Fibre Reinforced Concrete Composite Slabs

Design Guidance for TAB-Deck™ Composite Slabs using SMD metal decking reinforced with ArcelorMittal steel fibres
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Introduction

Steel fibre reinforced concrete is a composite material formed by adding steel fibres into the concrete mix prior to pouring on site. The addition of steel fibres turns the normally brittle concrete into a more ductile material with an enhanced post cracking behaviour.

Use of the TAB-Deck™ system can remove the need for traditional mesh reinforcement with all its associated problems of handling, storage and safety. Composite Metal Deck Slabs can be constructed faster and cheaper using the TAB-Deck™ system.

ArcelorMittal Wire Solutions has been one of the leading developers of steel fibre concrete technology for over 30 years. Steel fibres are already widely used for industrial floors constructed on grade or pile supported. Based on this experience, TAB-Deck™ has been developed by ArcelorMittal Wire Solutions in conjunction with Structural Metal Decks Ltd (SMD) for use with their decking profiles.

TAB-Deck™ performance data has been fully assessed and approved by The Steel Construction Institute referred to as SCI in this document.

The increasing popularity of fibre reinforced concrete as a replacement for traditional mesh reinforcement is a welcome technological development.

The TAB-Deck™ solution reduces site handling, storage and associated safety issues making it a positive choice for many contractors. The pre-reinforced nature of steel fibre reinforced concrete adds to the appeal of this new solution by removing one stage of the installation process and thus reducing the overall time required to construct a composite metal deck slab.
Intermediate Supports in Propped Construction or Special Finishes

In situations with a higher risk of cracking such as over intermediate supports for propped construction or where a special floor finish is to be applied, additional reinforcement greater than 0.1% of the gross cross section area of the concrete support will be required. CIRIA Report No 91 and BS 8110-2 give methods to determine the amount of reinforcement required to control cracking due to moisture or thermal movement. Additional guidance is given in Eurocode 4, which specifies more severe reinforcement requirements. Depending on circumstances this can require reinforcement of up to 0.4% of the gross cross section area of the concrete support. TAB-Deck™ can meet this requirement when used in conjunction with traditional rebar or wire mesh.

Situations when additional reinforcement may be required

TAB-Deck™ can be used to replace the traditional mesh reinforcement used for crack control and fire requirements (refer fire tables in this document). Additional reinforcement may be required in the following situations:

- For continuous slab spans and/or loading conditions, including concentrated loads, which exceed the capacity given by the published fire load / span tables.
- For single span slabs with over 30 minute fire rating, bottom reinforcement bars will normally be required; size and quantity to be determined by the load / span criteria.
- Cantilever slabs should be designed as reinforced concrete with top reinforcement by the structural engineer.
- Trimming reinforcement around square or round holes with an opening greater than 250mm but not exceeding 700mm. Where openings exceed 700mm, additional trimming beams will be required (to be designed and supplied by others).
- For edge composite beams where the distance from the edge of the concrete flange to the nearest row of shear connectors is less than 300mm, transverse U-Bar reinforcement will be required and is to be designed by the structural engineer.
- At Construction / Day Joints within the slab pour adequate continuity reinforcement will be required.

Guidance for Installing Service Holes in the Composite Slab

When it is necessary to form service holes in the composite slab, the following general guidelines should be followed for openings.
at right angles to the deck span.

1. Up to 250mm opening, no special treatment is required. Prior to casting the concrete the opening is boxed out. When the slab has cured the deck is then cut using non-percussive methods.

2. Openings greater than 250mm but less than 700mm. Additional reinforcement is required around the opening. The design should generally be in accordance with BS 8110 or Eurocode 2 when forming the hole as described above. Items 1 and 2 relate to isolated single holes and not to a series of holes transverse to the direction of span, holes in groups should be considered as a single overall opening dimension. In both cases 1 and 2 the metal decking should not be cut until the slab has cured.

3. Greater than 700mm. Structural trimming steelwork is required to be designed by the project engineer and supplied by a steelwork fabricator.

These are guidelines only and the project engineer should check particular requirements. SMD and ArcelorMittal Wire Solutions cannot take design responsibility for any additional framing or slab reinforcement for holes or openings.

**TAB-Deck™ Steel Fibre Reinforced Concrete**

**Concrete Mix**

The specific mix design will always depend on the local materials available but must follow these basic guidelines:

- **Cement** – minimum 350kg/m³ of CEM I or CEM IIIA
- **Aggregates** – maximum 20mm
- **Fines content** – minimum 450kg/m³ of smaller than 200µ including cementitious content
- **Water/Cement ratio ≤ 0.50**
- **Minimum Slump – 70mm** (before the addition of steel fibres and super-plasticizer)

ArcelorMittal Wire Solutions can provide advice on individual mix designs and check their suitability for specific projects.

**Addition of TAB-Deck™ Fibres to the Concrete Mix**

Steel fibres should be added at a rate of 30 kg/m³ into the mixer truck either at the batching plant or on the job site. Some ready-mix suppliers have suitable facilities for loading the fibres into the mixer at the batching plant. Where these do not exist the fibres can be added at the plant or job site using conveyor belts or “blast” machines.

The steel fibres should be added at a rate of 30-40kg per minute. If using a conveyor belt the fibres should be spread on the belt not heaped to avoid clumps of fibres. The maximum drum rotation should be 12-15 revolutions per minute. The truck mixer should be rotated at full speed for 8-12 minutes after adding the fibres.

Adding steel fibres to the concrete mix will typically reduce the slump of the concrete mix by around 35mm. It is recommended therefore that a Super-Plasticiser be added to the concrete before the addition of the fibres to raise the fibre concrete slump to the required level. This is particularly important when the concrete is to be pumped.

Note: When pumping TAB-Deck™ steel fibre reinforced concrete a minimum 125mm diameter hose should be used.

**Installation of TAB-Deck™ Fibre Reinforced Concrete**

TAB-Deck™ fibre reinforced concrete should be installed, cured and finished in exactly the same way as plain concrete.

**Fire Design of TAB-Deck™ Steel Fibre Reinforced Concrete**

The fire resistance of concrete composite slabs reinforced with 30 kg/m³ of HE 1/50 steel fibres has been investigated by SCI. The conclusions drawn with respect to the structural performance of the TR60+, TR80+ and R51 composite deck slabs in fire conditions are based on the results of fire tests carried out by Warringtonfire on behalf of SMD and ArcelorMittal Wire Solutions.

The fire test results have been used to calibrate a structural model developed by SCI. This model was subsequently used to produce fire design tables for composite slabs constructed using SMD TR60+, TR80+ and R51 decking and concrete reinforced with HE 1/50 steel fibres at the same design dosage (30kg/m³) as that used in the test specimens. Pages 8-10 include fire design tables for resistance periods of 60, 90 and 120 minutes for all SMD composite decking profiles.

For designs outside the scope of these tables, refer SMD Deck Design Software or contact ArcelorMittal Wire Solutions or Structural Metal Decks Ltd for further design information.
R51 is manufactured from S350 grade steel. This profile is a traditional re-entrant profile and is commonly used on inner city multi-storey projects where the structural zone and storey height is reduced, due to the relatively thin slab depth required to achieve a typical 1 hour fire rating.

The TR60 profile was SMD’s first trapezoidal profile, added to our product range in 1992. Further research and development in recent years has seen our trapezoidal products evolve into the TR+ range. The TR60+ profile enables un-propped spans in excess of 3.5m and is available in 0.9mm, 1.0mm and 1.2mm gauges in both S350 and S450 grade steel.

Initially added to our product range in 2002, the original TR80 has undergone further research and development, evolving to the now revised profile, renamed TR80+. This 80mm deep trapezoidal profile is available in 0.9mm, 1.0mm and 1.2mm gauges in both S350 and S450 grade steel.
## Technical specification HE 1/50

### Dimensions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wire diameter (d)</td>
<td>1.00 mm (± 0.04 mm)</td>
</tr>
<tr>
<td>Fibre length (L)</td>
<td>50.0 mm (+2/-3 mm)</td>
</tr>
<tr>
<td>Hook length (l and l')</td>
<td>1 – 4</td>
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<tr>
<td>Hook depth (h and h')</td>
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</tr>
<tr>
<td>Bending angle (a and a')</td>
<td>45° (min. 30°)</td>
</tr>
<tr>
<td>Aspect ratio (L/d)</td>
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<tr>
<td>Camber of the fibre</td>
<td>max. 5% of l'</td>
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<tr>
<td>Torsion angle of the fibre</td>
<td>&lt; 30°</td>
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<td>Number of fibres per kg</td>
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<tr>
<td>Total fibre length per 10 kg</td>
<td>1575 m</td>
</tr>
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</table>

### Packaging

- Recyclable cardboard boxes
- Net weight/box: 25 kg
- Boxes/palette: 48
- Weight/palette: 1200 kg
- The fibres are oriented in one direction
- Palettes are wrapped or welded in a plastic folio
- Available also in big bag of 500 kg

### Miscellaneous

- The described fibre is in accordance with the following standards:
  - EN 14889-1 type 1, cold-drawn wire
  - ASTM A820/A820M-04 type I, cold-drawn wire

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**Fire Tables – TAB-Deck™ Fibres**

The tables incorporate the following criteria:
- C25/30 concrete
- Support width of 100mm - Ultimate load factor of 1.0
- (The Ultimate load factor may be reduced in some cases, refer BS 5950 Part 8 Table 2)

The composite slab (not necessarily the metal deck) should be continuous over one or more internal supports. Continuity is taken to include all end bay conditions. The total imposed load should include live load, finishes, ceilings and services (all unfactored), but not the self-weight of the slab. For loads and span conditions beyond the scope of these tables refer to SMD Deck Design Software or contact SMD’s Technical Department.

Spans shown in red indicate where spans are limited by the fire condition, greater spans may be achievable by addition of bottom reinforcement. Spans shown in blue indicate where spans are limited by the composite/normal stage condition, greater spans may be achievable where shear studs are provided, refer SMD Deck Design Software or contact SMD Technical Department.

### Normal Weight Concrete

<table>
<thead>
<tr>
<th>Span Type</th>
<th>Fire Rating (hours)</th>
<th>Slab Depth (mm)</th>
<th>Steel Fibre</th>
<th>Maximum Permissible Span (m)</th>
<th>Total Unfactored Applied Load (kN/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
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<td></td>
<td>0.9mm Gauge</td>
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<tr>
<td>Double</td>
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<td>101 HE 1.0/50</td>
<td>3.32</td>
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<td>3.23</td>
</tr>
<tr>
<td></td>
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<th>Maximum Permissible Span (m)</th>
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<td>0.9mm Gauge</td>
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### Concrete Volume and Weight

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<th>Weight of Concrete (kg/m³)</th>
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Deflection – This table is based on concrete poured to a constant thickness and does not take account for deflection of the decking or supporting beams (as a guide, to account for the deflection of the decking a concrete volume of span/250 should be added to the figures indicated). Concrete Weight – These tables indicate concrete weight only and do not include the weight of decking or reinforcement. Concrete weights are based on the concrete densities specified in BS5950 Part 4 clause 3.3.3 as follows: Normal Weight Concrete – 2400kg/m³ (wet) and 2350 kg/m³ (dry). Lightweight Concrete – 1900kg/m³ (wet) and 1800 kg/m³ (dry).
The tables incorporate the following criteria:

C25/30 concrete
Support width of 100mm - Ultimate load factor of 1.0
(The Ultimate load factor may be reduced in some cases, refer BS 5950 Part 8 Table 2)

The composite slab (not necessarily the metal deck) should be continuous over one or more internal supports. Continuity is taken to include all end bay conditions. The total imposed load should include live load, finishes, ceilings and services (all unfactored), but not the self-weight of the slab. For loads and span conditions beyond the scope of these tables refer to SMD Deck Design Software or contact SMD’s Technical Department.

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### Normal Weight Concrete

<table>
<thead>
<tr>
<th>Span Type</th>
<th>Fire Rating (hours)</th>
<th>Slab Depth (mm)</th>
<th>Steel Fibre</th>
<th>0.9mm Gauge</th>
<th>1.0mm Gauge</th>
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### Lightweight Concrete

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### Concrete Volume and Weight

<table>
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<th>Slab Depth (mm)</th>
<th>Volume of Concrete (m³/m²)</th>
<th>Weight of Concrete (Normal Weight)</th>
<th>Weight of Concrete (Lightweight)</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
<td>Wet (kN/m³)</td>
<td>Dry (kN/m³)</td>
</tr>
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<tr>
<td>250</td>
<td>0.216</td>
<td>5.09</td>
<td>4.98</td>
</tr>
</tbody>
</table>

### Deflection

- This table is based on concrete poured to a constant thickness and does not take account for deflection of the decking or supporting beams (as a guide, to account for the deflection of the decking a concrete volume of span/250 should be added to the figures indicated). Concrete Weight – These tables indicate concrete weight only and do not include the weight of decking or reinforcement.

Concrete weights are based on the concrete densities specified in BS5950 Part 4 clause 3.3.3 as follows: Normal Weight Concrete – 2400kg/m³ (wet) and 2350 kg/m³ (dry). Lightweight Concrete – 1900kg/m³ (wet) and 1800 kg/m³ (dry).
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- Support width of 100mm - Ultimate load factor of 1.0
- (The Ultimate load factor may be reduced in some cases, refer BS 5950 Part 8 Table 2)

The composite slab (not necessarily the metal deck) should be continuous over one or more internal supports. Continuity is taken to include all end bay conditions. The total imposed load should include live load, finishes, ceilings and services (all unfactored), but not the self-weight of the slab. For loads and span conditions beyond the scope of these tables refer to SMD Deck Design Software or contact SMD’s Technical Department.

Spans shown in **red** indicate where spans are limited by the fire condition, greater spans may be achievable by addition of bottom reinforcement. Spans shown in **blue** indicate where spans are limited by the composite/normal stage condition, greater spans may be achievable where shear studs are provided, refer SMD Deck Design Software or contact SMD Technical Department.

### Normal Weight Concrete

<table>
<thead>
<tr>
<th>Span Type</th>
<th>Fire Rating (hours)</th>
<th>Slab Depth (mm)</th>
<th>Steel Fibre</th>
<th>0.9mm Gauge</th>
<th>Maximum Permissible Span (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>3.5</td>
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<tr>
<td>Double Span</td>
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<td>HE 1.0/50</td>
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<td>HE 1.0/50</td>
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### Lightweight Concrete

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<th>Slab Depth (mm)</th>
<th>Steel Fibre</th>
<th>0.9mm Gauge</th>
<th>Maximum Permissible Span (m)</th>
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### Concrete Volume and Weight

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<tr>
<th>Slab Depth</th>
<th>Volume of Concrete</th>
<th>Weight of Concrete (Normal Weight)</th>
<th>Weight of Concrete (Lightweight)</th>
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<td></td>
<td>m³/m²</td>
<td>Wet (kN/m²)</td>
<td>Dry (kN/m²)</td>
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<tr>
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<td>0.096</td>
<td>2.26</td>
<td>2.21</td>
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<td>150</td>
<td>0.106</td>
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<td>0.116</td>
<td>2.73</td>
<td>2.67</td>
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<td>170</td>
<td>0.126</td>
<td>2.97</td>
<td>2.90</td>
</tr>
<tr>
<td>180</td>
<td>0.136</td>
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<td>3.14</td>
</tr>
<tr>
<td>200</td>
<td>0.156</td>
<td>3.67</td>
<td>3.60</td>
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<tr>
<td>225</td>
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<tr>
<td>250</td>
<td>0.206</td>
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<td>4.75</td>
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</table>

Deflection - This table is based on concrete poured to a constant thickness and does not take account for deflection of the decking or supporting beams (as a guide, to account for the deflection of the decking a concrete volume of span/250 should be added to the figures indicated). Concrete Weight – These tables indicate concrete weight only and do not include the weight of decking or reinforcement. Concrete weights are based on the concrete densities specified in BS5950 Part 4 clause 3.3.3 as follows: Normal Weight Concrete – 2400kg/m³ (wet) and 2550 kg/m³ (dry); Lightweight Concrete – 1600kg/m³ (wet) and 1800 kg/m³ (dry).
Shear Stud Connectors

From a number of shear stud push tests it has been demonstrated that the resistance of thru deck welded shear studs was similar in specimens using concrete reinforced with a dosage of 30 kg/m³ of ArcelorMittal Wire Solutions HE 1/50 fibres (TAB-Deck™), when compared to identical specimens using conventional mesh reinforcement. The presence of fibres resulted in a significant enhancement to the ductility, for single and pairs of studs.

Longitudinal Shear

Testing has shown that in composite beam applications, the longitudinal shear resistance of floor slabs reinforced with 30 kg/m³ of HE 1/50 fibres is, in most cases, sufficient so as not to require provision of additional transverse reinforcement. For example, a dosage of 30 kg/m³ of HE 1/50 fibres was sufficient to provide a longitudinal shear resistance equivalent to an A393 mesh in a 150mm solid slab with \( f_{cy} = 30 \text{N/mm}^2 \). When 30 kg/m³ of HE 1/50 fibres are used in combination with conventional reinforcement, it may be possible to gain enhancement compared to cases when bars are embedded within plain concrete.

Design Rules

When profiled steel sheeting is oriented with the ribs parallel to the longitudinal axis of the beam (i.e. at primary beam positions) the longitudinal shear resistance may not be sufficient when the concrete is only reinforced with 30 kg/m³ of steel fibres. In such cases, supplementary transverse reinforcement in the form of conventional bars should be provided. Although the tests undertaken so far indicate that an enhancement of approximately 10% can be achieved when fibres are used in combination with conventional reinforcement bars, there is insufficient data at this time to allow improved design equations to be developed.

As a consequence of this, when supplementary reinforcement bars are provided, the fibres should be ignored and the design carried out according to the requirements given in Eurocode 4, 6.2.4 or Clause 5.6 of BS5950-3: 1990.

Eurocode 4

For design in accordance with Eurocode 4, the following equation should be used when normal weight concrete slab is reinforced with 30 kg/m³ of steel fibres.

\[
F_d = \frac{V f_{cy}}{2} \Delta h_i \frac{1}{Y_m} + \nu_{pcd}
\]

but 20 N/mm² ≤ \( f_{cy} \) ≤ 30 N/mm²

Where \( h_i \) is the effective thickness of the concrete flange, \( \Delta \) is the length under consideration (half the distance between the point of zero moment and maximum moment, i.e. 1/4 span for a simply supported beam with UDL), \( f_{cy} \) is the characteristic compressive cylinder strength of concrete, \( Y_p \) is the partial factor of safety (= 1.5), \( \nu \) is the strength reduction factor for concrete cracked in shear

\[
= 0.38 \left[ 1 - \frac{f_{cy}}{250} \right]
\]

and \( \nu_{pcd} \) is the contribution of the profiled steel sheeting if applicable, calculated according to BS EN 1994-1-1 clause 6.6.6.4.

BS5950-3: 1990

For design in accordance with BS5950-3: 1990, the following equation should be used when a normal weight concrete slab is reinforced with 30 kg/m³ of TAB-Deck™ fibres.

\[
\nu = 2.7 A_{cv} + \nu_p
\]

but 30 N/mm² ≤ \( f_{cy} \) ≤ 45 N/mm²

Where \( A_{cv} \) is the mean cross-sectional area per unit length of the concrete shear surface under consideration and \( \nu_p \) is the contribution of the profiled steel sheeting, if applicable, calculated to Clause 5.6.4 of BS5950-3: 1990.

The design resistance given in this equation is equivalent to that provided by an A393 mesh in a solid slab with \( f_{cy} = 30 \text{N/mm}^2 \). Further comparisons of longitudinal shear resistance for each profile at different slab depths using TAB-Deck™ at a dosage of 30kg/m³ compared to conventional mesh fabric can be found on page 15. These tables are in accordance with the above equation for BS5950-3 1990 based upon 0.9mm gauge S350 grade decking, 500N/mm² grade reinforcement and 30N/mm² Normal Weight Concrete.
## Composite Beam Design with TAB-Deck™ Steel Fibre Reinforced Concrete

### R61

<table>
<thead>
<tr>
<th>Slab Depth (mm)</th>
<th>Concrete Cross Section</th>
<th>A142 (Vr †)</th>
<th>A193 (Vr †)</th>
<th>A252 (Vr †)</th>
<th>A393 (Vr †)</th>
<th>TAB-Deck™ Fibre Concrete (30 kg/m³) (Vr †)</th>
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<tbody>
<tr>
<td>100</td>
<td>91000</td>
<td>432.6</td>
<td>93.8</td>
<td>450.5</td>
<td>111.7</td>
<td>471.1</td>
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### TR60

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<th>A193 (Vr †)</th>
<th>A252 (Vr †)</th>
<th>A393 (Vr †)</th>
<th>TAB-Deck™ Fibre Concrete (30 kg/m³) (Vr †)</th>
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### TR80

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<th>Concrete Cross Section</th>
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<th>A193 (Vr †)</th>
<th>A252 (Vr †)</th>
<th>A393 (Vr †)</th>
<th>TAB-Deck™ Fibre Concrete (30 kg/m³) (Vr †)</th>
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<tbody>
<tr>
<td>130</td>
<td>86000</td>
<td>428.1</td>
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<td>112.6</td>
<td>466.6</td>
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</tr>
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</table>

Notes:
† Secondary beam with continuous decking perpendicular to the longitudinal axis of the beam (with deck contribution vp)
‡ Primary beam with decking parallel to the longitudinal axis of the beam (no deck contribution)