

PASSIVE FIRE PROTECTION SYSTEMS **Application & Technical Manual:** **Concrete Upgrading**



Concrete Upgrading With Board Lining General Information _____	1 - 2
Concrete Upgrading With Board Lining System Index _____	3
PROMATECT®-H Upgraded Concrete Floor _____	4 - 5
PROMATECT®-H Upgraded Concrete/Brick Wall _____	6 - 7
PROMATECT®-H Concrete/Brick Upgrading Architectural Specification _____	8
Sprayed Concrete Upgrading General Information / System Index _____	9
Cafco FENDOLITE® MII Sprayed Upgrading Of Concrete/Brick Wall _____	10
Cafco MANDOLITE® CP2 Sprayed Upgrading Of Concrete Floor _____	11
Cafco MANDOLITE® CP2 Sprayed Upgrading Of Concrete/Brick Wall _____	12
Sprayed Concrete Upgrading Architectural Specification _____	13



Strengthening and upgrading structural systems to improve fire performance of an existing building is a common building renovation activity. For upgrade projects, design engineers must deal with structures in which every element carries a share of the existing load.

Contractors must also work with critical issues related to access of the work area, constructability of the repair, noise and dust control, as well as the type of construction materials. The latter may not be quite as critical as for new construction projects. Upgrading concrete systems with matrix engineered mineral board not only improves fire performance but also ensures that high, increased loading is not added to the construction. Equally important, Promat's concrete upgrading systems have been tested in a series of fire resistance tests of concrete floors and walls lined with PROMATECT®-H board. Results are presented in terms of the thickness of PROMATECT®-H linings required to give a specified improvement in performance over the performance of unprotected concrete. Please consult Promat for the base concrete thicknesses.

The fire resistance of a reinforced concrete structure depends, to a large extent, on:

- The overall thickness of the section (in order to keep heat transfer through the member within acceptable limits),
- The average concrete cover to the reinforcement (in order to keep the temperature of the reinforcement below critical values).

The tendency of concrete to spall, or break up, in a fire can lead to loss of the insulating cover to the steel and reduction in overall thickness of the member. In some constructions, supplementary reinforcement is necessary to reduce these effects. The overall thickness and cover is determined by the properties of the aggregate used. For example, lightweight aggregate formed from expanded pulverised fly ash has low thermal conductivity and expansion, and is, to some degree, more resistant to spalling, enabling thickness and cover reduction to be made without lowering the fire resistance.

Fire Testing Methods

Concrete floors should normally be tested or assessed in accordance with AS 1530: Part 4: 1990 or BS 476: Part 21: 1987 and are required to satisfy the three failure criteria of loadbearing capacity, integrity and insulation when exposed to fire from below. Floors protected with a suspended ceiling should be tested or assessed to BS 476: Part 23: 1987. The systems detailed in this section satisfy the above requirements. However, some concrete structures can be exposed to more onerous heating conditions, e.g. in tunnels. Please refer to Promat for further information.

Design Considerations

Following are some of the factors that should be considered when determining the correct specifications that ensure a concrete floor provides the required fire performance:

1 Concrete Density

Density not only affects the strength of concrete but also its insulation properties and susceptibility to spalling when exposed to fire.

2 Concrete Moisture Content

Depending on the concrete type, concrete will spall severely when exposed to fire if its moisture content is greater than 2-3%.

3 Concrete Thickness & Cover To Reinforcing Bars

The overall slab thickness will contribute to the strength and insulation of the structure but the concrete cover to the lowest reinforcing bars is also critical. The concrete slab may need upgrading if inadequate cover has been provided.

4 Supporting Steelwork

Care should be taken that any structural steel supporting the concrete slab is adequately protected against fire.

5 Other Factors

The reference made to suspended ceilings, light fittings, service penetrations, cavity barriers and loading in the timber floor section of this handbook apply equally to concrete floors.

6 Type of Fire Exposure

The rate of increase in temperature is critical to the susceptibility of concrete to spall or collapse when exposed to fire. The more rapid the rise in temperature, the greater the likelihood of damage to concrete occurring. For more details concerning the effects of fire on concrete, please refer to the *Promat Tunnel Fire Protection Handbook*.

Guidance Notes

Cover

Cover may be taken in all situations as the distance between the nearest heated face of the concrete and the surface of the main reinforcement or an average value, determined as follows.

For floors, cover is the average distance from the soffit or the heated face. With one way spanning single layer reinforcement the actual distance is used, i.e. C1. With two way spanning floors the average distance is calculated taking into account reinforcement in both directions as multi layer reinforcement. With one way spanning floors, only multi layer reinforcement in the same direction should be used to determine the average distance.

The average distance cover is calculated:

$$\text{Cover} = \frac{A_1 C_1 + A_2 C_2 + A_3 C_3 + \dots + A_n C_n}{A_1 + A_2 + A_3 + \dots + A_n} = \frac{\sum AC}{\sum A}$$

Where A = Area of tensile reinforcement/tendons

C = Distance between the nearest exposed surface and the main reinforcement

Floor Thickness

In the case of solid floors or ribbed floors, the thickness to consider is the actual thickness of the floor (including any non combustible finish screed on top).

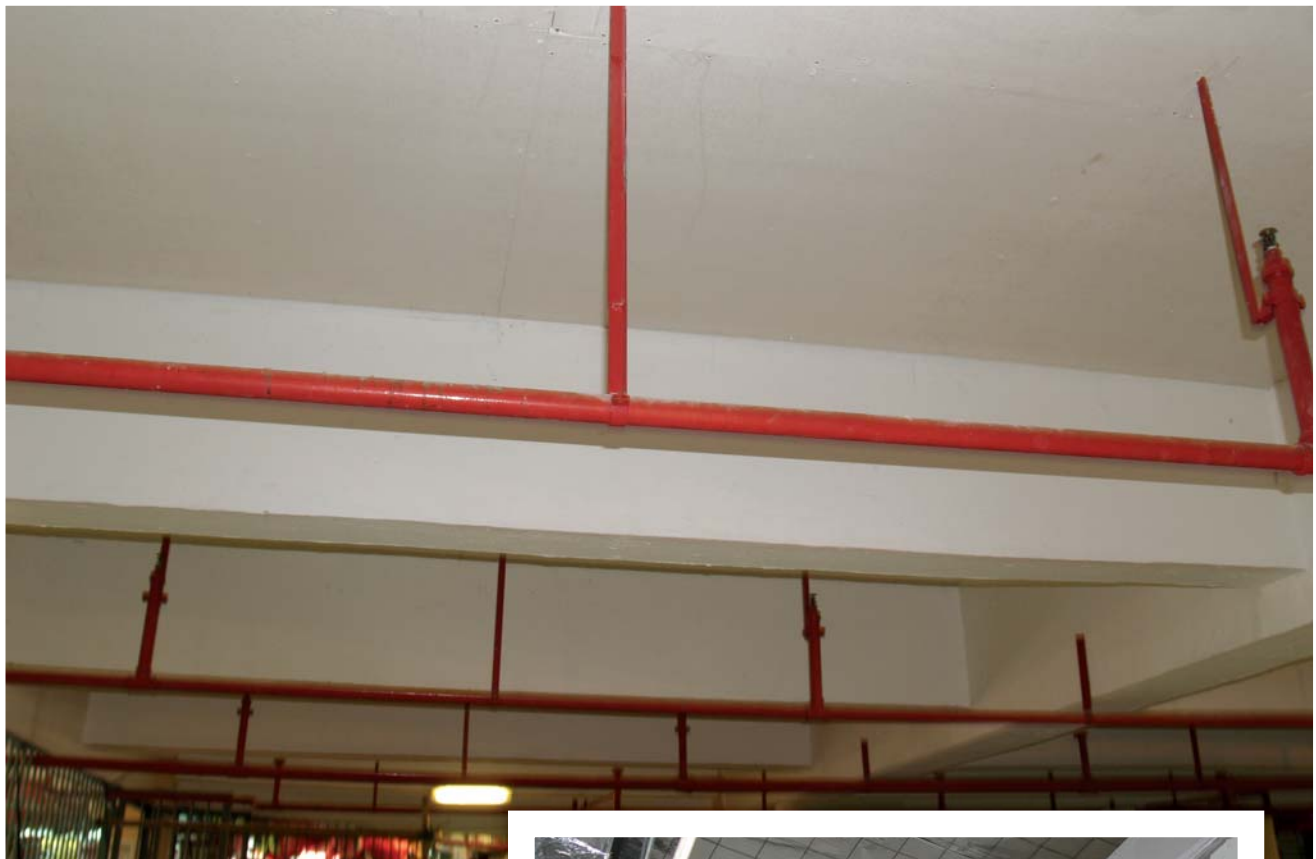
For hollow floors (or beams with filler blocks) the effective thickness 't_e' should be obtained by considering the total solid per unit width, as follows:

$$t_e = h \times \sqrt{S} + t_f$$

Where h = Actual thickness of floor

S = Proportion of solid material per unit width of floor

t_f = Thickness of non combustible finish



All projects using PROMATECT®-H boards for concrete upgrading:

60 to 120 minute fire resistance upgrade of concrete floors for renovation work at the wet market of Kwai Shing West Public Housing Estate in Hong Kong (above).

Up to 60 minute fire resistance upgrade of one sided brick wall at a warehouse in Alexandria, Sydney, Australia.

Overall upgrade to concrete ceiling at a factory in Tai Po Industrial Estate, Hong Kong.

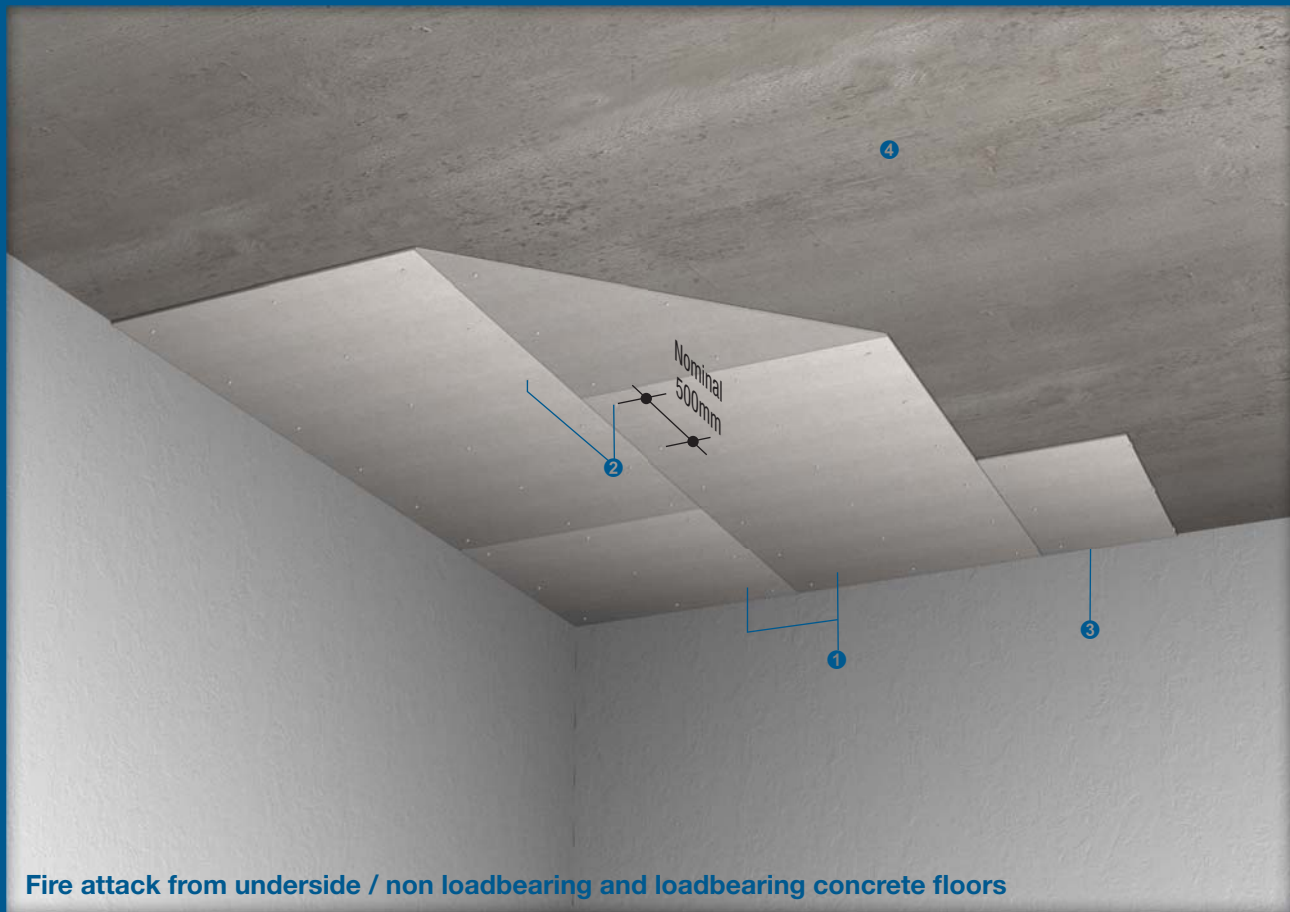




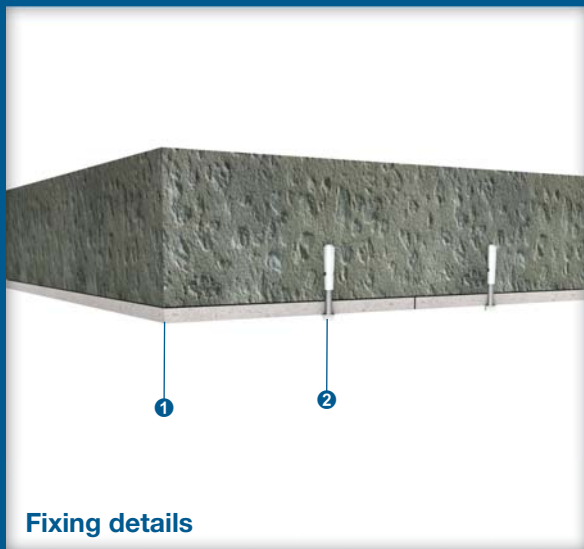
Type	Fire resistance of concrete upgrading	Concrete/brick thickness	Board thickness	Test/Approval no.	Page no.
<p>Upgraded concrete floor (Direct fixing)</p>	From 60 to 120 minutes	100mm thick concrete ⁽²⁾	1 x 9mm (underside)	BRANZ 96/876 Issue 3 and BTL FP 2138 to the requirements of BS 476: Parts 21 and 22: 1987 and/or AS 1530: Part 4: 1990	4
	From 120 to 240 minutes	125mm thick concrete ⁽²⁾	1 x 12mm (underside)		
<p>Upgraded concrete floor (Steel hat fixing)</p>	From 60 to 120 minutes	100mm thick concrete ⁽²⁾	1 x 9mm (underside)	BRANZ 96/876 Issue 3 and BTL FP 2138 to the requirements of BS 476: Parts 21 and 22: 1987 and/or AS 1530: Part 4: 1990	5
<p>Upgraded concrete/brick wall (Two sided direct fixing)</p>	From 90 to 240 minutes	100mm thick concrete ⁽²⁾	1 x 15mm (each side)	BRANZ 96/876 Issue 3, BRANZ 99/1355, BRANZ FAR 2419, BTL FP 2138 and BTL 97/1029 to the requirements of BS 476: Parts 21 and 22: 1987 and/or AS 1530: Part 4: 1990	6
	From 60 to 120 minutes	75mm thick concrete ⁽²⁾	1 x 12mm (each side)		
	From 120 to 240 minutes	100mm thick lightweight concrete ⁽³⁾	1 x 9mm (each side)		
	From 120 to 240 minutes ⁽¹⁾	225mm thick brick or 100mm thick brick with 13mm gypsum plaster	1 x 9mm (each side)		
	From 60 to 240 minutes	100mm thick brick	1 x 20mm (each side)		
	From 120 to 240 minutes	100mm thick brick	1 x 6mm (each side)		
<p>Upgraded concrete/brick wall (One sided direct fixing)</p>	From 90 to 240 minutes	100mm thick concrete ⁽²⁾	1 x 20mm ⁽⁴⁾ or 1 x 15mm ⁽⁵⁾	BRANZ 96/876 Issue 3, BRANZ 99/1355, BRANZ FAR 2419, BRANZ FP 2138 and BTL 97/1029 to the requirements of BS 476: Parts 21 and 22: 1987 and/or AS 1530: Part 4: 1990	6
	From 60 to 120 minutes	75mm thick concrete ⁽²⁾	1 x 15mm ⁽⁴⁾ or 1 x 12mm ⁽⁵⁾		
	From 120 to 240 minutes	100mm thick lightweight concrete ⁽³⁾	1 x 20mm ⁽⁴⁾ or 1 x 15mm ⁽⁵⁾		
	From 120 to 240 minutes ⁽¹⁾	225mm thick brick or 100mm thick brick with 13mm gypsum plaster	1 x 20mm ⁽⁴⁾		
	From 60 to 240 minutes	100mm thick brick	1 x 29mm ⁽⁴⁾ or 1 x 20mm ⁽⁵⁾		
	From 60 to 120 minutes	100mm thick brick	1 x 12mm ⁽⁴⁾		
<p>Upgraded concrete/brick wall (Steel hat fixing)</p>	From 60 to 120 minutes	100mm thick concrete ⁽²⁾	1 x 9mm (each side)	BRANZ 96/876 Issue 3, BRANZ 99/1355 and BTL FP 2138 to the requirements of BS 476: Parts 21 and 22: 1987 and/or AS 1530: Part 4: 1990	7
	From 60 to 120 minutes ⁽¹⁾	225mm thick brick or 75mm thick brick with 13mm gypsum plaster	1 x 9mm (each side)		

NOTE:

- ⁽¹⁾ applicable in Hong Kong only.
- ⁽²⁾ applicable for concrete floors or walls with a nominal density of 2100kg/m³.
- ⁽³⁾ applicable for lightweight concrete walls with a nominal density of 700kg/m³.
- ⁽⁴⁾ applicable for fire risk from either side of the concrete or brick walls.
- ⁽⁵⁾ applicable for fire risk from board side only of the concrete or brick walls.



Fire attack from underside / non loadbearing and loadbearing concrete floors



Fixing details

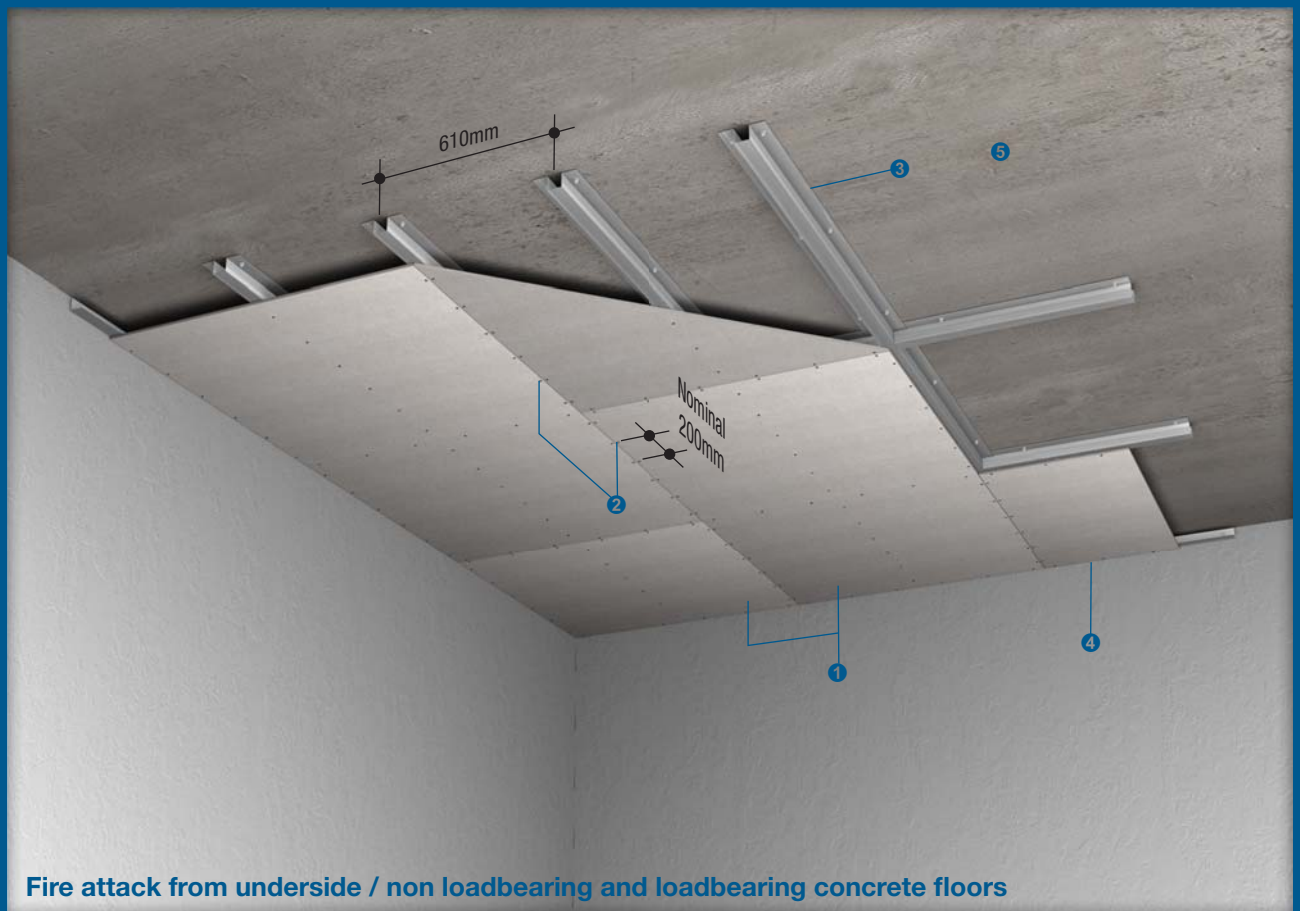
Upgraded to 120 or 240 minute fire resistance in accordance with the requirements of BS 476: Parts 21 and 22: 1987 and/or AS 1530: Part 4: 2005

- ❶ PROMATECT®-H board fixed directly to the underside of concrete floor slab, thickness in accordance with table below

Board thickness	Concrete thickness	Fire resistance of concrete upgrading
9mm	100mm	From 60 to 120 minutes
12mm	125mm	From 120 to 240 minutes

- ❷ M6 masonry anchors with 16mm steel washers, minimum anchor length should allow for 25mm penetration into the concrete, fixed at 500mm centred between 13mm and nominal 15mm from sheet edges
- ❸ Caulk all perimeter gaps with PROMASEAL®-A Acrylic Sealant
- ❹ Concrete floors

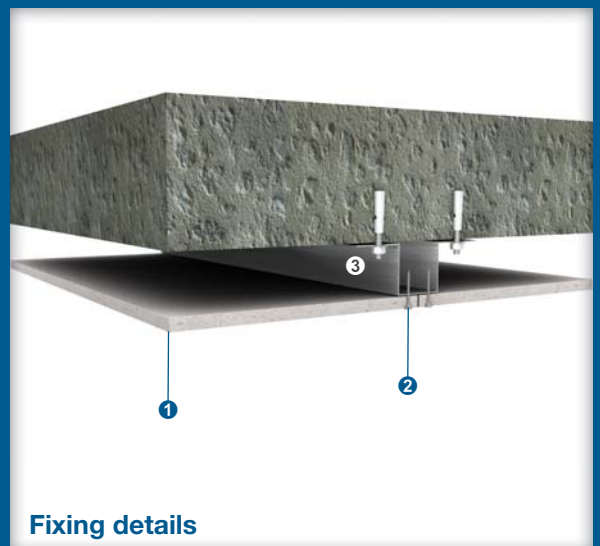
The board thickness of the protection material is relevant to the strength of the concrete and the cover to the reinforcement. In some instances, such as very high strength concrete, a greater thickness of protection material may be required. Please consult Promat for details



Fire attack from underside / non loadbearing and loadbearing concrete floors

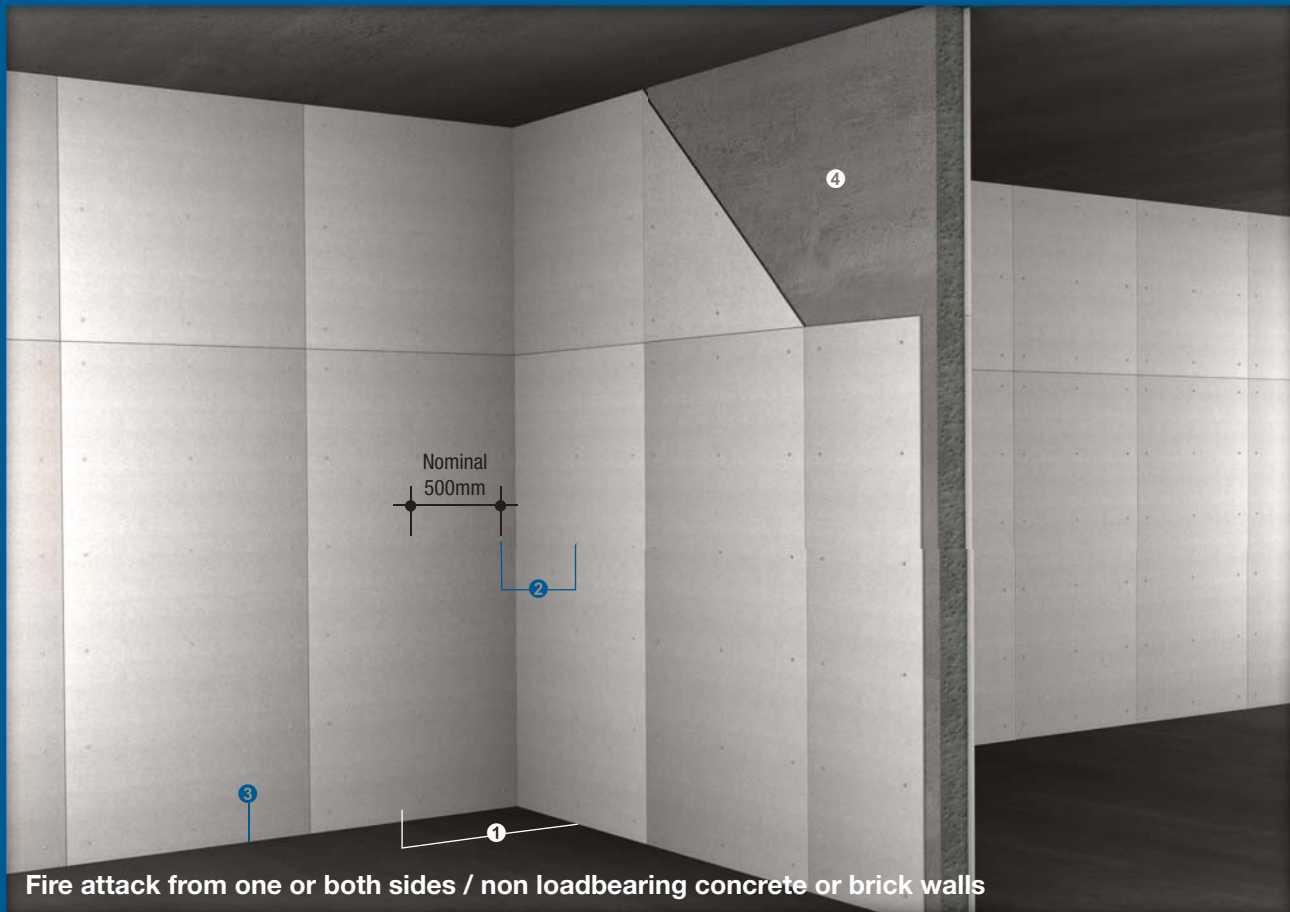
Upgraded from 60 to 120 minute fire resistance in accordance with the requirements of BS 476: Parts 21 and 22: 1987 and/or AS 1530: Part 4: 2005

- ❶ PROMATECT®-H board 9mm thick, fixed with steel hats to the underside of concrete floor
- ❷ No. 8 self-tapping screws 25mm long at nominal 200mm centres
- ❸ Steel top hats 50mm x 50mm x 50mm x 1.2mm thick at 1220mm x 610mm grid spacing, fixed with M6 masonry anchors at nominal 500mm centres with a minimum 25mm penetration into the concrete
- ❹ Caulk all perimeter gaps with PROMASEAL®-A Acrylic Sealant
- ❺ Concrete floors

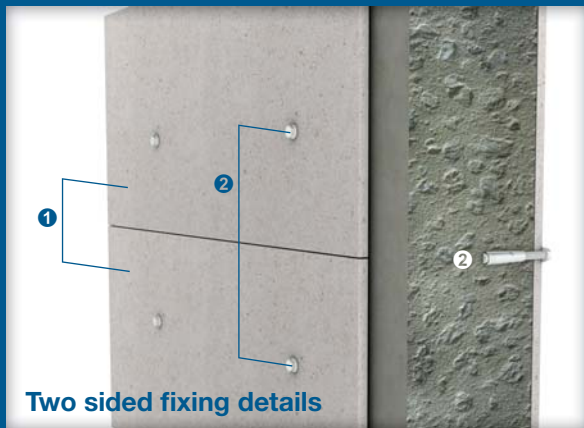


Fixing details

The board thickness of the protection material is relevant to the strength of the concrete and the cover to the reinforcement. In some instances, such as very high strength concrete, a greater thickness of protection material may be required. Please consult Promat for details



Fire attack from one or both sides / non loadbearing concrete or brick walls



Two sided fixing details

Upgraded from 120 to 240 minute fire resistance in accordance with the requirements of BS 476: Parts 21 and 22: 1987 and/or AS 1530: Part 4: 2005

- ① PROMATECT®-H board fixed directly to one or both sides of the concrete/brick walls, requirements in accordance with table on page 3
- ② M6 masonry anchors with 16mm steel washers, minimum anchor length should allow for 25mm penetration into the concrete, fixed at 500mm centres
- ③ Caulk all perimeter gaps with PROMASEAL®-A Acrylic Sealant
- ④ Concrete/brick walls



One sided fixing details

For loadbearing upgrading, the concrete cover to the reinforcing at the non board side must be of minimum 30mm thick and minimum 50mm thick for 120 minute and 240 minute fire resistant wall respectively

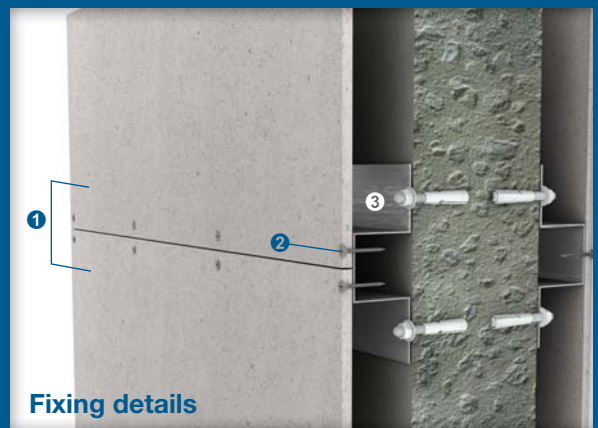
The board thickness of the protection material is relevant to the strength of the concrete and the cover to the reinforcement. In some instances, e.g. for high strength (Grade B70) condition, PROMATECT®-H 50mm thick is required for 120 minute fire resistance performance tested to RWS fire curve. This applies to all exposure curves



Fire attack from both sides / non loadbearing concrete or brick walls

Upgraded from 60 to 120 minute fire resistance in accordance with the requirements of BS 476: Parts 21 and 22: 1987 and/or AS 1530: Part 4: 2005

- ❶ PROMATECT®-H board 9mm thick, fixed with steel hats to both sides of the concrete/brick walls
- ❷ No. 8 self-tapping screws 25mm long at nominal 200mm centres
- ❸ Steel top hats 50mm x 50mm x 50mm x 1.2mm thick at 1220mm x 610mm grid spacing, fixed with M6 masonry anchors at nominal 200mm centres with a minimum 25mm penetration into the concrete
- ❹ Caulk all perimeter gaps with PROMASEAL®-A Acrylic Sealant
- ❺ Concrete/brick walls



Fixing details

For loadbearing upgrading, the concrete cover to the reinforcing at the non board side must be of minimum 30mm thick and minimum 50mm thick for 120 minute and 240 minute fire resistant wall respectively

The board thickness of the protection material is relevant to the strength of the concrete and the cover to the reinforcement. In some instances, e.g. for high strength (Grade B70) condition, PROMATECT®-H 50mm thick is required for 120 minute fire resistance performance tested to RWS fire curve. This applies to all exposure curves

The following is the standard Architectural Specification for concrete/brick floor or wall upgrading using PROMATECT®-H. The designer must determine the suitability of the design for the proposed application and regulatory requirements before undertaking or constructing any works relating to the specifications and where in doubt should obtain the advice of a suitably qualified engineer. All installations must be certified as appropriate.

Fire Attack From Underside / Fire Attack From One Side / Fire Attack From Both Sides / Non Loadbearing / Loadbearing

Integrity and insulation for up to 120 or 240 minutes⁽¹⁾ in accordance with the relevant criteria of BS 476: Parts 21 and 22: 1987 and/or AS 1530: Part 4: 2005⁽²⁾. Applicable for loadbearing and non loadbearing concrete floors, walls and bricks respectively.

Supporting Structure

Care should be taken to ensure that the concrete upgrading system, when applied to any structural element, is adequately supported. Minimum penetration of fixings into substrate is 25mm.

Lining Boards

Single layer each side / one side⁽³⁾ _____mm⁽⁴⁾ PROMATECT®-H matrix engineered mineral boards as manufactured by Promat International (Asia Pacific) Ltd. Standard board dimensions 1220mm x 2440mm x _____mm⁽⁴⁾ to provide _____minutes⁽⁵⁾ of fire resistance level.

Fixing

Options for fixing the PROMATECT®-H concrete upgrading construction:

- 1) Lining fixed directly to concrete floor or wall with M6 anchor bolts at 500mm centres allowing sufficient length to ensure minimum 25mm penetration into concrete.
- 2) Lining fixed to top hat section steel battens with M4 self-tapping screws at nominal 200mm centres. Steel battens fixed to concrete floor or wall with M6 anchor bolts at nominal 500mm centres, allowing a minimum 25mm penetration into the substrate.

Similar details apply for brick wall constructions.

Tests & Standards

The complete system along with all materials and the framing should be tested and assessed in accordance with the criteria of BS 476: Part 21: 1987 and AS 1530: Part 4: 2005 for loadbearing floors and walls, and BS 476: Part 22: 1987 for non loadbearing floors and walls.

Jointing

Plain butt joints between machined edges of boards.⁽⁶⁾

Joints filled in preparation for painting.⁽⁷⁾




Joints filled and taped in preparation for decoration.⁽⁸⁾

Follow-on Trades

Surface of boards to be prepared for painting/plastering/tiling⁽⁷⁾ in accordance with manufacturer's recommendations.

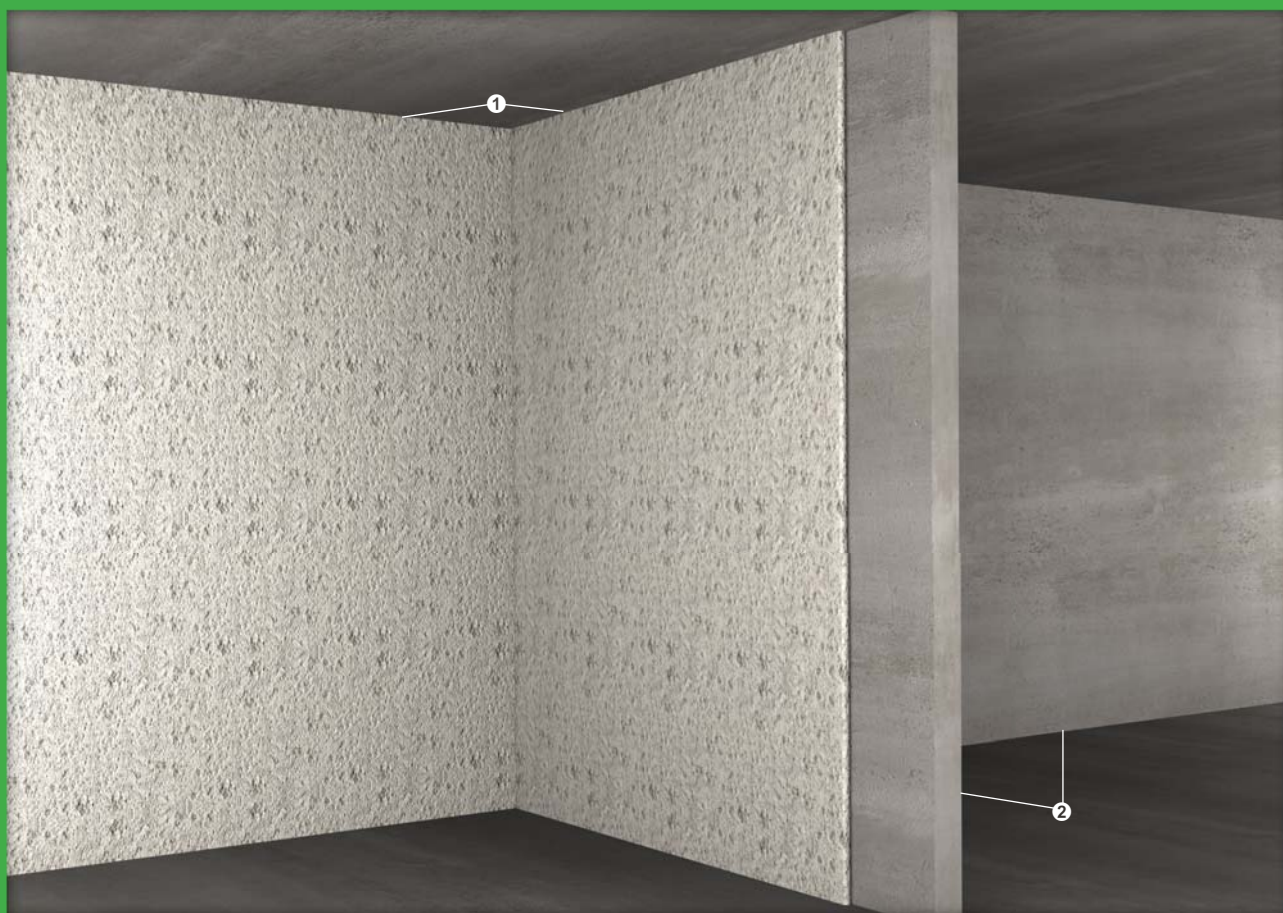
NOTE:

- (1), (2), (3), (6), (7), (8) delete as appropriate.
- (4) refer to [page 2](#) to ascertain the required board thickness.
- (5) insert the required fire resistance level not exceeding 240 minutes.
- Perimeter gaps will be filled with fire resistant PROMASEAL®-A Acrylic Sealant.

Type	Fire resistance of concrete upgrading	Concrete/brick thickness	Test/Approval no.	Page no.
 <p>Caferco FENDOLITE® MII sprayed upgrading of concrete/brick wall</p>	From 240 minutes with 180 minute insulation to 240 minutes with equivalent insulation	150mm thick concrete/brick, including 60mm covering measured from the reinforcement steel bar within	BRANZ FAR 2632 to the requirements of AS 3600: 2001 Section 5.10	10
 <p>Caferco MANDOLITE® CP2 sprayed upgrading of pre-stressed or reinforced concrete floor</p>	From 30-180 minutes with equivalent insulation ⁽¹⁾ to 240 minutes with equivalent insulation ⁽²⁾	75-150mm thick concrete	WFRC CP 92117 and WF 173530A to the requirements of BS 476: Part 21: 1987	11
 <p>Caferco MANDOLITE® CP2 sprayed upgrading of concrete/brick wall</p>	From 30 to 60 minutes ⁽³⁾	Not specified	BRANZ FAR 2160 to the requirements of AS 1530: Part 4: 2005	12
	From 30 to 90 minutes ⁽³⁾			
	From 30 to 120 minutes ⁽³⁾			
	From 60 to 90 minutes ⁽³⁾			
	From 60 to 120 minutes ⁽³⁾			
	From 60 to 180 minutes ⁽³⁾			
	From 120 to 180 minutes ⁽³⁾			

NOTE:

- ⁽¹⁾ Existing fire resistance of concrete floor (30-180 minutes with equivalent insulation) is with reference to BS 8110: Part 2: 1985.
- ⁽²⁾ 240 minute insulation may not be achieved for structural stability of a pre-stressed or reinforced floor that is at risk due to inadequate concrete cover.
- ⁽³⁾ Equivalent insulation applies to all existing and upgraded fire resistance.



Upgraded to 240 minute fire resistance and insulation in accordance with the requirements of AS 3600: 2001 Section 5.10

- ❶ Cafco FENDOLITE® MII vermiculite and Portland cement based wet mix, minimum 15mm thick
- ❷ Concrete/brick walls



Upgraded to 30, 60, 90, 120, 180 or 240 minute fire resistance and insulation in accordance with the requirements of BS 476: Part 21: 1987

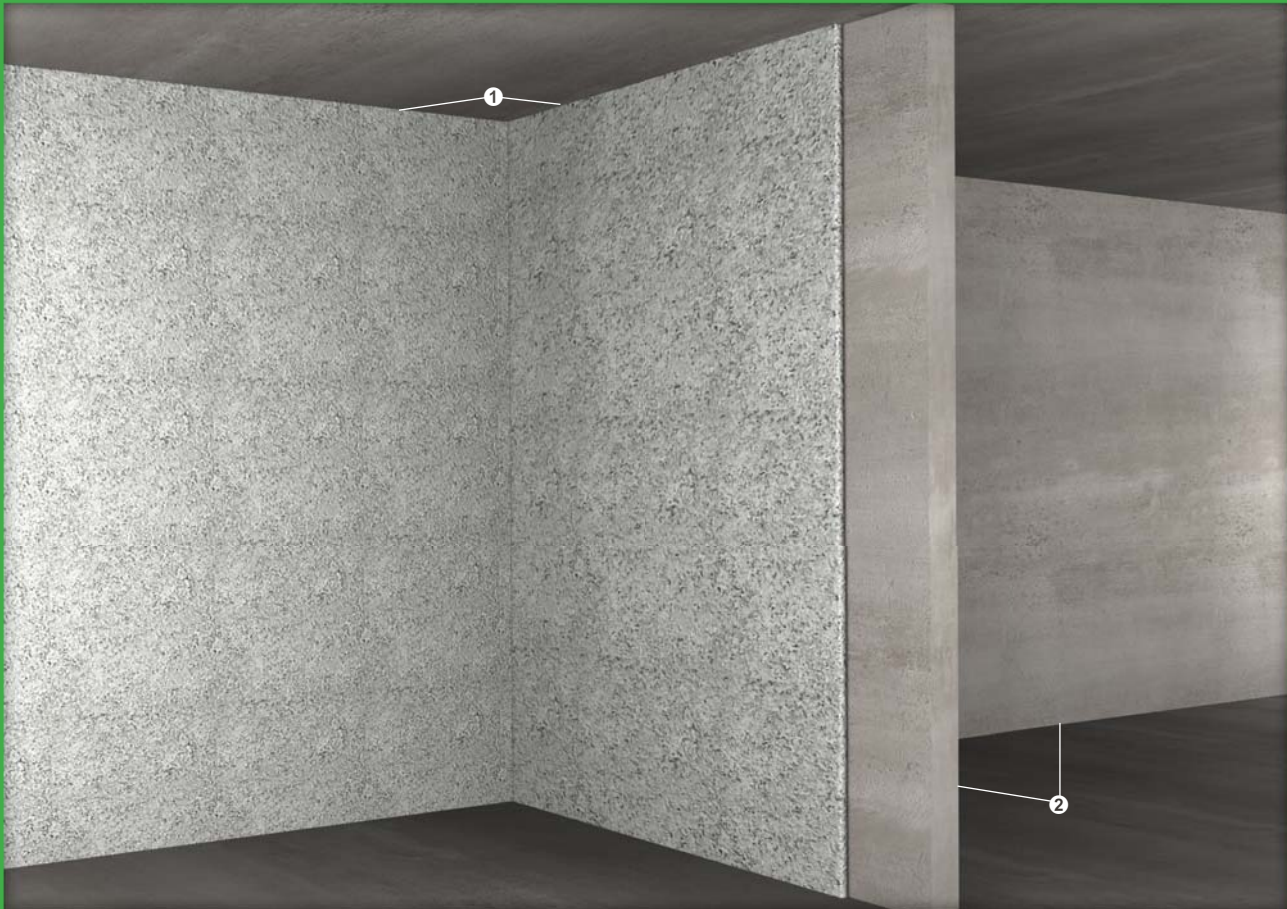
① Cafco MANDOLITE® CP2 vermiculite and Portland cement based wet mix, thickness in accordance with table below

Existing thickness of concrete covering measured from the reinforcement steel bar within	Structural stability performance for required fire resistance of pre-stressed concrete floor at maximum 400°C of critical temperature at steel tendons					
10mm	9.5mm	9.5mm	9.5mm	13mm	18mm	22mm
15mm	–	–	9.5mm	11mm	16mm	20mm
20mm	–	–	–	9.5mm	14mm	18mm
25mm	–	–	–	–	12mm	16mm
30mm	–	–	–	–	10mm	14mm
40mm	–	–	–	–	–	10mm
50mm	–	–	–	–	–	9.5mm
	30 minutes	60 minutes	90 minutes	120 minutes	180 minutes	240 minutes

Existing thickness of concrete covering measured from the reinforcement steel bar within	Structural stability performance for required fire resistance of reinforced concrete floor at maximum 550°C of critical temperature at reinforcement steel bar					
10mm	9.5mm	9.5mm	9.5mm	10mm	14mm	18mm
15mm	–	–	–	9.5mm	12mm	16mm
20mm	–	–	–	9.5mm	10mm	14mm
25mm	–	–	–	–	9.5mm	12mm
30mm	–	–	–	–	9.5mm	10mm
40mm	–	–	–	–	–	9.5mm
50mm	–	–	–	–	–	9.5mm
	30 minutes	60 minutes	90 minutes	120 minutes	180 minutes	240 minutes

Existing thickness of concrete covering measured from the reinforcement steel bar within	Overall insulation performance for required fire resistance of both pre-stressed and reinforced concrete floors					
75mm	–	9.5mm	15mm	20mm	29mm	37mm
80mm	–	–	13mm	18mm	27mm	35mm
90mm	–	–	9.5mm	14mm	23mm	31mm
100mm	–	–	–	10mm	19mm	27mm
110mm	–	–	–	9.5mm	15mm	23mm
120mm	–	–	–	–	11mm	19mm
130mm	–	–	–	–	9.5mm	15mm
140mm	–	–	–	–	–	11mm
150mm	–	–	–	–	–	9.5mm
	30 minutes	60 minutes	90 minutes	120 minutes	180 minutes	240 minutes

② Concrete floors



Upgraded to 60, 90, 120 or 180 minute fire resistance and insulation in accordance with the requirements of AS 1530: Part 4: 2005

❶ Cafco MANDOLITE® CP2 vermiculite and Portland cement based wet mix, thickness in accordance with table below

Sprayed thickness on each side of the concrete	Concrete fire resistance upgrading
25mm	From 30 to 60 minutes
45mm	From 30 to 90 minutes
55mm	From 30 to 120 minutes
25mm	From 60 to 90 minutes
45mm	From 60 to 120 minutes
60mm	From 60 to 180 minutes
45mm	From 120 to 180 minutes

❷ Concrete/brick walls

The following is the standard Architectural Specification for concrete/brick floor or wall upgrading using Cafco FENDOLITE® MII or Cafco MANDOLITE® CP2⁽¹⁾. Please note that Cafco FENDOLITE® MII or Cafco MANDOLITE® CP2⁽¹⁾ should be installed by a trained or approved applicator using appropriate and recommended equipment. The end user must determine the suitability of the design for the proposed application and regulatory requirements before undertaking or constructing any works relating to the specifications and where in doubt should obtain the advice of a suitably qualified engineer. All installations must be certified as appropriate.

Fire Attack From Underside / Fire Attack From Both Sides / Non Loadbearing / Loadbearing

Integrity and insulation for up to 240 minutes in accordance with the relevant criteria of BS 476: Part 21: 1987, AS 1530: Part 4: 2005 and/or AS 3600: 2001 Section 5.10⁽²⁾. Applicable for loadbearing and non loadbearing concrete floors, walls and bricks respectively.

Type of Construction

_____ minute⁽³⁾ fire resistance to Cafco FENDOLITE® MII or Cafco MANDOLITE® CP2⁽¹⁾ floor or wall⁽⁴⁾.

Spray Materials

Cafco FENDOLITE® MII in 20kg bags or Cafco MANDOLITE® CP2 in 12.5kg/15kg bags⁽⁵⁾ as supplied by licensed manufacturers of Promat International (Asia Pacific) Ltd.

Surface Preparation

The substrate to be coated should be clean, dry and free from dust, or any other condition preventing good adhesion.

Method of Application

Pre mix Cafco FENDOLITE® MII or Cafco MANDOLITE® CP2⁽¹⁾ with water in suitable type of mixer and apply to the surface of substrate by direct spraying. Material-water mixing ratio should be applied strictly in accordance with Promat's recommendations by a trained and approved applicator.

The application of Cafco FENDOLITE® MII or Cafco MANDOLITE® CP2⁽¹⁾ is recommended by using a suitable spray head with adequate capacity of air compressor.

Follow-on Trades

Surface of coating materials to be finished off smoothly or with suitable top coat⁽⁶⁾ in accordance with manufacturer's recommendations.

NOTE:

- (1), (2), (4), (5), (6) delete as appropriate.
- (3) insert required fire resistance level (not exceeding 240 minutes).

For latest information of the Promat Asia Pacific organisation, please refer to www.promat-ap.com.

ASIA PACIFIC HEADQUARTERS

Promat International (Asia Pacific) Ltd.

Unit 19-02-01, Level 2 PNB Damansara
No.19 Lorong Dungun, Damansara Heights
50490 Kuala Lumpur
MALAYSIA
Tel: +60 (3) 2095 5111
Fax: +60 (3) 2095 6111
Email: info@promat-ap.com

AUSTRALIA

Promat Australia Pty. Ltd.

1 Scotland Road
Mile End South, SA 5031
Tel: 1800 PROMAT (776 628)
Fax: +61 (8) 8352 1014
Email: mail@promat.com.au

New South Wales Office

Promat Australia Pty. Ltd.

Unit 1, 175 Briens Road
Northmead, NSW 2152
Tel: 1800 PROMAT (776 628)
Fax: +61 (2) 9630 0258
Email: mail@promat.com.au

Victoria Office

Promat Australia Pty. Ltd.

Suite 205, 198 Harbour Esplanade
Docklands, VIC 3008
Tel: 1800 PROMAT (776 628)
Fax: 1800 334 598
Email: mail@promat.com.au

Queensland Office

Promat Australia Pty. Ltd.

1/68 Lisgar Street
Virginia, QLD 4014
Tel: 1800 011 376
Fax: 1800 334 598
Email: mail@promat.com.au

CHINA

Promat China Ltd.

Room 506, Block A, Qi Lin Plaza
13-35 Pan Fu Road
510180 Guangzhou
Tel: +86 (20) 8136 1167
Fax: +86 (20) 8136 1372
Email: info@promat.com.cn

Beijing Office

Promat North China

(Division of Promat China Ltd.)

Room 1507 Building 5, SOHO Xiandaicheng
No.88 Jianguo Road, Chaoyang District
100022 Beijing
Tel: +86 (10) 8589 1254
Fax: +86 (10) 8589 2904
Email: info@promat.com.cn

For Promat International and its worldwide group, see www.promat-international.com.

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HONG KONG

Promat International (Asia Pacific) Ltd.

Room 1010, C.C. Wu Building
302-308 Hennessy Road
Wanchai
Tel: +852 2836 3692
Fax: +852 2834 4313
Email: apromath@promat.com.hk

INDIA

Promat (Malaysia) Sdn. Bhd.

(India Representative Office)

610-611, Ansal Imperial Tower
C-Block, Community Centre
Naraina Vihar, Naraina
New Delhi 110028
Tel: +91 (11) 2577 8413
Fax: +91 (11) 2577 8414
Email: info-india@promat-asia.com

Bangalore Office

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(India Representative Office)

Cabin No. BC-10
Oculus Workspaces, No.66/1, 2nd Floor
Coles Road, Frazer Town
Bangalore 560005
Tel: +91 (80) 4031 4151
Fax: +91 (80) 4125 2135
Email: info-india@promat-asia.com

MALAYSIA

Promat (Malaysia) Sdn. Bhd.

Unit 19-02-01, Level 2 PNB Damansara
No.19 Lorong Dungun, Damansara Heights
50490 Kuala Lumpur
Tel: +60 (3) 2095 8555
Fax: +60 (3) 2095 2111
Email: info@promat.com.my

SINGAPORE

Promat Building System Pte. Ltd.

10 Science Park Road, #03-14 The Alpha
Singapore Science Park II
Singapore 117684
Tel: +65 6776 7635
Fax: +65 6776 7624
Email: info@promat.com.sg

SOUTH KOREA

Promat International (Asia Pacific) Ltd.

(Korea Branch Office)

Room 406, 811-2
Yeoksam-dong Gangnam-gu
Seoul 135080
Tel: +82 (70) 7794 8216
Email: apromath@promat.com.hk

Your local Promat supplier

