MoorLine

Bekaert

Mooring for floating offshore wind

More reliable | Lower TCO | Scalable | Easier to install | Reduced footprint

Welcome to the new possible

The world's growing population seeks new solutions. People's behaviours are changing towards new ways of living. Global communities are evolving at a dynamic speed of growth.

We believe it's our responsibility to contribute to finding solutions for these challenges. Bekaert has always been a pioneer and we will continue to bring our expertise to make a positive difference for future generations.

Shaping the way we live and move - safe, smart, sustainable

Bekaert's ambition is to be the leading partner for shaping the way we live and move, and to always do this in a way that is safe, smart, and sustainable.

You might know us as the global market leader of advanced rubber reinforcement solutions - 30% of all tires in the world are reinforced with Bekaert steel cord.

Or maybe you know our **Dramix**® steel fibres, used to reinforce over 10 million cubic meters of concrete annually. **Dramix**® is a proven low-carbon concrete solution which reduces the CO2 emissions of construction projects by 20 to 50%, compared to traditional steel solutions.

Did you know Bekaert is a technology leader in solutions that drive the green energy shift?

Bekaert has established a technology and market leadership position in porous transport layers for electrolysis technologies with the brand name **Currento**®.

Our **Bezinox**® cable armouring solution protects sub-sea power cables that transfer electricity from offshore wind farms ashore.

Our steel and synthetic mooring ropes connect anchors on the seabed to floating offshore wind turbines and eliminate the need for extensive foundations.

Moreover, we offer a very wide range of advanced solutions for various other sectors. You can find Bekaert products in cars and trucks, in elevators and mines, in tunnels and bridges, at home and in the office, in machines and offshore. If it drives, ascends, hoists, filters, reinforces or fastens, there is a good chance Bekaert is inside.

Leading innovator, developer and producer of mission critical ropes across a range of global industries

Bekaert's ropes, widely known via our brands **Bridon**® and **WRI**® are trusted globally in a broad range of sectors including offshore renewable energy, offshore oil & gas, construction machinery, marine, mining, fishing and aquaculture.

1. Offshore renewable energy
For newly emerging applications such as floating offshore wind, Bekaert relies on its current mooring experiences to solve new and existing challenges.

2. Offshore oil & gas
Bekaert's understanding of the challenges within the oil & gas industry has resulted in the production of ropes that can endure demanding applications.

3. Construction machinery
Bekaert's comprehensive range of crane and industrial ropes offer an enhanced service life for demanding lifting applications.

4. Marine
Working with ship-owners and operators, Bekaert's ropes meet the safety standards required for critical operations such as towing and mooring vessels.

5. Mining
Bekaert's industry leading mining ropes are engineered to withstand abrasion, bend fatigue, internal corrosion and extreme temperatures.

6. Fishing & aquaculture
Fishing and aquaculture demand high rope performance, Bekaert's specifically engineered solutions maximise efficiency and productivity.

A heritage in world class manufacturing and innovation

Bekaert synthetic ropes

Bekaert are a world leading manufacturer of mooring rope solutions. We are committed to supporting every client with solutions that answer the challenges of the industry.

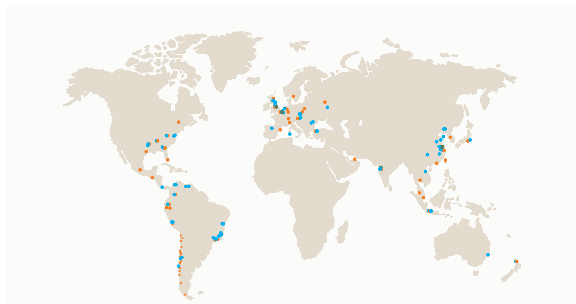
A global leader in material science of steel wire transformation and coating technologies. Bekaert also have a combination of over 300 years of experience in steel wire and synthetic fibre ropes. Providing solutions to thousands of customers across the world. Our heritage, combined with a strong vision, purposeful goals and impactful leadership have made us world leaders in our field.

Factors that make Bekaert unique, include:

The engagement and expertise of our people, who are at the core of our business. It is their knowledge, experience and commitment that provide the foundation of our competitive advantage.

Our technology leadership, provides a platform that separates Bekaert, in the market for mission critical ropes.

The ability to serve a range of industries, including renewables, offshore oil and gas, marine, mining, cranes, fishing and aquaculture.



Our global footprint, with 75 manufacturing plants in 25 countries globally. Bekaert are preferred partner serving customers in 130 countries.

Grangemouth, Scotland

Coatbridge, Scotland

Enabling the mooring supply chain for floating offshore wind

Bekaert's facilities in Coatbridge and Grangemouth, Scotland, boast a combined 8,000m^2 of production area. Our Coatbridge facility has been providing solutions to the offshore and marine industries for over 20 years. Including deep water mooring ropes as well as single point mooring (SPM) ropes.

Grangemouth is our latest facility, is located at the heart of Scotland's largest deep water container port. Therefore, is configured to maximise logistic efficiency for our customers. An additional 4,000m^2 storage area, located directly beside the ports numerous deep water berthing quays, further improves product deployment effectiveness.

Backed by Bekaert's global presence and technological support, customers can benefit from our commitment to local service. You can rely on a worldwide manufacturing footprint and sales network that is responsive to specific market needs.

Unlocking the advantages of synthetic mooring systems

The use of synthetic fibre ropes for mooring applications goes back decades. Prior to deep water mooring applications, they have been used for ship-to-shore mooring, towing and single point mooring (SPM).

Following various joint industry projects (JIP), polyester was established to have the desirable stretch characteristics for deep water mooring applications. And after some early success in the 1990s, it was widely adopted for projects in Brazil and the Gulf of Mexico.

An early example of a polyester rope mooring system was on a floating production, storage and offloading vessel (FPSO). The vessel was secured in water depths over 1,400m using a 160mm diameter polyester rope. Many of the earliest polyester ropes used for permanent deep water mooring applications were manufactured at Bekaert's Coatbridge facility in Scotland.

By the 2000s floating offshore production had reached water depths of 1,800-2,400m. As a result, polyester synthetic fibre ropes were established as a tried and tested method for mooring. To date Bekaert's MoorLine Polyester range has a track record of 3 decades in operation. With over 1,000km of mooring ropes deployed in oceans around the world.

Harnessing the power of the wind for a sustainable future

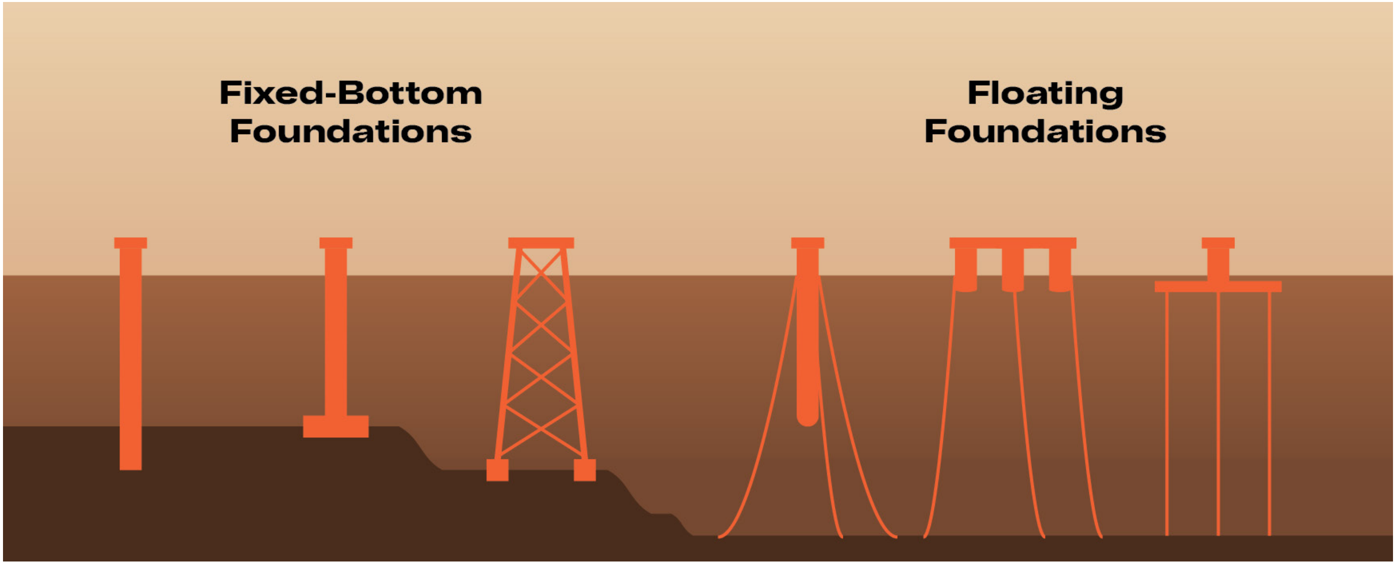
Building on solid foundations

Recent increases in energy costs combined with environmental concerns have furthered the interest in commercial wind power.

Wind power has a long history dating back thousands of years. However, the modern era of wind power began in the late 19th century with the invention of wind turbines. In 1887, Professor James Blyth built and installed a wind turbine to supply electricity to his cottage in Scotland. This was the earliest documented example of a wind turbine used for generating electricity.

Over 100 years later, in 1991, one of the first offshore wind farms, Vindeby, was commissioned off the coast of Denmark. Consisting of 11 wind turbines the farm produced a total capacity of 4.95MW. The water depths at Vindeby farm site were less than 10m, therefore the project utilised fixed-bottom foundations.

As offshore wind technology advanced, farms have been constructed in deeper waters. However, as was found in the oil and gas industry as water depths increase, traditional fixed-bottom foundations become less feasible. A key factor being an increase in cost and complexity in the construction of the foundations.



Floating into the future of offshore wind

There will continue to be a demand for fixed-bottom wind farms as the worldwide capacity for offshore wind power increases. However, floating offshore wind farms provide a solution for water depths where fixed-bottom turbines cannot be deployed. Therefore floating wind will compliment fixed-bottom in the global offshore wind industry.

Floating turbines can also take advantage of the stronger and more consistent wind speeds. Usually found in locations at these water depths.

Hywind is considered the first, large-capacity floating offshore wind project. It was deployed off the coast of Norway in 2009 in water depths of 220m. The demonstration project consisted of a 2.3MW turbine, mounted to a floating spar buoy. This was then moored to the seabed using a steel chain catenary configuration.

The success of the Hywind demo, combined with other prototypes led to the development of the first floating offshore wind farm. Hywind Scotland was deployed in 2017 in water depths between 95-120m. Considered the first floating wind farm, it consists of 5x 6MW turbines, providing a total capacity of 30MW. This generates enough renewable energy to power approximately 20,000 homes.

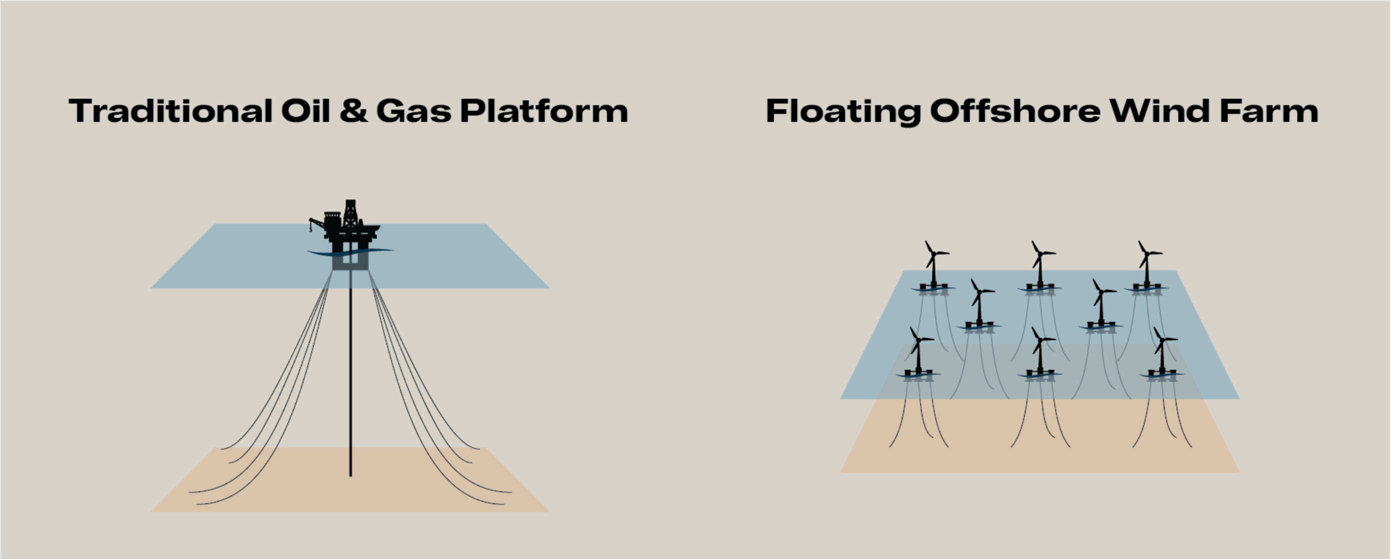
As of 2021 the total worldwide capacity of offshore wind power was 57.2 GW. The majority of this will be fixed-bottom turbines however the proportion of floating offshore wind is set to increase.

Introduction to mooring challenges

The offshore oil and gas industry provides many insights for permanent mooring solutions. However, for floating offshore wind farms there will be some new and unique challenges to solve.

Mooring multiple floating assets in shallow waters, compared to a single asset in deep water. The impact of the mooring footprint and how to achieve restoring forces with shorter mooring lines. Potential to enable seabed contact for synthetic fibre ropes or mitigate against it completely. Address some existing challenges with regard to synthetic fibre ropes such as marine fouling and cutting damage.

Bekaert are dedicated to addressing these market challenges. Utilising our experience and expertise in material science and coating technologies. To date Bekaert have worked in various joint industry projects (JIP) dedicated to floating offshore wind. As well as supplying mooring solutions to many projects around the world.



Shallow water depths and high dynamic load challenges

A unique challenge

Floating offshore wind will provide access to stronger and more consistent wind speeds when compared to fixed turbines. Floating wind farms will be located in shallow water depths in contrast to traditional offshore oil and gas platforms. The effects of the environmental conditions are typically more sever at these shallow water depths.

Platform stability is critical for the turbines power production efficiency. This is less of an issue for fixed-bottom turbines as they are not affected by waves, wind or sea currents. Floating structures in deep waters will allow for longer mooring lines, that provide the required compliance.

The combination of floating offshore wind farms and shallow water depths present a unique challenge. To moor a single wind turbine, longer lines could be implemented to dampen the higher dynamic loads on the platform. However, this would result in a larger mooring footprint. This becomes more problematic when introducing multiple floating wind turbines due to space limitations.

A portfolio of stiffness characteristics

Mooring lines in a floating wind farm need a compact footprint. They must also have the necessary dampening characteristics for peak loads. Therefore, to develop a floating offshore wind farm mooring solution that operates efficiently, the stiffness properties must be considered. MoorLine by Bekaert, is available in a range of materials and offers a portfolio of stiffness characteristics.

The mooring line material is an important factor with regard to the stiffness properties within the system. Polyester is a tried and tested solution in deep water mooring applications, as a result the stiffness properties are well understood. High-modulus polyethylene (HMPE) has higher stiffness properties compared to polyester, therefore makes it an interesting material for tension leg platforms (TLP). Nylon has also had an extensive offshore track record, although in much harsher applications such as single point mooring (SPM).

Did you know:

Nylon was the first fully synthetic fibre

Nylon was invented in 1935 and became a household name after the New York Worlds Fair in 1939 where the first nylon stockings were shown.

Nylon has worked in harsh applications

Nylon hawsers have been used in extreme weather conditions, heavy offshore operations and high-tension environments.

The most cost-effective method of mooring for floating offshore wind

Compared to polyester and chain, nylon increases the compliance of the mooring system. The higher compliance enables a dampening effect in the mooring line which reduces the magnitude of peak loads in dynamic scenarios.

This reduction of loads can provide the option of two major benefits. Either an improved lifetime of all the components as fatigue lifespan is increased. Or, being able to reduce the size of all mooring components, due to the lower requirements on tensile strength.

In 2017, Bekaert, together with 8 European organisations took part in a joint industry project (JIP). The JIP was funded by the Scottish Government and administered by the Carbon Trust under the Marine Renewables Commercialisation Fund (MRCF). The objective was to test and qualify new nylon components for permanent mooring applications.

A testing programme was carried out, confirming promising results for the long-term effectiveness of a nylon-based mooring system. The tests also confirmed the potential cost savings of nylon when compared to chain-based mooring systems at a commercial scale.

Due to the traditional use of nylon in more harsh applications, there is a negative perception of the materials fatigue properties. However, the combination of coated nylon fibres with an optimised rope design, have shown an improvement for long term applications. As the relevant fatigue and abrasion failure modes have been minimised.

A taut-leg configuration, utilising MoorLine Nylon could be the most cost-effective method of mooring for floating offshore wind farms. Bekaert continue to work closely with class societies. In order to demonstrate that nylon ropes are suitable for permanent mooring applications. Providing an additional material solution to the Bekaert MoorLine toolbox.

The design of the mooring system will heavily depend upon the type of floating foundations and location of the farm. For your next demonstration or full-scale project, Bekaert are ready to assist in your mooring requirements.

Strategies to protect mooring ropes

Seabed contact

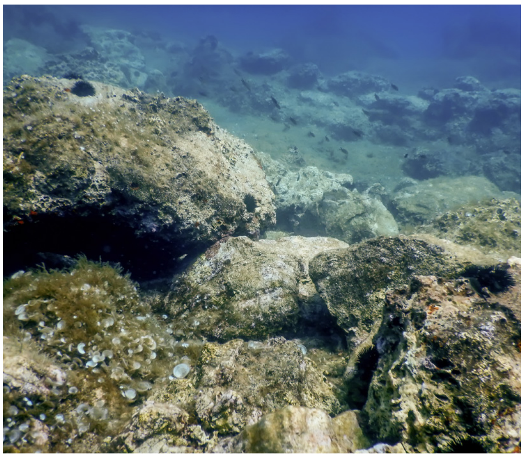
Seabed contact has historically been a challenge for synthetic fibre ropes in mooring systems. Offshore standards, such as API RP 2SM and DNV-OS-E303, state that previously tensioned synthetic ropes should not come into contact with the seabed during operation. This can increase the likelihood of particle ingress, which can lead to a major reduction in rope life from internal abrasion.

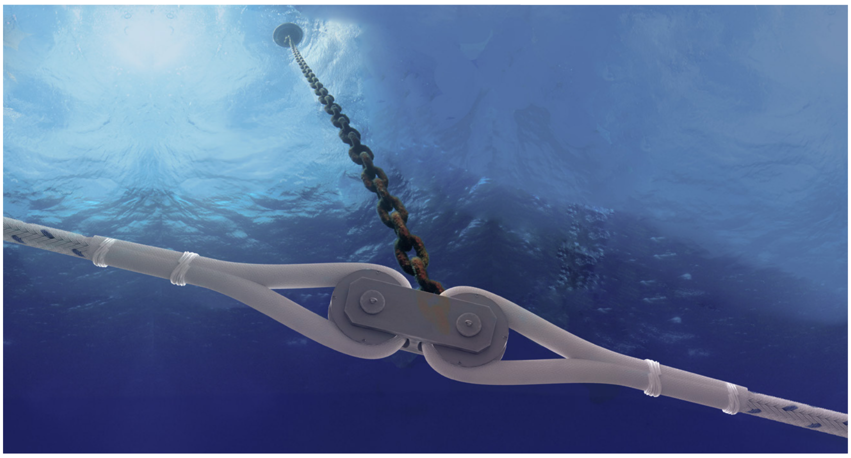
A method of rope protection is the use of a high-performance particle filter layer, such as that found in Bekaert's MoorLine. The filter layer is wrapped around the load bearing sub-ropes and provides up to 5-micron particle ingress protection.

When the mooring analysis determines the potential of seabed contact, while in service, another approach has been to include buoyancy elements. These buoyancy modules provide the necessary uplift to keep the synthetic rope away from the seabed during operation. Therefore fulfilling the offshore standards.

Traditionally, external buoys are added to the mooring system. While this is the most common approach it can increase the complexity of the mooring line, as more components are necessary. Therefore, the cost of the mooring system, as well as a risk of mechanical failure via the additional components is increased.

Bekaert can provide a range of external buoyancy options from their network of supply-chain partners. And, to further compliment this offer, can also manufacture ropes with integrated buoyancy. Integral buoyancy eliminates the necessity of additional components and reduces the complexity and cost of the overall mooring system.










Marine fouling

It is expected that many floating offshore wind turbines will operate in shallow water areas. As a result of being quite close to the sea surface, the mooring ropes will be likely exposed to marine fouling. This marine growth leads to additional weight and changes on the rope's hydrodynamics, that will effect the mooring rope behaviour.

This is particularly relevant for systems with submerged buoys in equilibrium. Or TLPs that need to account for the drag and vortex induced vibrations created by the mooring lines. Additionally, there is the concern that hard shell and other marine life, could migrate into the rope core. To the best of our knowledge internal marine fouling is unlikely due to the absence of light, nutrients and due to high internal loads.

Cutting damage

Experience from the oil and gas industry indicate that many offshore wind farms will have strong fishing lobbies. The fishing lobbies will request that the mooring lines are trawlable for fishing vessels. Insufficient safety perimeters, combined with the potential of 'corner crossing', increase the risk of cutting damage to mooring lines.

A level of abrasion resistance is offered as part of Bekaert's MoorLine, at the rope is constructed with a braided jacket. The jacket is designed in accordance with ISO 18692.

Advanced composite structures

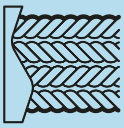
Bekaert can also provide additional protection solutions via a portfolio of enhanced coating solutions. Perfect, for environments where seabed contact, marine fouling or cutting damage is of particular concern.

Protection for mooring lines continues to be innovated from our expertise in material science and coating technologies. These coatings offer enhanced benefits to abrasion, tear and impact resistance, compared to a braided jacket alone.

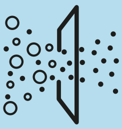
The advanced composite structure combines the known characteristics of a braided jacket with an elastomeric matrix. This additional layer provides even greater abrasion and tear resistance. As well as well as being chemically inert while having high elongation properties. It will also provide a platform to additional cutting protection and will enable for cleaning of synthetic mooring lines.

MoorLine

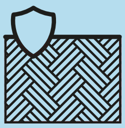
High tenacity fibres, made from either polyester, nylon or HMPE



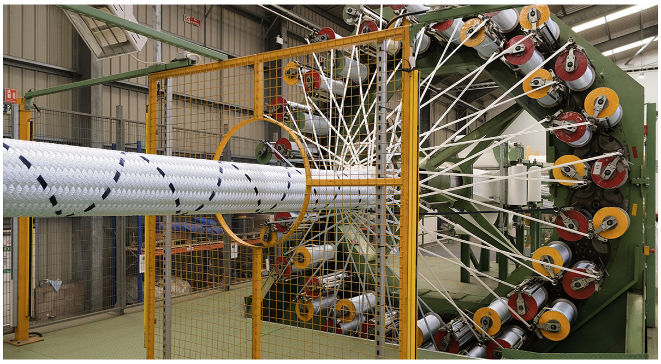
Core of multiple load-bearing parallel strand sub-ropes

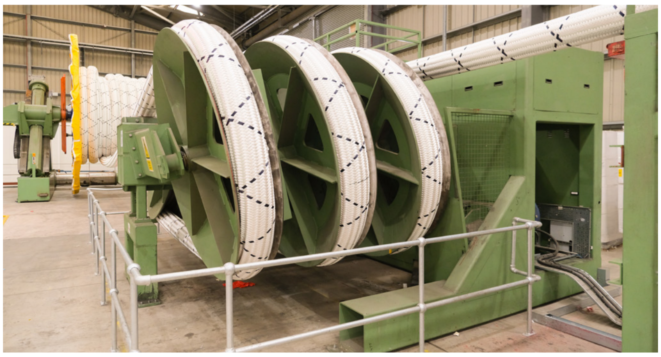


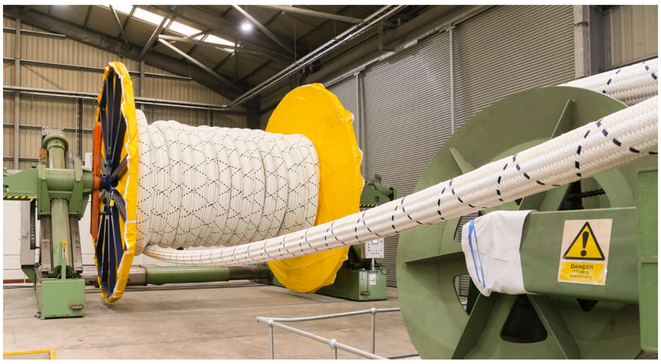
High performance fabric filter layer



Polyester braided jacket with other material options available

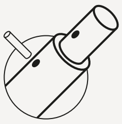


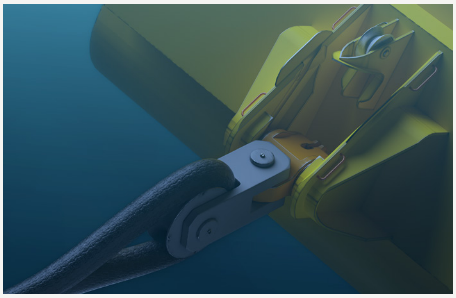




Advanced mooring solutions

FLINTSTONE
CHALLENGE IMPROVE DELIVER



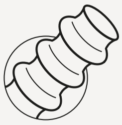


Flintstone smart connectors and tensioners

A mooring systems technology company for the global energy market providing problem solving, innovation and practical solutions. Flintstone offers a range of mooring line components covering turret and hull connectors, seabed connectors and chain tensioning.

www.flint-tech.com →

TFI Marine

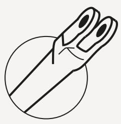


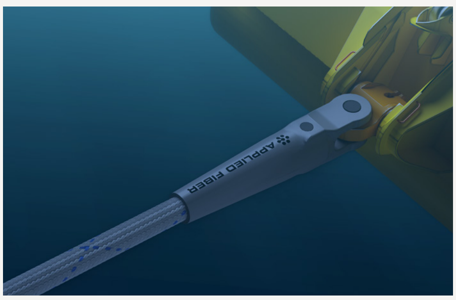
TFI Marine SeaSpring load reduction devices

An integral player in the future of Mooring Solutions for Floating Wind and Aquaculture. The patented SeaSpring product is revolutionising the industry through its cost saving, efficiency and sustainability credentials.

www.tfimarine.com →

APPLIED FIBER

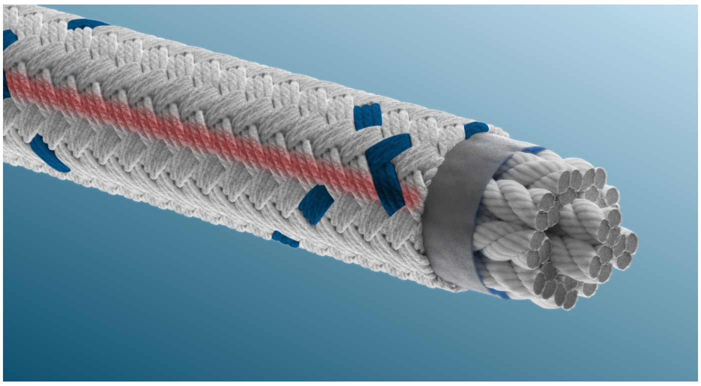




Applied Fiber advanced termination sockets

Applied Fiber is the most trusted company for terminated synthetic fibre systems worldwide. Offshore customers and partners depend on Applied Fiber's technology and experience to consistently deliver reliable performance.

www.applied-fiber.com →

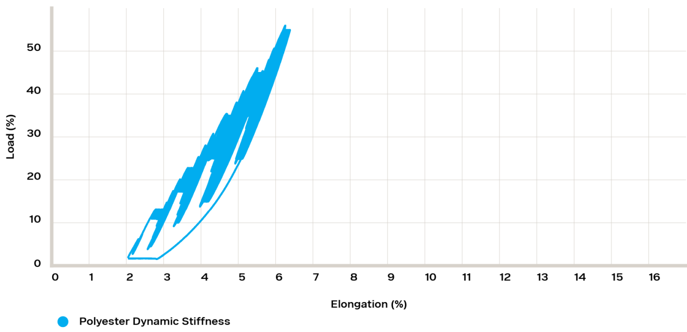


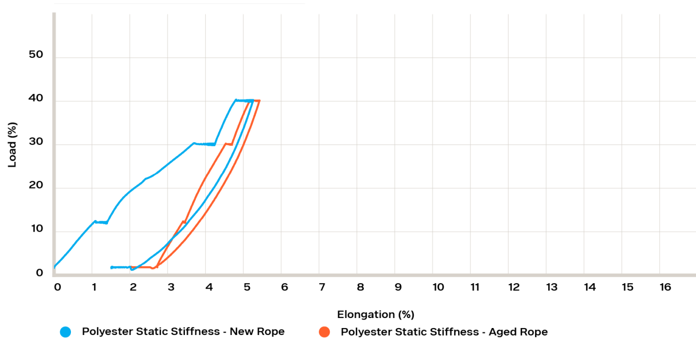
Characteristics | Polyester

The technological advancement of synthetic fibre ropes was a significant breakthrough for new mooring solutions, with polyester being at the forefront. The reduced weight and stiffness characteristics compared to chain and steel wire rope, combined with the high strength conversion of a parallel strand rope construction, creates an ideal solution for deepwater mooring applications.

Specific gravity: **1.38 (sub ropes only)**

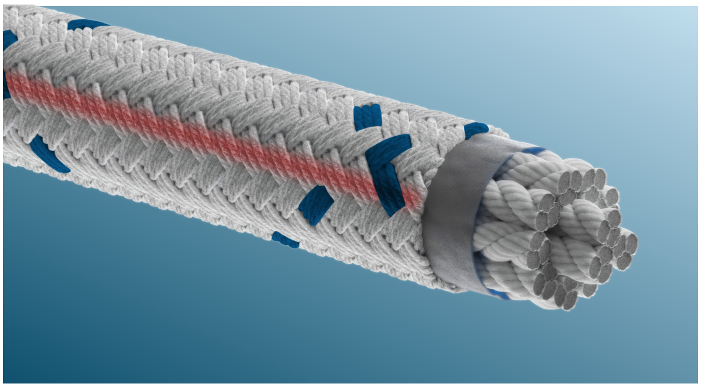
Melting point: **260°C**





Nominal Diameter	Linear Density				Minimum Breaking Strength (MBS)		
	In Air		In Water		Spliced		
mm	kg / m	lb / ft	kg / m	lb / ft	kN	ton	lbs
74	4.19	2.81	1.07	0.72	1,681	171	377,791
82	5.20	3.49	1.33	0.89	2,040	208	458,543
90	6.28	4.22	1.60	1.08	2,463	251	553,637
98	7.47	5.02	1.91	1.28	2,921	298	656,554
106	8.73	5.86	2.23	1.50	3,390	346	762,080
114	9.84	6.62	2.52	1.69	3,911	399	879,318
122	11.02	7.40	2.82	1.89	4,433	452	996,555
130	12.38	8.32	3.17	2.13	5,065	516	1,138,545
138	13.77	9.25	3.52	2.37	5,702	581	1,281,838
146	15.25	10.25	3.90	2.62	6,374	650	1,432,954
154	16.72	11.23	4.28	2.87	7,041	718	1,582,767
162	18.47	12.41	4.73	3.18	7,823	798	1,758,635
170	20.11	13.51	5.15	3.46	8,605	878	1,934,503
178	21.67	14.56	5.55	3.73	9,329	951	2,097,332
186	23.77	15.97	6.08	4.09	10,326	1,053	2,321,399
194	25.62	17.21	6.56	4.41	11,195	1,142	2,516,803
202	27.35	18.38	7.00	4.71	11,995	1,223	2,696,560
210	29.53	19.84	7.56	5.08	13,038	1,330	2,931,058
218	31.74	21.33	8.13	5.46	14,081	1,436	3,165,534
226	33.98	22.83	8.70	5.85	15,137	1,544	3,402,955
234	36.25	24.36	9.28	6.24	16,193	1,651	3,640,376
242	38.64	25.96	9.90	6.65	17,326	1,767	3,895,039
250	40.85	27.45	10.46	7.03	18,392	1,876	4,134,753
258	43.59	29.29	11.16	7.50	19,713	2,010	4,431,748
266	46.15	31.01	11.82	7.94	20,930	2,134	4,705,318
274	48.80	32.79	12.50	8.40	22,178	2,262	4,985,722
282	51.37	34.52	13.16	8.84	23,390	2,385	5,258,303
290	53.90	36.22	13.81	9.28	24,642	2,513	5,539,696
298	57.02	38.31	14.61	9.82	26,122	2,664	5,872,526
306	60.40	40.59	15.47	10.40	27,722	2,827	6,232,085
314	63.34	42.56	16.23	10.90	29,205	2,978	6,565,566
322	66.14	44.45	16.95	11.39	30,509	3,111	6,858,672

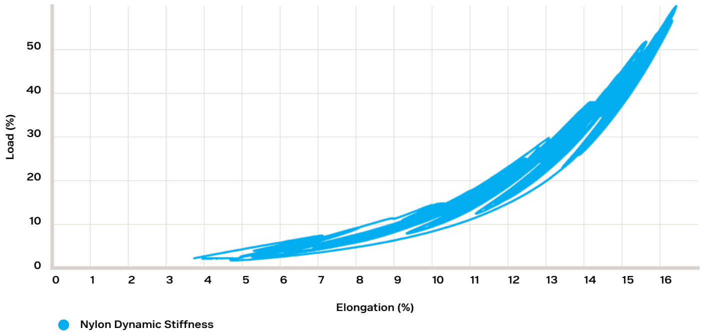
Values are indicative and subjected to change without prior notification.
Our ropes are specifically designed to fulfil project requirements therefore variations in diameter and linear density can be expected.
Diameter refers to the nominal diameter and not the actual diameter of the rope (this will change depending on the condition, tension, and historical highest tension of the rope.

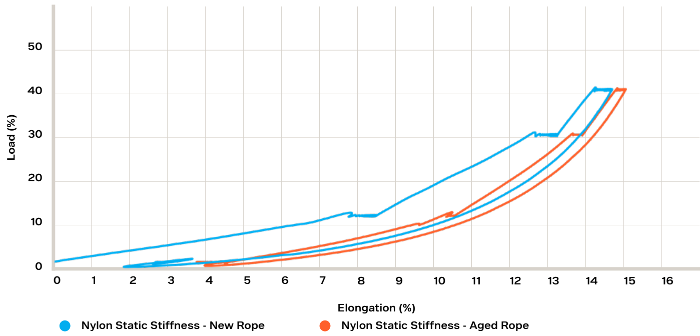


Characteristics | Nylon

Floating offshore wind turbines create the requirement for new mooring solutions suitable for shallow water depths. Nylon offers even lower stiffness characteristics than polyester therefore further reducing mooring line loads, improving on compliance as a result.

Specific gravity: **1.14 (sub ropes only)**
Melting point: **215°C**





Nominal Diameter	Linear Density				Minimum Breaking Strength (MBS)		
	In Air		In Water		Spliced		
mm	kg / m	lb / ft	kg / m	lb / ft	kN	ton	lbs
72	3.19	2.15	0.47	0.31	1,128	115	253,609
80	4.02	2.70	0.60	0.40	1,388	142	312,134
88	4.92	3.30	0.73	0.49	1,698	173	381,716
96	5.81	3.90	0.86	0.58	2,018	206	453,696
104	6.80	4.57	1.01	0.68	2,348	239	527,858
112	7.72	5.18	1.13	0.76	2,496	254	561,037
120	8.70	5.85	1.25	0.84	3,153	322	708,900
128	9.69	6.51	1.37	0.92	3,580	365	804,875
136	10.84	7.28	1.52	1.02	4,056	414	911,755
144	11.98	8.05	1.66	1.12	4,536	463	1,019,726
152	13.15	8.84	1.80	1.21	5,045	514	1,134,241
160	14.45	9.71	1.97	1.32	5,579	569	1,254,208
168	15.71	10.55	2.12	1.42	6,137	626	1,379,629
176	17.18	11.54	2.30	1.54	6,780	691	1,524,136
184	18.48	12.42	2.45	1.64	7,368	751	1,656,373
192	20.07	13.48	2.64	1.77	8,056	821	1,810,968
200	21.61	14.52	2.82	1.89	8,761	893	1,969,652
208	23.04	15.48	2.99	2.01	9,373	956	2,107,070
216	24.92	16.74	3.21	2.16	10,217	1,042	2,296,837
224	26.51	17.81	3.40	2.29	10,915	1,113	2,453,886
232	28.50	19.15	3.64	2.45	11,789	1,202	2,650,197
240	30.06	20.20	3.82	2.57	12,497	1,274	2,809,427
248	32.13	21.59	4.06	2.73	13,448	1,371	3,023,187
256	33.96	22.82	4.28	2.87	14,263	1,454	3,206,411
264	36.25	24.36	4.55	3.05	15,282	1,558	3,435,440
272	38.06	25.58	4.76	3.20	16,068	1,638	3,612,120
280	40.34	27.11	5.03	3.38	17,115	1,745	3,847,693
288	42.39	28.48	5.25	3.53	18,076	1,843	4,063,635
296	44.80	30.10	5.53	3.72	19,157	1,953	4,306,570
304	47.06	31.63	5.80	3.90	20,172	2,057	4,534,781
312	49.00	32.93	6.01	4.04	21,089	2,150	4,740,908
320	51.69	34.74	6.32	4.24	22,316	2,276	5,016,833

Values are indicative and subjected to change without prior notification.
Our ropes are specifically designed to fulfil project requirements therefore variations in diameter and linear density can be expected.
Diameter refers to the nominal diameter and not the actual diameter of the rope (this will change depending on the condition, tension, and historical highest tension of the rope.

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