

# Bending Stiffeners

Engineered Systems



**Trelleborg Offshore**

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# Introduction

Trelleborg CRP bending stiffeners have been in service for over 15 years protecting and supporting all types of dynamic risers (flexible risers, umbilicals, mooring lines and cables), adding local stiffness to the riser adjacent to a rigid connection to limit bending stresses and curvature to acceptable levels.

Each bending stiffener manufactured by Trelleborg CRP is individually designed

to meet the load cases of each individual application. Over the last 15 years Trelleborg CRP have built up a track record in service and in dynamic testing which is unrivalled for the production of bending stiffeners.

Trelleborg CRP are **Proven to Perform.**



## Company Profile

In January 2006, all CRP group companies were acquired by Trelleborg AB, a company with over 23,000 employees operating in more than 45 countries. Trelleborg's market leading positions are based on advanced polymer technologies and in depth applications know how.

Trelleborg CRP is a member of the Trelleborg Offshore group of companies,

all with a shared interest in the provision of solutions for the offshore industry.

As part of Trelleborg Offshore, Trelleborg CRP benefits from a number of synergies with other group companies including combined research and development programmes, materials technology, cost efficiency initiatives, production and logistical flexibility and a sound financial platform.

Despite being part of a large global network of companies, Trelleborg CRP has remained true to the principles of customer service and product innovation that launched the company over 30 years ago, continuing to offer engineered solutions that assist its clients to increase the efficiency, cost effectiveness and onsite safety of all their projects, no matter where in the world.

### Customer Service

All Trelleborg Offshore companies pride themselves on customer focus and Trelleborg CRP's global team of dedicated professionals are committed to helping ensure that all clients' projects are completed on time and within budget.

As a result, Trelleborg CRP provides a comprehensive range of premium services and support.

### Trelleborg Offshore Global Network and Markets

Trelleborg Offshore group companies employ more than 1250 highly trained staff in strategically located manufacturing and office facilities across the globe. These facilities are complemented by a number of polyurethane processing and dispensing plants servicing global subsea requirements.

#### Companies currently within Trelleborg Offshore are:

- Trelleborg CRP Ltd., Skelmersdale, UK (two facilities).
- Trelleborg Offshore, France.
- Trelleborg Offshore, Norway.
- Trelleborg CRP Inc., Houston, USA (two facilities).

- Trelleborg Emerson & Cuming, Inc., Boston (two facilities).
- Trelleborg OCP Ltd., Barrow-in-Furness, UK.
- Trelleborg Viking AS, Mjøndalen, Norway.
- Trelleborg Fillite, UK & USA.

#### The companies service the following core sectors:

- Cable & Flowline Protection.
- Engineered Products.
- Drilling.
- Thermal Insulation.
- Subsea.
- Marine.
- Glass Microspheres.
- Seismic.
- Defence.
- Industrial.
- Fire Protection.
- Downhole Products.

# Bending Stiffeners

Dynamic flexible risers, power cables and umbilicals may be connected to a rigid structure such as a subsea riser base or the turret exit of a floating production vessel. The presence of environmental loads subsequently causes the riser to flex about this fixed location. This movement, in combination with large axial loads may cause damage to the riser structure due to overbending and fatigue.

Trelleborg CRP produce individually designed integral bending stiffeners for rigid riser end fittings. These conically shaped polyurethane mouldings add local stiffness to a riser, flowline, cable or umbilical to limit bending stresses and curvature to acceptable levels.

The bending stiffener has a conical external profile and a central hollow cylindrical section allowing it to slide over the end of the riser.

Each bending stiffener is designed individually to protect the riser minimum bend radius (MBR) under the defined tension and angle combinations, meeting the loadcases (tension vs angle) of each application, and are specified as either dynamic or static depending on their intended use.

## Dynamic Bending Stiffeners

Dynamic Bending Stiffeners are a fully engineered solution to protect flexible risers or umbilicals in demanding applications where a long service life is required. The bending stiffener is manufactured from moulded polyurethane elastomers specifically developed, qualified and tested over many years.

The dynamic bending stiffener protects the riser/umbilical MBR under defined tension/angle combinations. The local stiffness added to the riser/umbilical limits bending stresses and curvature to acceptable levels. Each dynamic bending stiffener is specifically tailored to individual requirements using specifically written design software and manufactured incorporating integral steelwork designed to interface with the client's connecting structure.

## Static Bending Stiffeners

Static Bending Stiffeners are used primarily for overbend protection during installation and overboarding.

Static bending stiffeners are manufactured from moulded polyurethane elastomers and have been specifically developed, qualified and tested over many years. Protecting the power cable/mooring line, static bending stiffeners are typically 1-2m long with various interfaces available to suit specific requirements such as at subsea terminations, by adding local stiffness to the power cable/umbilical adjacent to the rigid connection, limiting bending stresses and curvature to acceptable levels.

## Interface Structure

In order to transfer loads out of the polyurethane section of the bending stiffener a steel interface structure is moulded into the base of conical section. Trelleborg CRP have the in-house capability to design and manufacture a wide range of steel interface structures to enable the bending stiffener to be connected to the adjacent rigid connection. Often requiring complex interface engineering Trelleborg CRP work closely with clients to ensure ease of construction, installation and integrity in service are considered during the design.

Trelleborg CRP have extensive experience of designing and building such structures from simple adaptor plates to highly engineered diverless connectors, generating detailed structural design and fatigue analyses of the complete bending stiffener system.

## Diverless Bending Stiffener Connector

For applications where the bending stiffener is prefitted to the riser prior to deployment and reeled off the laybarge before being pulled into the I Tube, Trelleborg CRP developed the Diverless Bending Stiffener Connector System (DBSC).

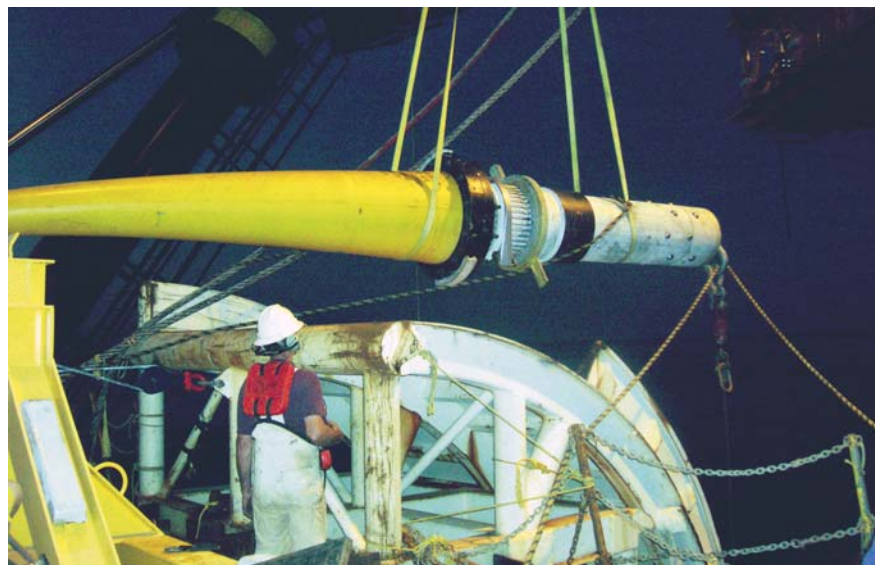
The DBSC assembly normally consists of the following components:

- **Female Interface** – the main interface for the connection of the bending stiffener connecto.
- **Diverless Bending Stiffener Connector** – self activating and diverless.
- **Bending Stiffener**
- **ROV Removable Clamp** – required during installation of the DBSC then removed.
- **Fixed Clamp/Back-up Clamp** – required during installation of the DBSC, remaining in place during normal service life then used to facilitate the removal of the DBSC should it be required.

The Trelleborg CRP DBSC is secured within the bore of the female interface.

via a fatigue resistant locking arrangement.

The process is quick and reliable with minimal ROV assistance required during installation.



Diverless Bending Stiffener Connector System

# Specification & Analysis

The crucial pieces of information required for the design of a bending stiffener include the following:

- Umbilical/flowline/cable/riser diameter, MBR and stiffness.
- Loadcases (tensions vs angle) – a complex process requiring careful liaison with both pipe supplier and system designer to ensure that the true worst case conditions are used in the design.
- Operating temperature of both pipe contents and ambient environment.
- Operational environment – water or air.
- Interface requirements with load bearing steelwork/end termination.
- Fatigue loads and cycles. (for dynamic bend stiffener design)
- Tension and angle combination. (for dynamic bend stiffener design)

Once this information has been obtained, the preliminary and detailed design of the bending stiffener is assisted by Trelleborg CRP's proprietary finite element software packages – **Stiffener** and **Orcabend**.

These programs were developed and customised by MCS and Orcina specifically for Trelleborg CRP, based on their Flexcom 3-D and Orcaflex software packages, which are recognised as market leading dynamic analysis software packages throughout the offshore industry.

The software packages generate a 2-D Finite Element Model of a bending stiffener to suit a given set of design conditions using a specified set of properties for the stiffener body material. The software predicts the performance of the bending stiffener when subjected to a range of loadcases, temperatures and also the stress and strain being exerted within the stiffener.

Another important output produced by the program is the bending moments and shear loads generated within the stiffener which need to be transferred into the rigid interfacing structure.

A further software package known as SPOST.R is used to address the design of the metallic load transfer structure and any other interface structure required to connect the stiffener.

The satisfactory performance of all the computer software packages used by Trelleborg CRP has been extensively verified by the use of the following:

- 3-D Finite element analysis.
- Static bend tests.
- Dynamic bending testing installation.

# Design & Engineering

Trelleborg CRP have assembled a design and engineering team with significant technical knowledge and experience gained over many years in the offshore and oceanographic industries designing and installing flexible pipes, cables and umbilicals.

This experience is important when working in close cooperation with clients to understand in detail the functional requirements such as:

- Operating conditions.
- Installation constraints.
- Interface requirements.

In particular, the accurate definition of the operating conditions is necessary prior to the commencement of detailed engineering.

Having captured all the required design information it is then necessary to analyse the data, interpret the results and consider

any particular mechanical interfacing requirements in order to produce a bending stiffener design to suit the clients specification and installation requirements in the most cost effective way.



# Materials & Manufacture



## Materials

The bending stiffener body is manufactured from moulded polyurethane elastomers specifically developed, qualified and tested over many years.

Trelleborg CRP has a range of materials to suit different applications, all of which are extremely tough, durable and suitable for extended service in arduous subsea and topside applications.

The choice of polyurethane elastomer is based upon its low modulus and high elongation at break. A comparison between the stress vs strain properties of steel and a typical polyurethane elastomer is illustrated in the graph below.

Trelleborg CRP has invested significantly in the development of new materials and the conduct of qualification programmes to demonstrate their suitability for use in such an application. Typical test requirements

are listed below:

- Fatigue resistance.
- Creep resistance.
- Tensile strength.
- Tear resistance.
- Temperature dependency.
- Ageing in air and seawater.
- UV resistance.

If an adjacent cathodic protection system is present, the steel interface component of a bending stiffener is usually fabricated from high strength structural grade carbon steel. Alternatively it can be produced using more exotic corrosion resistant materials.

## Manufacture

Trelleborg CRP has built up over 20 years of experience in the manufacture of polyurethane products for the oil, gas and marine markets, and has harnessed this wealth of knowledge to ensure its place at the forefront of bending stiffener manufacture.

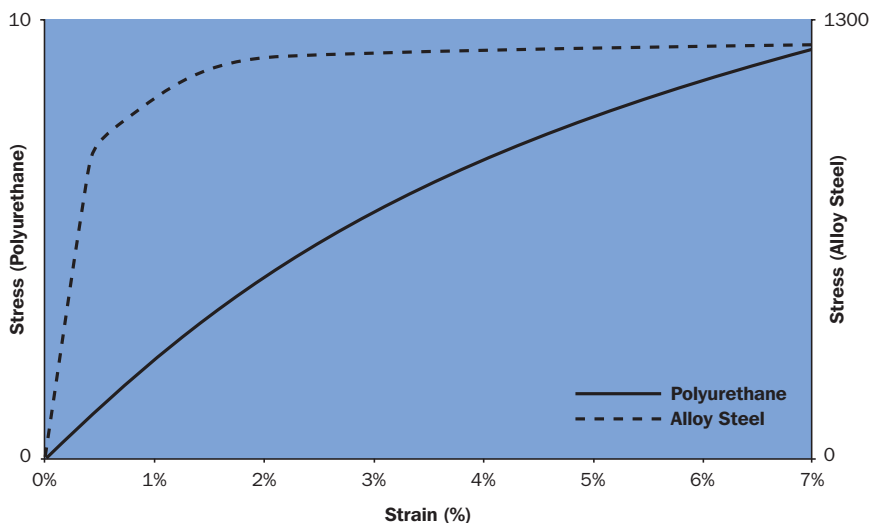
The manufacturing process for bending stiffeners can be broken down into a number of key stages:

- Mould tool production.
- Steel insert component production.
- Assembly of mould tool and steel insert.
- Pre-heat tooling.
- Inject polyurethane into mould.
- Cure cycle.
- Demould and finish.

This apparently simple process includes a number of complex and demanding requirements, for example, the world's largest bending stiffener, produced by Trelleborg CRP for the Banff Field required an oven 12m long to house the assembled mould tool for the pre-heating process.

From the final design, the production of the stiffener takes place in Trelleborg CRP's modern moulding facility, utilising state of the art polyurethane processing equipment, giant ovens and a tightly controlled factory environment. Trelleborg CRP has without doubt the world's largest and most technically sophisticated production equipment anywhere in the world, enabling Trelleborg CRP to meet the ever increasing demands of the oil and gas industry.

Polyurethane Properties – Stress Strain Curve



# Quality & Testing

Over the last 15 years Trelleborg CRP has built up a track record in service and in dynamic testing which is unrivalled for the production of bending stiffeners and the group has produced thousands of units.

The testing of bending stiffeners can be divided into three main categories:

- **Material testing** – to verify that the polyurethane materials used in manufacture have properties that match those used to model the bending stiffeners in the design software.
- **Static bend testing** – to verify that the actual bending stiffener deflects to the same shape predicted by the design software, under a given tension/angle loadcase.
- **Dynamic testing** – to verify the performance of the bending stiffener in simulated in-service conditions, and demonstrate fatigue life, etc.

Trelleborg CRP has an extensive track record for supplying large dynamic bending stiffeners and conducting full-scale dynamic test programmes to demonstrate their fatigue performance.



Trelleborg CRP Bending Stiffeners undergoing dynamic testing

## Test programs undertaken using Trelleborg CRP Bending Stiffeners

Client	Project	End User
Dunlop Armaline	Emerald	Sovereign Oil & Gas
Wellstream	Blenheim	Arco-British
Alcatel	Mars	Shell Offshore
Wellstream	JIP	Joint Industry Project
Alcatel	Norn	Statoil
Alcatel	Deepstar	Texaco-Deepwater Research Programme
Kvaerner	Asgard A	Statoil
Alcatel	Macaroni	Shell Offshore
Wellstream	Asgard B	Statoil
Wellstream	Roncador	Petrobras
Alcatel	Fram	Norsk Hydro
Alcatel	Roncador	Petrobras
Pirelli	Roncador	Petrobras
Alcatel	Europa	Shell Offshore
NKT	Deepwater JIP	Joint Industry Project
Coflexip Stena Offshore	Qualification	Coflexip Stena Offshore
Duco Inc	Typhoon	Chevron
Duco Inc	Serrano	Shell US
Duco Inc	Nile	BP Amoco
Wellstream Inc	Barracuda/Caratinga	Petrobras
Wellstream Inc	Barracuda/Caratinga	Petrobras
Wellstream Inc	Barracuda/Caratinga	Petrobras
Nexans	Nakika	Shell
Wellstream	Albacora	Lest
Wellstream	ASAP	
Nexans	Thunder Horse TH-EOH2	Shell
Nexans	Thunder Horse TH-ST1	Shell
Nexans	Atlantic AT-ST2	Shell
Nexans	Atlantic AT-E01	Shell
Wellstream	R033	
Nexans	King	BP

## EUROPE

### Trelleborg Offshore

Stanley Way, Skelmersdale  
Lancashire WN8 8EA, UK  
Tel: +44 (0)1695 712000  
Fax: +44 (0)1695 712111

114 rue Saint Lazare - BP20609  
60476 - Compiègne cedex 2, France  
Tel: +33 (0)3 44 23 03 50  
Fax: +33 (0)3 44 23 03 49

Sothammargeilen 9, Dusavikbasen  
Bygg 1, 4029 Stavanger, Norway  
Tel: +47 51 54 38 00  
Fax: +47 51 54 35 00

Email: [offshoresales@trelleborg.com](mailto:offshoresales@trelleborg.com)  
Website: [www.trelleborg.com/offshore](http://www.trelleborg.com/offshore)

### Trelleborg Viking AS

PO Box A, 3051 Mjøndalen,  
Norway  
Tel: +47 32 23 20 00  
Fax: +47 32 23 22 00

Email: [viking@trelleborg.com](mailto:viking@trelleborg.com)  
Website: [www.trelleborg.com/viking](http://www.trelleborg.com/viking)

### Trelleborg CRP Ltd.

Paxton Place, West Pimbo, Skelmersdale,  
Lancashire WN8 9QH, UK  
Tel: +44 (0)1695 714300  
Fax: +44 (0)1695 555586

Stanley Way, Skelmersdale  
Lancashire WN8 8EA, UK  
Tel: +44 (0)1695 712000  
Fax: +44 (0)1695 712111

Email: [crpsales@trelleborg.com](mailto:crpsales@trelleborg.com)  
Website: [www.trelleborg.com/crp](http://www.trelleborg.com/crp)

### Trelleborg OCP Ltd.

3 Peter Green Way, Barrow-in-Furness  
Cumbria LA14 2PE, UK  
Tel: +44 (0)1229 842070  
Fax: +44 (0)1229 842071

Email: [ocpsales@trelleborg.com](mailto:ocpsales@trelleborg.com)  
Website: [www.trelleborg.com/ocp](http://www.trelleborg.com/ocp)

### Trelleborg Fillite Ltd.

Goddard Road, Astmoor Industrial Estate,  
Runcorn, Cheshire WA7 1QF, UK  
Tel: +44 (0)1928 566661  
Fax: +44 (0)1928 572380

Email: [fillite@trelleborg.com](mailto:fillite@trelleborg.com)  
Website: [www.trelleborg.com/fillite](http://www.trelleborg.com/fillite)

## NORTH AMERICA

### Trelleborg CRP Inc.

519 N Sam Houston Pkwy E, Suite 200,  
Houston, TX 77060, USA  
Tel: +1 (832) 456 8300  
Fax: +1 (832) 456 8385

1902 Rankin Road, Houston  
TX 77073, USA  
Tel: +1 (281) 774 2600  
Fax: +1 (281) 774 2626

Email: [crpsales@trelleborg.com](mailto:crpsales@trelleborg.com)  
Website: [www.trelleborg.com/crp](http://www.trelleborg.com/crp)

### Trelleborg Emerson & Cuming, Inc.

209 Forbes Boulevard, Mansfield  
MA 02048, USA  
Tel: +1 (774) 719 1400  
Fax: +1 (774) 719 1410

24 Teed Drive, Randolph  
MA 02368, USA  
Tel: +1 (781) 963 6794  
Fax: +1 (781) 963 6788

Email: [emerson@trelleborg.com](mailto:emerson@trelleborg.com)  
Website: [www.trelleborg.com/emerson](http://www.trelleborg.com/emerson)

### Trelleborg Fillite Ltd.

1856 Corporate Drive, Suite 135,  
Norcross, Georgia 30093-2925, USA  
Tel: +1 (770) 729 8030  
Fax: +1 (770) 729 9639

Email: [fillite@trelleborg.com](mailto:fillite@trelleborg.com)  
Website: [www.trelleborg.com/fillite](http://www.trelleborg.com/fillite)

