

**TATA STEEL**



**Technical paper**

Diaphragm design for structural roof decks

# Contents

- 2 Introduction
- 3 Principles of diaphragm action
- 4 Types of diaphragm
  - a) Sheeting laid directly on rafters
  - b) Sheeting on purlins
- 5 Roofs of irregular shape
- 5 Openings
- 7 Pitched roof with a ridge
- 7 Diaphragm deflection
- 8 Layout drawings and O&M manuals
- 8 Responsibility
- 9 Diaphragm design requirements
- 9 References
- 10 RoofDek profiles
- 11 Professional design support

# Introduction

**Steel roof decks are specified extensively to support flat roofs in schools, industrial and office buildings. Stressed skin diaphragm design, which enables the roof to be constructed without bracing, has become an accepted practice in the UK.**

**Bracing flat roofs can be undesirable for architectural and economic reasons, and diaphragm design offers an attractive solution to the problem.**

The content in this article has been extracted from various sources listed in the 'References' section, including BS EN 1090-4:2018(i), with a view of assisting Engineers on the diaphragm design utilising structural roof deck. The design checks are carried out in accordance with EN 1993-1-3:2006(ii) for steel profiles, and EN 1999-1-4:2007(iii) for aluminium profiles, both of which refer to 'European recommendations for the application of metal sheeting acting as

a diaphragm' by European Convention for Constructional steelwork (ECCS) No.88 (1995)(iv), and are subject to the limitations and conditions specified therein. The standard procedures for diaphragm design are equally applicable to diaphragms constructed using structural liner trays (Eurocode 3: Part 1.3 (10.3.5))(ii). This technical paper also specifies the parameters required for the roof deck diaphragm design.

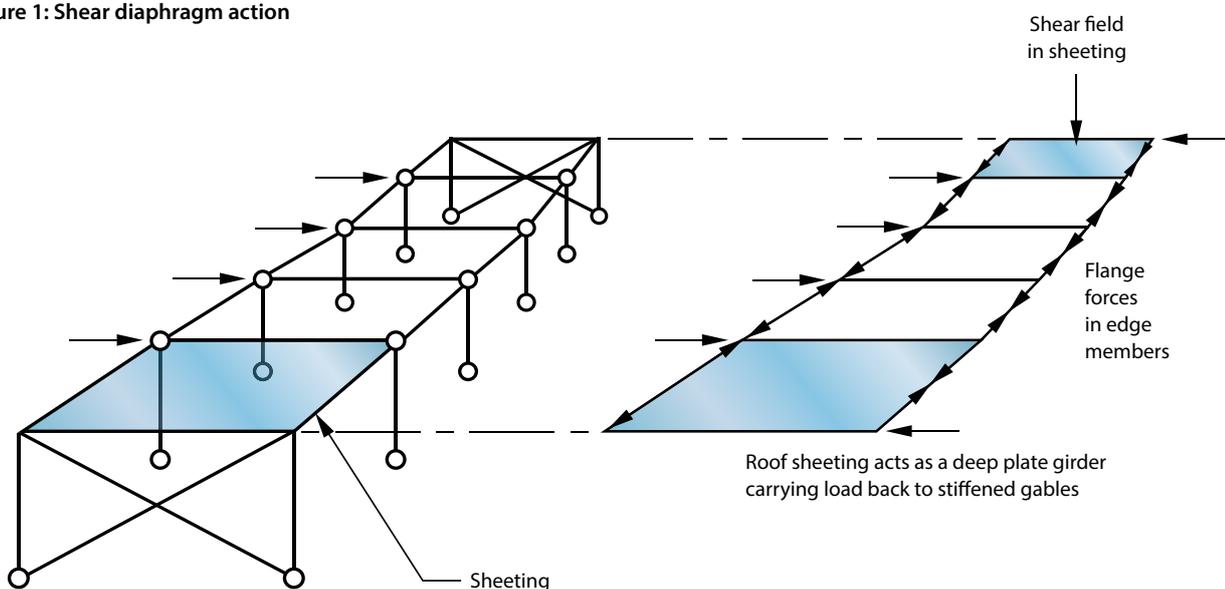


# Principles of diaphragm action

Properly fastened roof decking, together with its supporting members can act as a shear diaphragm to resist in-plane forces and displacements.

The action of the decking needs to behave like the web of a deep plate girder, in which longitudinal edge members act as flanges, carrying axial tension and compression as shown in Figure 1 (below).

Figure 1: Shear diaphragm action



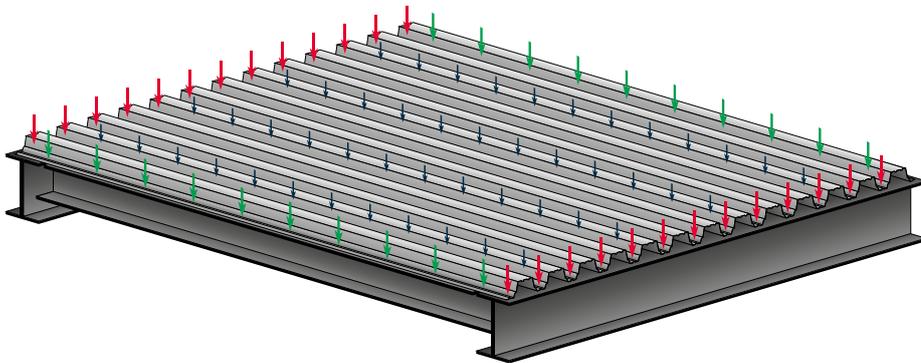
# Types of diaphragm

In roof deck diaphragm design, there are two types of deck supports, mainly rafters and purlins.

## a) Sheeting laid directly on rafters

When fixing to primary steelwork grids, the top flange of members are typically in the same plane, which provides a standard end and parallel fix for the roof deck as shown in Figure 2 (below).

Figure 2: Fixing decks to rafters



### Deck to support fastener positions

(red arrows):

- Each arrow may signify more than one fixing.
- Fastener specification to be determined by fastener manufacturer to suit support structure.
- Shot fired pins determined by manufacturer subject to minimum flange thickness (not suitable for timber supports).

### Deck to parallel beam fastener positions

(green arrows):

- Perimeter screw centres will be determined from diaphragm design calculations.

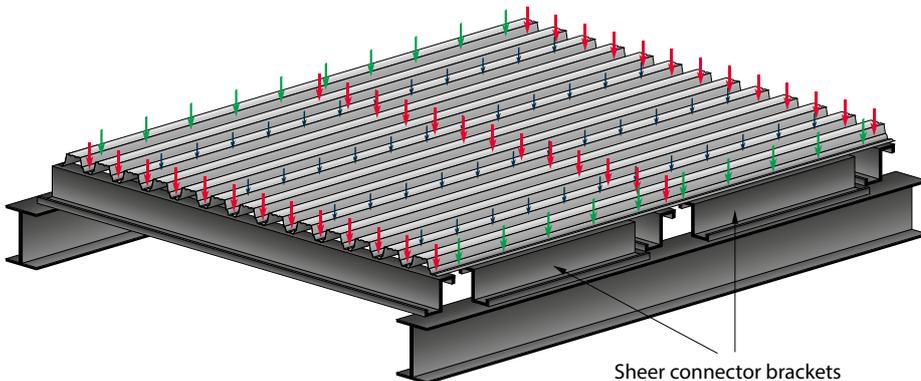
### Side lap fastener (blue arrows):

- Stitching centres will be determined from diaphragm design calculations.
- Stitching fastener specification to be determined by fastener manufacturer.
- Alternative rivet specification to be determined by fastener manufacturer.

## b) Sheeting on purlins

When the deck is laid on purlins, shear connector brackets are needed to enable the connection to the parallel rafters Figure 3 (below).

Figure 3: Fixing decks to purlins



### Deck to support fastener positions

(red arrows):

- Each arrow may signify more than one fixing.
- Fastener specification to be determined by fastener manufacturer to suit support structure.
- Shot fired pins determined by manufacturer subject to minimum flange thickness (not suitable for timber supports).

### Deck to parallel beam fastener positions

(green arrows):

- Perimeter screw centres will be determined from diaphragm design calculations.

### Side lap fasteners (blue arrows):

- Stitching centres will be determined from diaphragm design calculations.
- Stitching fastener specification to be determined by fastener manufacturer.
- Alternative rivet specification to be determined by fastener manufacturer.

# Roofs of irregular shape

## Irregular plan roofs can be zoned and stabilised by a rectangular diaphragm zone to resist forces.

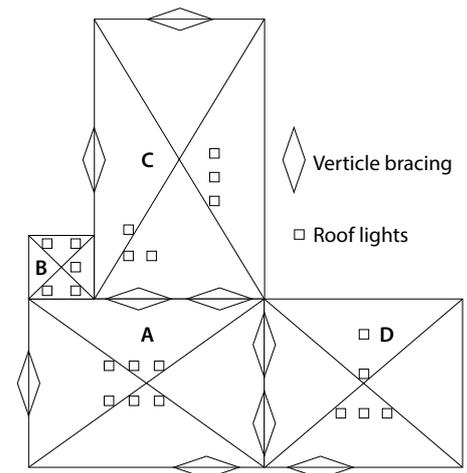
When a roof is required to act as a diaphragm, which has an irregular plan form and/or parts of the roof at different levels, it is necessary to divide the roof into zones so that each part of the building is stabilised by a rectangular diaphragm zone to resist horizontal forces applied in both the longitudinal and transverse directions.

In the design calculations each zone is then treated as a separate diaphragm.

The diagram (Figure 4, right) shows a typical roof plan of such a building in which the roof is divided into Zones A, B, C, D.

Zones A and C act as conventional diaphragms spanning between vertical bracings to resist both North/South and East/West loads. Zone B contains a relatively high proportion of roof lights but is in fact surplus to requirements and need not be designed as a diaphragm. Zone D resists North/ South loads only and acts as a cantilever off Zone A. Zone D resists North/ South loads only and acts as a cantilever off Zone A.

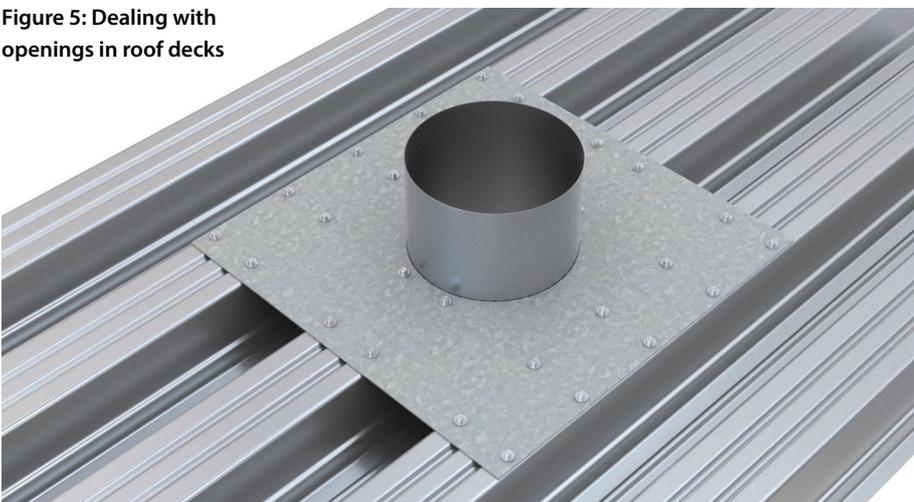
Figure 4: Irregular roof plans and diaphragm zones



# Openings

## Openings in decks must be trimmed or fully supported according to the guidance provided in Tata Steel's RoofDek manual.

Figure 5: Dealing with openings in roof decks



Openings totalling more than 3% of the area in each panel should not be permitted unless they conform to (ECCS) No. 88 clause 8.3.

Openings of less than 3% of the area in each panel may be permitted without special calculation provided the total number of fasteners in each panel is not reduced.

Example of reinforcement around small holes in roof diaphragm is shown (left) in Figure 5.



# Pitched roof with a ridge

**A full structural connection must be made between the deck sheets on each side of a ridge.**

**Figure 6: Fixing roof decks to pitched roofs**



Where the deck runs perpendicular to the ridge, a connection between both slopes is required to complete the structural connection. A 1.6mm galvanised steel flashing connection between the steels positioned to the underside of the deck, as shown opposite, is normally sufficient.

If large loads are experienced further reinforcement can be attained by use of an additional 1.6mm galvanised flashing fixed to the upper crown of the deck

Where the deck runs parallel with the ridge, the load is normally less and 1.2mm galvanised plate and can be used to connect the slopes and supporting steelwork, see Figure 6 (left).

## Diaphragm deflection

An overall deflection is calculated, however no limits within the BS or EN codes are provided. It is up to the building designer to define an acceptable level of deflection of the diaphragm together considering the overall building design requirements. The deflection calculation does not include axial strain in edge members on glulam frames.

# Layout drawings and O&M manuals

Roof areas where diaphragm action is planned are important for the stability of a building.

Figure 7: Diaphragm warning signs on drawings



Roofs fully braced or partially braced by roof deck, that are intended to act as a diaphragm for the stabilisation of a whole building, should be specially marked in the layout drawings as “diaphragm”. There should be clearly visible permanent warning signs on the finished construction as shown (left) in Figure 7.

The information in the operations and maintenance manual shall indicate that the stability of the whole building will be at risk if alterations are subsequently undertaken to the diaphragms without a suitable analysis.

The owner of the building shall be informed about size, position and significance of the diaphragm.

## Responsibility

The designer responsible for the overall stability of the structure should ensure the compatibility of the design and details of all parts and components, including stressed skin shear diaphragms.



As the provider of diaphragm calculations, Tata Steel is not responsible for the overall stability of the structure. The responsibility for this stability lies with the Structural Engineer responsible for the project.

It is essential that the principle designer considers adequate wall bracing and foundation design to restrain diaphragm forces.

# Diaphragm design requirements

Tata Steel provides diaphragm design for our roof decks. In order to carry out the diaphragm design, we would require:

## Profile details

- Profile name.
- Gauge of profile.
- Plain/perforated.
- Steel /aluminium.

## Other details

- A dimensioned plan drawing showing position of main steelwork/purlins/ timber rafter.
- Position of vertical braced frames or other forms of sway resistance.
- The roof is divided into rectangular diaphragms, and each area must be surrounded by at least three braced walls (please see section 'Roofs of irregular shape').
- The drawing must show the wind load from the walls expressed as a line load (kN/m) at the eaves.
- The normal loads are required as the primary purpose of the roof deck is for carrying UDL loads, ie, dead, imposed, snow, snow drift, wind pressure, point and line loads. Wind suction load is required for calculating fixing's residual shear capacity.

## References



- i) BS EN 1090-4:2018: Execution of steel structures and aluminium structures.
- ii) BS EN 1993-1-3:2006: Eurocode 3: Design of Steel Structures.
- iii) BS EN 1999-1-4:2007: Eurocode 9: Design of Aluminium Structures.
- iv) ECCS No 88 (1995): European recommendations for the application of metal sheeting acting as a diaphragm.
- v) E.R. Bryan and J.M.Davies: Steel Diaphragm Roof Decks ,Granada 1981.
- vi) Torsten Høglund: Stabilisation by stressed skin diaphragm action, Swedish Institute of Steel construction.
- vii) Tata Steel's RoofDek manual: Structural roof decking and trays, 2018.

For further information please do not hesitate to get in touch with our Technical Department:

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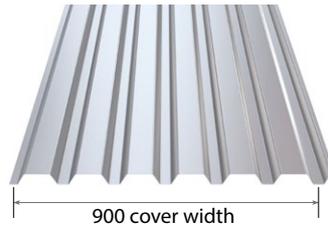
# RoofDek profiles

## Trapezoidal profiles 32mm to 60mm deep

RoofDek D325



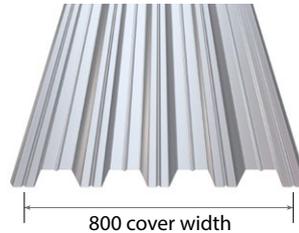
RoofDek D35



RoofDek D46

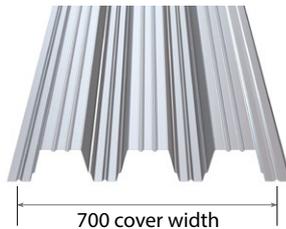


RoofDek D60

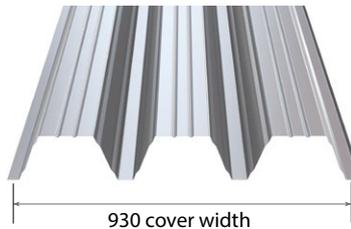


## Decks to span between main frames

RoofDek D100



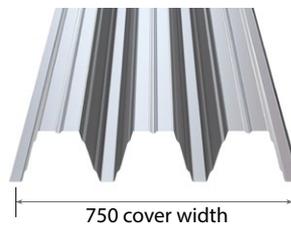
RoofDek D137



RoofDek D153



RoofDek D159



RoofDek D200



RoofDek D210



### The RoofDek range

Tata Steel offers the most comprehensive range of structural roof decking on the market. Manufactured in the UK at our Shotton site in North Wales, our steel and aluminium RoofDek profiles support all types of insulated roof systems including single ply membrane, standing seam, green and brown roofs, built-up cladding, slates and tiles, three-ply felt and asphalt roofing applications.

Our RoofDek range consists of ten unique trapezoidal deck profiles and three structural liner tray profiles in three steel and two aluminium gauges to enable effective and efficient design. A range of steel RoofDek profiles have been FM approved in particular gauges and finishes.

Shallow RoofDek profiles range from 32mm to 60mm deep and have been developed to optimise the designer's needs for efficiency, aesthetics and structural performance. Our deep RoofDek profiles range from 100mm to 210mm deep and are designed for exceptional strength and span capability for all roofing types. We also provide a range of structural liner trays.

For more information on our RoofDek range of profiles and their applications please contact a member of our technical team:

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# Professional design support

**Tata Steel maintains a friendly technical help desk which is freely available to all architects, engineers and contractors to assist with all aspects of RoofDek trapezoidal deck and liner tray design.**

Our team of engineers have many years' experience within the construction industry and a great understanding of our RoofDek range of products – the benefits they provide and how they perform. They are on-hand to provide help and support on any technical issues when designing with our RoofDek, such as design calculations or diaphragm design calculations.

Tata Steel has also developed software packages that have been designed to assist and help with the analysis of your roof deck design and with the selection of the right profile to support your structure.

## Design calculations and diaphragm design

Our technical team are able to provide design calculations for live, dead, wind and snow drift loads and where required, diaphragm design calculations.

The diaphragm design service we offer is free when using our RoofDek range of profiles.

## Specification service

Tata Steel's RoofDek team provide a comprehensive specification service. Assistance in creating specifications for RoofDek and liner trays can be provided to ensure the correct deck or liner tray is specified for the right application.

## Product data at your fingertips

Tata Steel's DNA profiler is the first product data tool of its kind that will allow you to access Tata Steel's product data using a large range of BIM software formats. You can now search for any of our construction products.

Data-rich BIM objects including contact details, mechanical properties, and performance characteristics are available via our DNA profiler. This powerful resource is free to use and can be found at [www.tatasteelDNAprofiler.com](http://www.tatasteelDNAprofiler.com)

## RoofDek analysis software

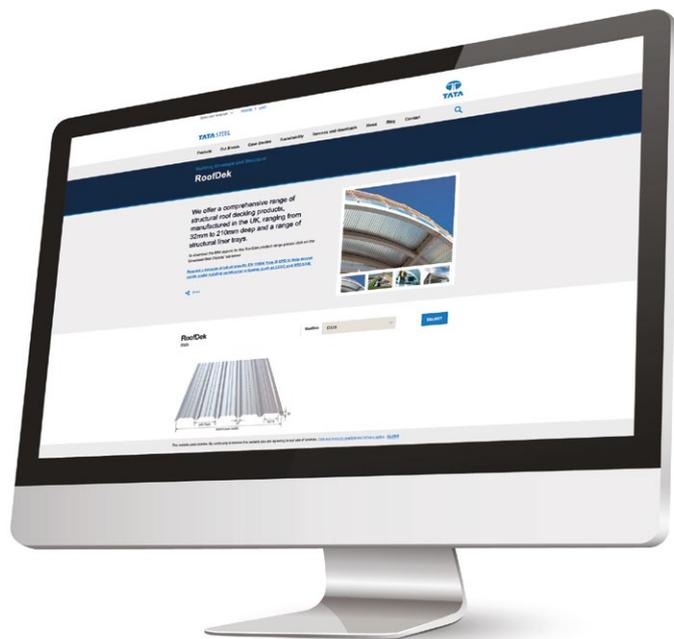
Analysis Software has been created in partnership with leading international developer Trimble, best known for the very widely adopted Tekla Tedds structural design software. With all calculations compliant with Eurocodes, the package enables structural

engineers and designers to carry out full deck analysis to achieve optimum design and cost efficiencies.

## On-line RoofDek selector

RoofDek on-line selector provides a quick and easy method to find the right RoofDek profile for any application, with a calculation summary available for any particular selection made.

To download any of our software or find out more about our RoofDek range, please visit [www.tatasteelconstruction.com/roofdek](http://www.tatasteelconstruction.com/roofdek)



[www.tatasteelconstruction.com](http://www.tatasteelconstruction.com)

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