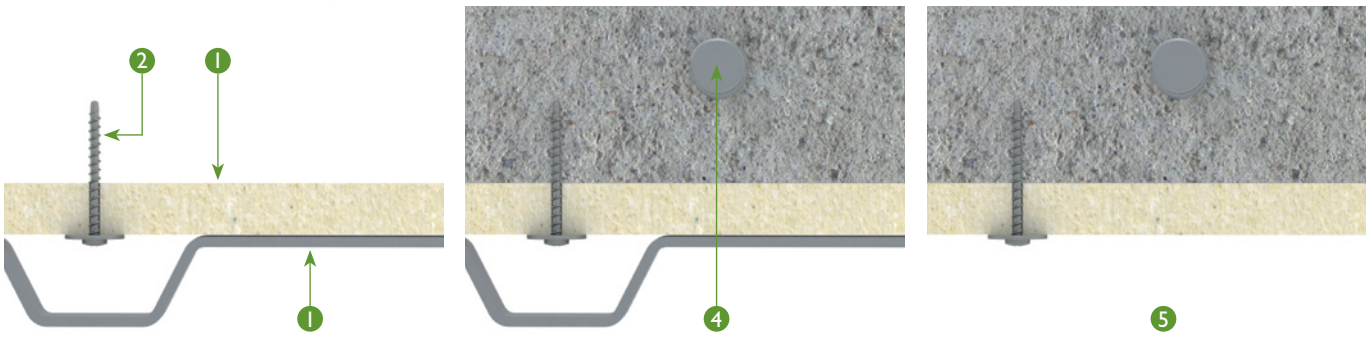
1. FP®-900/FirePro® board
2. M6 masonry drill
3. M6 All-steel or stainless steel A2/A4 nail anchor and washer
4. Concrete tunnel structure
5. Drill hole

Lost Formwork Fixing

FP®-900/FirePro® boards as a part of formwork for the tunnel concrete ceiling and walls. The boards are pre-installed with steel anchors and laid on top of the false work supporting the ceiling concrete works. For walls, the boards are stationed to the shuttering by steel ties and structs. Then concrete is poured into the formwork. The pre-installed steel anchors are M6 pan head screw anchor. Each anchor is fixed to the board in combination with a steel washer 29mm diameter x 1.2mm thick. The steel anchors and washers should be either zinc coated rust resistance or grade A2/A4 stainless steel. The anchors are located at 500mm maximum centres longitudinally and 450mm maximum centres transversely. The nominal board edge distance for anchors is 100mm to 150mm. The minimum depth of engagement of the anchors into concrete is at least 40mm. The boards all are butt jointed next to each other.



Lost formwork construction



Step 1 Step 2 Step 3

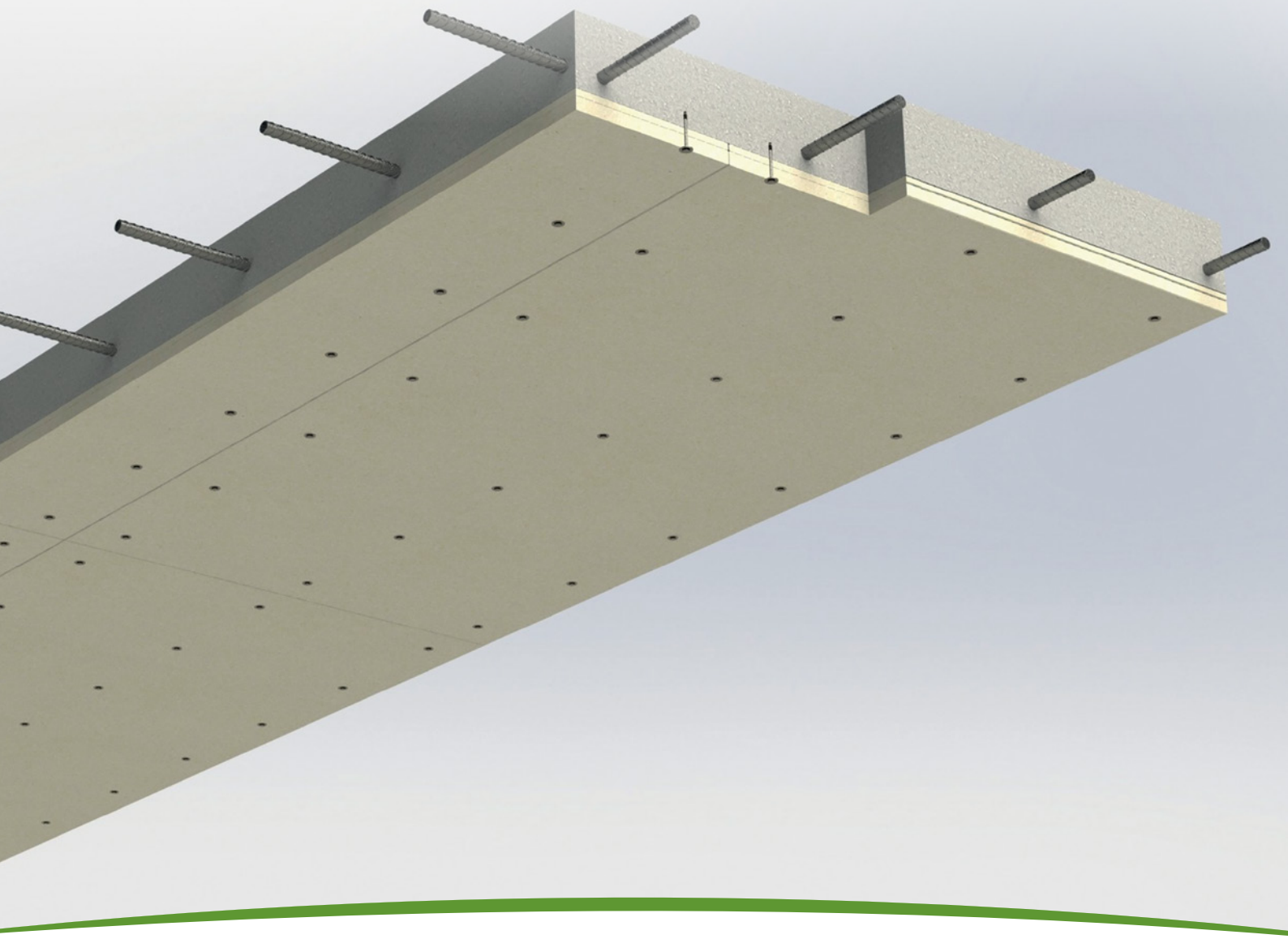
TECHNICAL DATA

1. FP®-900/FirePro® board
2. Pre-installed M6 steel or stainless steel screw anchor & steel washer
3. False work supporting the board for concreting
4. Reinforcement of tunnel structure
5. After concreting and removal of false work

SOBEN INTERNATIONAL

BOARD INSTALLATION

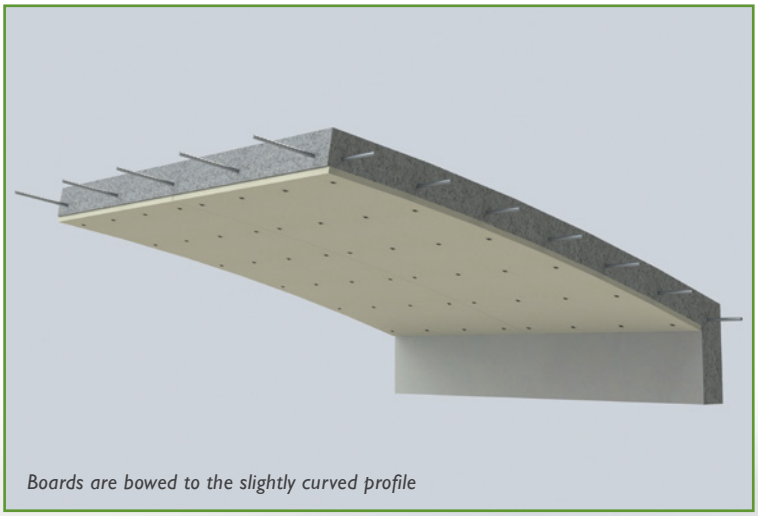
The required tunnel protective board of FP®-900/FirePro® system can be either one or two layers of board installed onto a concrete tunnel. Installing the two-layer board system is similar to the one-layer board system. When FP®-900/FirePro® two-layer board is applied at a tunnel ceiling, two board layers may not be the same thickness. In such case, the thin board layer should be positioned in contact with the soffit of ceiling. The board joints of two layers can be lapped or straight joint. The straight joint arrangement had been tested to confirm that would not degrade fire protection and insulation to the concrete structure. The same board fixing arrangement is applied to tunnel walls.



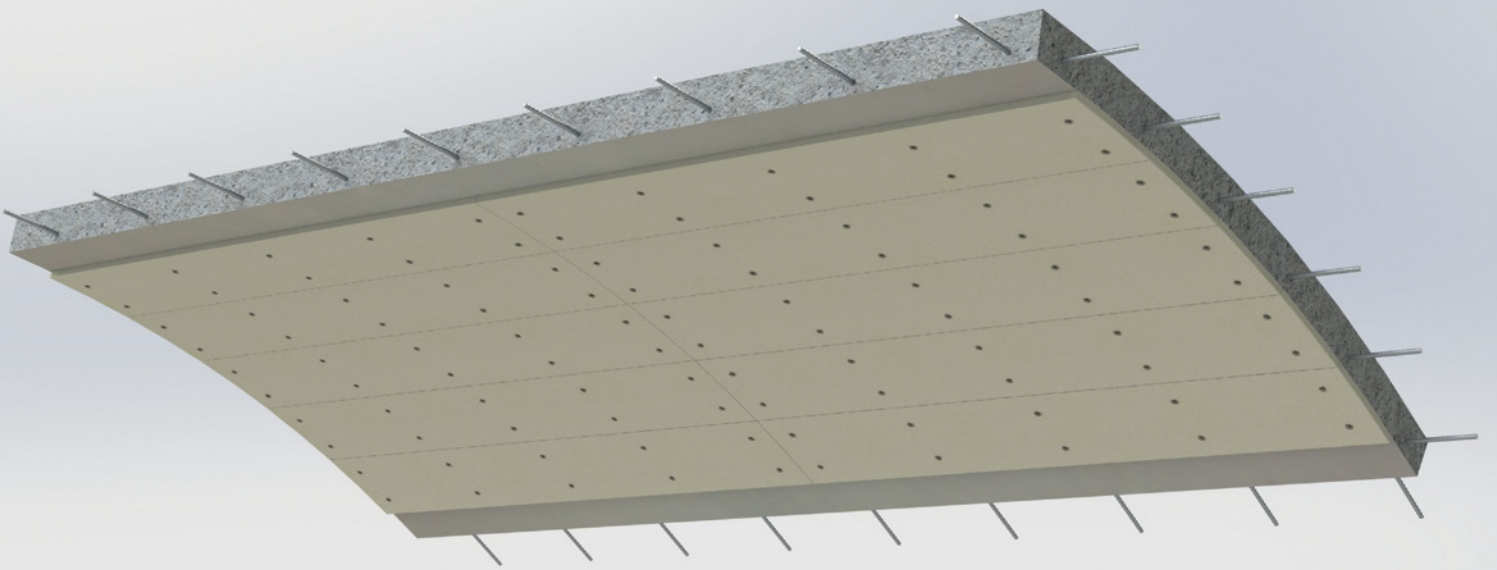
SOBEN INTERNATIONAL

BOARDS INSTALLED ON THE CURVED CONCRETE TUNNEL PROFILE

Installation of FP®-900/FirePro® boards on a curved tunnel ceiling or a large diameter-bored tunnel, the board can be bowed to install. For instance, the maximum allowable deflection of a 17mm thick board with 2440mm in length is approximate 200mm. The board can be installed to a bored tunnel with internal diameter 11m. For a smaller diameter-bored tunnel, boards are cut to narrow width to fit the curved concrete face. For more information please contact the technical team of Soben International.



Boards are bowed to the slightly curved profile



Narrow boards fit to the curved profile

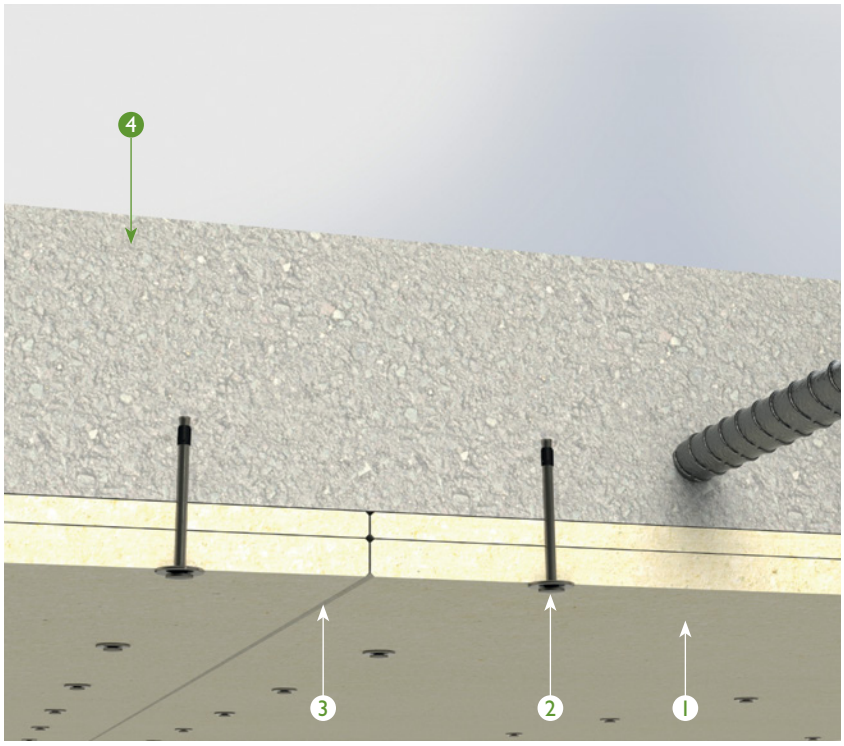
FP®-900/FirePro®
Tunnel Concrete Structures
INSTALLATION

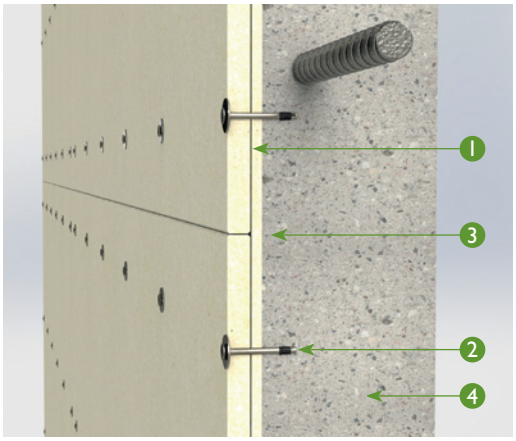
SOBEN INTERNATIONAL

KO HO-COLOANE
TUNNEL, MACAU

SOBEN INTERNATIONAL

TYPICAL BOARD JOINT

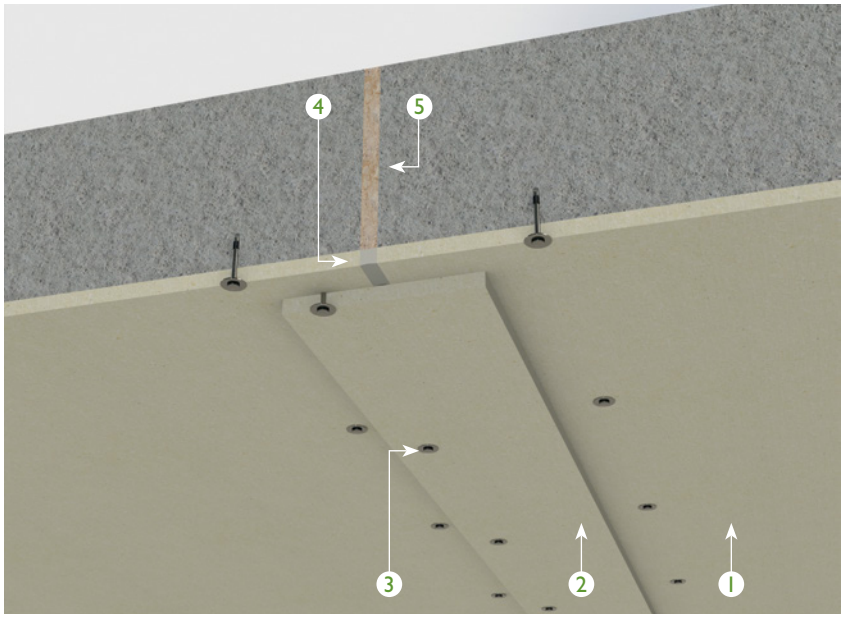




TECHNICAL DATA

1. FP®-900/FirePro® with one or two layers
2. M6 All-steel or stainless steel A2/A4 nail anchors and washers
3. Either straight or lapped joint
4. Tunnel concrete structure

MOVEMENT JOINT



TECHNICAL DATA

1. FP®-900/FirePro® with one or two layers
2. FP®-900/FirePro® cover strip 300 wide and lap over the joint at least 100mm
3. Fixing the cover strip with M6 All-steel or stainless steel A2/A4 nail anchors and washers at 300mm maximum centres, board edge distance at least 50mm
4. Fire rated sealant
5. Movement joint of concrete structure

SOBEN INTERNATIONAL

HONG KONG
Soben International (Asia Pacific) Ltd
Tel: +852 3173 2683 Fax: +852 3173 2688
Email: international@sobenboard.com
www.sobenboard.com

N. IRELAND. UK
Soben International (Europe)
Tel: +44 78 9423 0583
Email: europe@sobenboard.com

SINGAPORE
Soben International (Singapore)
Tel: +65 9680 6132
Email: sg@sobenboard.com

PERTH, WA
Soben International (Australia)
Tel: +61 (0)4 1532 3888
Email: aus@sobenboard.com

INCHEON, KOREA
Soben International (Korea)
Tel: +82 10 9015 5750
Email: kor@sobenboard.com

Your Local Distributor

SALES IN HONG KONG & MACAU REGIONS
Supreme Ecoform Limited
Tel: +852 3741 2689 Fax: +852 3741 2690
Email: info@hkseco.com

• V1910