# GOOD MORNING AND WELCOME TO ALLERØD

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## **WELCOME TO DENMARK:**



# WELCOME TO DENMARK: THE GLOBAL LEADER IN SPECIAL STEEL STRUCTURES

NORDIC STEEL 2019,  $18^{TH} - 20^{TH}$  SERTEMBER 2019 COPENHAGEN



STEEL STRUCTURES SINCE 1945





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Bright ideas. Sustainable change.

#### THE GLOBAL LEADER IN SPECIAL STEEL STRUCTURES

- Although small in size and without any domestic production of steel, Denmark has over the years contributed with a series of innovative steel structural designs, and today plays a key role globally in design and construction of some special steel structures.
- Danish engineers have a solid technical education and have been pioneers internationally in many fields. They have a good reputation worldwide. This is also the case within steel structures.
- Danish consulting engineering firms are very big compared to the size of the Danish population.
- These firms contribute significantly to global ranking within special steel structures, as for instance: Masts and Towers, Steel Foundations for Offshore Wind Turbines and Large Span Steel Bridges.
- Traditions from the Vikings. Why stay in Denmark when you can conquer other markets?



#### **DENMARK: NOT THE LARGEST COUNTRY IN THE WORLD**



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#### DENMARK: NOT THE LARGEST COUNTRY IN THE WORLD BUT INCLUDING GREENLAND 4 TIMES BIGGER THAN FRANCE



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#### **DENMARK: NOT SO MANY PEOPLE**





#### THE NORDIC COUNTRIES ARE ALL IN TOP 10 OF ENGINEERING



Figure 22: Engineering Index scores and ranking for the CAETS countries

The Engineering Index has been constructed using data from 99 countries from across the globe.

Source: Cebr analysis

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#### THE TECHNICAL UNIVERSITY OF DENMARK IS SECOND BEST



#### **DENMARK HAS A LONG TRADITION FOR THE USE OF STEEL**



The modern vikings use even more steel.

The Danish vikings were very good using steel in their daily life some thousand years ago.



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#### **GLOBAL NO. 1 DESIGN FIRM ON TOWERS AND MASTS**





RAMBOLL MASTS AND TOWERS SINCE 1945 More than 150,000 masts and towers worldwide Denmark: Tipeignal ther RAMBOLE tratem provide Steel 2019/Dansk ståldag 2020

#### **TOWERS IS NOT A NEW PHENOMENA**





#### **TOWERS IS NOT A NEW PHENOMENA BUT TIMES ARE CHANGING**



Denmark: The Global Leader in Special Steel Structures, Nordic Steel 2019/Dansk ståldag 2020

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13









#### **TRIANGULAR TUBULAR TOWER** 60M TOWER COMPARISON – TWO TOWER DESIGNS

Local Design: Square tower with all members in angle bars Ramboll Design: Triangular tower with all members in circular tubes





#### **TRIANGULAR TUBULAR TOWER 60M TOWER COMPARISON**





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#### **GLOBAL NO. 1 DESIGN FIRM ON TOWERS AND MASTS**



Education and training of the local production of towers is important.



You are not always in charge of the local riggers.



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#### **THE NEW ANTENNA TOWERS**





#### **OFF SHORE WIND – DENMARK FIRST MOVER**

In spite of Denmark's limited size, the country has had tremendous success with the development of offshore wind industry. The natural resources as a long coastline, excellent wind resources and shallow waters provided a solid starting point for this new industry born somore than 25 years ago.

In 1991 Denmark was the first country in the world to take wind turbines out to sea with 115 x 450kW turbines in the Vindeby offshore wind farm. This was followed by a number of smaller demonstration projects, leading to the first two large offshore wind farms Horns Rev I and Nysted with outputs of 160MW and 165MW respectively.



Vindeby offshore wind farm with a capacity of 5MW was the first offshore wind form in the world when it was opened in 1991.



#### **OFF SHORE WIND – STEEL MONOPILE FOUNDATION**







The steel monopile foundation for offshore wind turbines has been designed and constantly optimised by RAMBOLL ever since its introduction some 20 years ago.

#### **OFF SHORE WIND – THE CAPACITY WILL INCREASE**

#### Cumulative installed capacity (GW)

#### **Global offshore wind- REmap Case**



#### **OFF SHORE WIND – THE WIND TURBINES WILL BE BIGGER**





RAMBOLL OFFSHORE WIND FROM THE BEGINNING The rapidly increasing demand for renewable energy will push the development of the devel

#### **OFF SHORE WIND – STEEL JACKETS FOR DEEPER WATER**





Steel jackets are more cost-effective for turbines in deeper water depths. This picture shows the installation of a jacket foundation with suction buckets for the Borkern offshore, wind fam. Designed by RAMBOLL and Ørsted

## **OFF SHORE WIND - 80% OF THE STEEL FOUNDATIONS IN THE WORLD ARE DESIGNED BY DANISH ENGINEERS**





Burbo Bank Offshore Wind Farm is constructed at a water depth of 3.5-7.5 m on Burbo Flats in Liverpool Bay. RAMBOLL has prepared detailed design of thore that 60% of all offshore foundations for wind farms in the World.

#### **OFF SHORE WIND – FLOATING WIND TURBINES FOR DEEP WATER**



Floating wind turbines are effective for turbines in deep water depths. But new designs show to be cost effective also in less deep water.



*Floating wind turbine foundation developed by Henrik Stiesdal, Denmark. Left demonstration in Norway by DNV GL. Right tests at DHI).* 



#### **WORLDS BIGGEST WIND TURBINE MANUFACTURER IS DANISH**





Denmark is leading within wind energy and a lot of steel is used for the production or the threshold the towers.

With many islands, Denmark has a long history of bridges.

The construction of fixed links between the islands had long been under consideration in the beginning of last century, and after the first World War these plans were transformed into design and construction.

The Danish civil engineers were technically well prepared, with an excellent education from the Technical University of Denmark, and on the practical side, a number of internationally recognized Danish contracting firms were capable of constructing the bridges.







The "old" Little Belt Bridge opened in 1935. Monberg & Thorsen was main contractor. Denmark: The Global Leader in Special Steel Structures, Nordic Steel 2019/Dansk ståldag 2020





The Storstrøm Bridge opened in 1937 and was in many years the longest combined road and rail bridge in Europe. Christiani & Nielsen and Dorman, Long & Co. were contractors.





The "new" Little Belt Bridge opened in 1970 and is Denmark's first major suspension bridge with a 600m main span. The bridge represents a notable development stage in modern suspension bridge development stage in modern suspension bridge development. The count of the bridge represents a notable development stage in modern suspension bridge development.

35





The Great Belt Bridge was opened in 1998 and with a main span of 1624m it would had been the longest free span in the world, but it was taken over by the Japanese Akashi-Kaikyo bridge which was opened less than one year before. Designed by CBR (COWI-RAMBOLL, JV).



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The Osman Gazi Bridge crossing the Gulf of İzmit is under construction and will with a free span of 1550m be No. 4 longest free span brigger in the world when it opens soon. Besigned by COWI.





The new 1915 Canakkale Bridge crossing the Dardanelles Strait in Turkey is under design and will with a free span of 2023m be the longest free span bridge in the world when it opens in 2022. Picture is from the webpage <u>http://www.1915canakkale.ncotibia/hation special stee</u>l Structures, Nordic Steel 2019/Dansk ståldag 2020 38 Designed by COWI.

#### **3 OF THE TOP 6 WORLD'S LONGEST SPAN BRIDGES WILL IN 2022 BE DESIGNED IN DENMARK**

	Rank	Name	Span	Opened	Location	Designed
	1	1915 Canakkale Bridge	2023m	2022	Dardanelles Strait, Turkey	
	2	Akashi-Kaikyo Bridge	1991m	1998	Kobe, Japan	
	3	Nizhou Waterway Bridge	1688m	2019	Guangdong, China	
1	4	Xihoumen Bridge	1650m	2009	Zhoushan, China	
	5	Great Belt Bridge	1624m	1998	Great Belt, Denmark	
	6	Osman Gazi Bridge	1550m	2016	Gulf of İzmit, Turkey	

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Queensferry Crossing in Scotland, a special cable stayed bridge where the stays of the middle pylon are crossing the stays of the two adjacent pylons. It is the longest triple pylon cable-stayed bridge in the world. Denmark: The Global Leader in Special Steel Structures, Nordic Steel 2019/Dansk ståldag 2020 Designed by RAMBOLL.

#### **K-10000 ANOTHER DANISH WORLD RECORD**



The largest tower crane in the world, with a capacity of 10000Tonsmeter, the K10000 is designed and fabricated by Krøll Cranes. The crane was designed for the installation of the central unit in nuclear power plants to be built in the US and in Russia.



#### **K-10000 ANOTHER DANISH WORLD RECORD**





The comparison with the US landmarks was of course changed to Russian landmarks when the crane was used for the installation of nuclear power plants in Russia.



#### **COPENHAGEN OPERA HAS ONE OF THE LONGEST FREE CANTILEVERED ROOF WORLDWIDE**



Measuring 158mx90m the Opera roof is one of the largest roof construction in the world, and the 43m cantilever over the front plazza is the longest free cantilevered roof in the world. The Copenhagen Opera won "The 2008 IABSE Outstanding Structure Award" because of the innovative design of the steel roof, designed by RAMBOLL in cooperation with HenningLarsen Architects.

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#### **COPENHAGEN OPERA HAS ONE OF THE LONGEST FREE CANTILEVERED ROOF WORLDWIDE – IN STEEL OF COURSE**



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#### THE RUSTY LOOK – SHALL LAST FOR AT LEAST 50 YEARS



For the electrification of the Danish State Railways the requirement to the structures was that they had to be maintenance free for at least 50 years, and in the beginning, everybody was considering using concrete pylons to support the overhead catenary system. But then the structures in weathering steel was introduced.

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## THE RUSTY LOOK – THE ARCHITECTS LOVE IT



The architects love the rusty look. The structures for the eletrification of the Danish State Railways received the European Steel Award in 1987. Designed by RAMBOLL in cooperation with the architechs at the DSB.



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## **WEATHERING STEEL – DESIGN RULES**

#### **DESIGN OF JOINTS:**

Thin plates shall have a gab at least 3 mm

Thicker plates can be allowed contact under certain conditions

Clamps shall have a gab of at least 3 mm to the structure

All welds shall be continuous and fully closed.

Confined spaces shall either be closed airtight or secured to be well ventilated

Fasteners shall be stainless A4

Washers are used under both head and nut of bolts



Clamps on a test mast after 30 years exposure.



#### THE RUSTY LOOK -DETAILS STILL WORKS AFTER 30 YEARS





An extensive test programme with test masts placed at 6 different locations with varying environmental souroundings, show that after 30 years of exposure the corrosion rate is even smaller that assumed at the design stage.



#### **WEATHERING STEEL - 30 YEARS CORROSION RATES**



After 30 years of exposure the corrosion rate is much smaller that assumed at the design stage, and the 0.6mm assumed loos corresponds to a life time of more than 80 years.





Thank you for listening – Non-Danish can wake up now Bright ideas. Sustainable change.

