FORIDA HYBRID TOWERS

The towers for next generation of Wind Turbines

FINAL REPORT

Version 1.0 May 2014

FORIDA HYBRID TOWERS – the towers for next generation of Wind Turbines

Final report, EUDP, J.nr.: 64011-0039

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Contents:

1. Summary and conclusions

The project aimed to develop and demonstrate a new competitive tower system for very high wind turbines (+125 m). The goal was to create a tower system using steel fiber reinforced ultra-high-strength concrete (UHPFRC) that distanced itself technically and economically from the existing tower systems as tubular steel towers and towers of traditional concrete.

Project participants in the development process was Forida Development A / S, Vestas Wind Systems A / S and Aalborg University (AAU).

The tower system should be fully documented with calculation methods, material properties and installation principles and should be completed with the construction of a demonstration tower on Foridas Gingsholm wind farm in northern Jutland.

The UHPFRC part of the tower should be performed in a newly developed type of high-strength concrete, Forida CRC Mix, which differs from previously used CRC concretes by the fiber volume and by Forida CRC mix contains a coarse aggregate (crushed granite 4-8).

The project's objective was adjusted along the way so the demonstration phase was changed from the physical construction of the tower to obtain a certification of tower concept. The reason for the adjustment of the success criteria was primarily triggered by the certification process which was much more time consuming than expected and at times the dialogue with certification agency DNV went so sluggish that the possibility of finding another certification agency was studied and a meeting with Germanischer Lloyd (GL) was held. This option was abandoned when the two companies merged. Certification is in-built conservatism hampered also making full use of UHPFRC material's potential. During the development Vestas closed its development center in Colorado United States, which until closing constituted Vestas main project participation. This closure resulted in several changes of staff in the development group, which was not conducive to the overall process.

The project has proven to design and obtain approval of the hybrid tower, which consists of a tubular steel tower part, a transition piece and an element divided UHPFRC tower part. Wall thickness and thus the weight of UHPFRC elements are significantly less than similar items made of conventional concrete.

A benchmarking that compares a 140 m high Forida Hybrid Tower with a traditional 140-meter high steel tube tower shows the price savings in the order of 20%.

Thereby this project meets the revised criteria for success.

Forida Development and Aalborg University have applied EUDP for a grant for the continuation of the project which, in addition to the construction of the prototype tower, also includes elements such as up-scaling of the tower from 94m to 140m hub height, conversion of the tower from a hybrid tower for a fully UHPFRC tower - especially for areas where steel is faces heavy taxes and a design optimization of the conservative elements that reduce UHPFRC concrete design freedoms.

2. Resume og konklusion.

Projektets formål var at udvikle og demonstrere et nyt konkurrencedygtigt tårnsystem for meget høje vindmøller(+125 m). målet var at skabe et tårnsystem der ved at anvende stålfiberarmeret ultra-højstyrke beton (UHPFRC) distancerede sig teknisk og økonomisk fra eksisterende tårnsystemer som stålrørs tårne og tårne i traditionel beton.

Projektdeltagerne i udviklingen var Forida Development A/S, Vestas Wind Systems A/S og Aalborg Universitet (AAU).

Tårnsystemet skulle være fuldt dokumenteret med beregningsmetoder, materialeegenskaber og montageprincipper og skulle afsluttes med opførelsen af et demonstrationstårn på Foridas vindmøllepark Gingsholm i Nordjylland.

UHPFRC delen af tårnet skal udføres i en nyudviklet type af højstyrkebeton, Forida CRC Mix, der adskiller sig fra tidligere anvendte CRC betoner ved fibermængden og ved at Forida CRC Mixet indeholder et grovere tilslag (nedknust granit 4-8).

Projektets målsætning blev justeret undervejs, at demonstrationsfasen blev ændret fra den fysiske udførelse af tårnet til opnåelse af en certificering af tårnkonceptet. Grunden til justeringen af succeskriterierne var primært affødt af at certificeringsdelen var meget mere tidskrævende end forventet og i perioder gik dialogen med certificeringen hos DNV så trægt at muligheden for at finde et andet certificerings bureau blev undersøgt, og der blev afholdt er møde med Germanischer Lloyd (GL). Denne mulighed blev dog opgivet da de to firmaer fusionerede. Certificeringens indbyggede konservatisme vanskeliggjorde desuden den fulde udnyttelse af UHPFRC materialets potentiale. Undervejs i udviklingen lukkede Vestas sin udviklingsafdeling i Colorado USA, som indtil lukningen havde udgjort Vestas primære projekt deltagelse. Denne nedlæggelse medførte en del personudskiftninger i udviklingsgruppen, hvilket ikke var fremmende for den samlede proces.

Projektet har bevist at man kan designe og opnå godkendelse af hybridtårnet, der består af en stålrørs tårndel, et overgangsstykke og en elementopdelt UHPFRC tårndel. Vægtykkelser og dermed egenvægt for UHPFRC elementerne er væsentlig mindre end tilsvarende elementer udført i traditionel beton.

En benchmarking der sammenligner et 140 m højt Forida Hybridtårn med et traditionelt 140 m højt stålrørstårn viser prisbesparelse i størrelsesordenen på 20 %.

Dermed opfylder projektet de justerede succeskriterier.

Forida Development og Aalborg Universitet har søgt EUDP om tilskud til en fortsættelse af projektet, der udover opførelsen af prototypetårnet også omfatter elementer som opskalering af tårnet fra 94m til 140 m navhøjde, konvertering af tårnet fra et hybridtårn til et fuldt UHPFRC tårn - specielt til områder hvor stål er toldbelagt samt designoptimering af de konservative bestemmelser der reducerer UHPFRC betonens design friheder.

3. Introduction:

This is the final reporting of the results of the EUDP project 64011-0039 FORIDA HYBRID TOWERS – the towers for next generation of Wind Turbines. This report describes the background for the project, the activities and the results produced.

The purpose for the project participants FORIDA Development, Vestas and Aalborg University was to develop a new wind turbine tower solution (The FORIDA Tower) for very tall wind turbines. The tower is going to be a hybrid of materials combining steel and an element divided tower system of Ultra High Performance Fiber Reinforced Concrete (UHPFRC). The FORIDA Tower has great competitiveness regarding price, design, flexibility and durability compared to traditional steel tube towers for very tall wind turbine towers.

The fundamental idea in the present project was to mimic current steel design and construct a hybrid tower in which the bottom part is constructed with UHPFRC and the upper part is in steel.
The UHPFRC-elements will be prefabricated and then assembled on site.
This production method offers great flexibility in the design and huge advances in transportation.

With this new technology it will be possible to produce towers of a height that today is not profitable.

The height of towers plays an important role especially for onshore wind turbines where an increase in height also leads to a significant increase in average energy production.

The wind turbine industry expects that a growing part of the market will be with tower heights of +125 m.

The steel towers which are dominant today face severe challenges for the increased heights.
Tubular steel towers are the most dominant design today as they offer a good technical and economical solution for turbines dimensioned according to present standards.
Today most wind turbines of steel have a tower height of 94 – 105 m. When tower height increases, the weight of the steel tower increases disproportionately; a tower with a height in excess of 125m could possess a weight more than double that of an 80m tower.

The project consists of two main phases: Development and demonstration.

The development phase aims to formulate guidelines for design of UHPC concrete structures for the tower.
This is achieved by structural and material analysis, tests and optimization of preliminary design.
Succeeding this, the project will move into the demonstration phase.
The criteria of success for the demonstration phase was to build a demonstration tower, but because of unexpected problems and delays in the certification process the success criteria for the demonstration phase were changed to the achievement of a certification from DNV.

The project contains the following objectives:

1. Design method for the hybrid tower and its components.
2. Technical documentation of the UHPC-material.
3. Detailed design of a prototype tower of 94 m.
4. Achieve certification of the tower construction in UHPC, including calculation methods.

Parallel to the EUDP project Forida Energy has on own funds raised three Vestas V 112 3.0 MW HH94 m Wind turbines in a wind farm "Gingsholm" in the northern part of Jutland. Two of those turbines are conventional turbines with steel tube towers but monitored to give detailed data for the production conditions on the site. The third turbine is also an installed on a conventional steel tube tower but here the foundation is prepared for the installation of a Forida Hybrid tower.

4. Design methods for the hybrid tower and its components

The hybrid tower system consists of three main components:

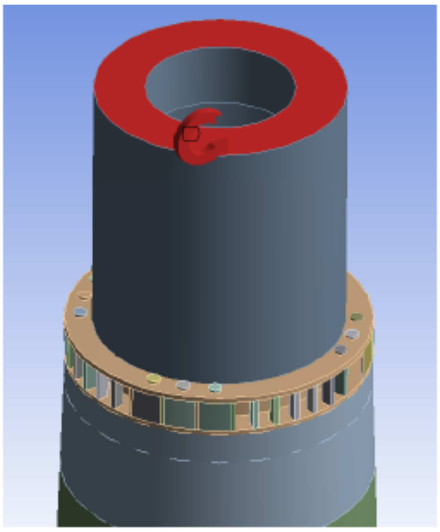
- The transition piece
- The UHPFRC Tower sections
- The foundation

4.1 Transition Piece

The transition piece is made as a steel construction a steel structure with an H-shaped ring beam with offset web. Around the circumference a number of web stiffeners are placed. In the top flange bolt holes for the steel tower are made. The anchor heads for the post tension cables are placed on the up-side of the transition piece. The post-tension cables will be spread out by the tromplates in order to transfer load to the concrete grout which will be encased.

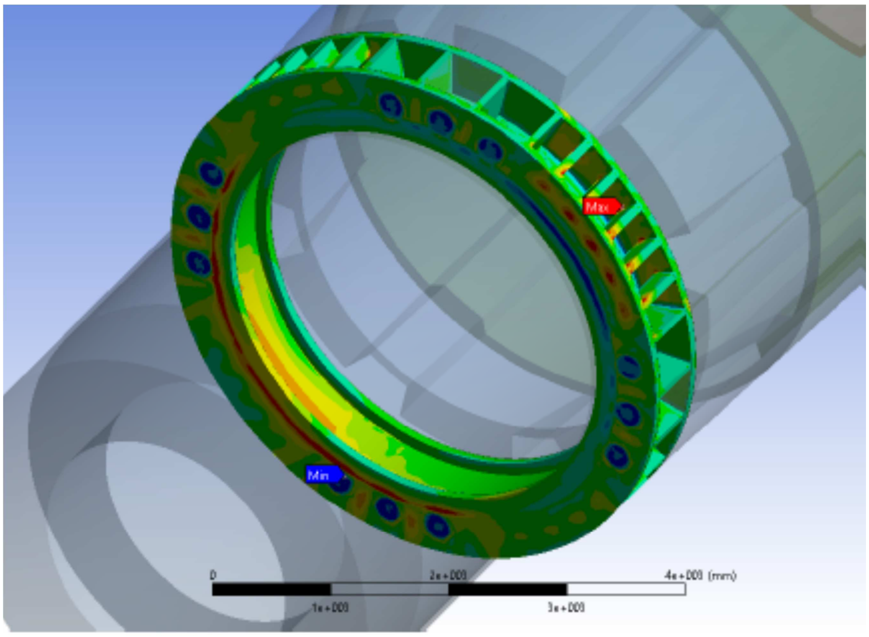
The design of the transition piece is based on a FE model which includes a global model representing the total UHPFRC tower, the transition piece, the post tension cables and a part of the steel tower. The displacement of the global model is then transferred to a sub-model only representing the transition piece.

The external loads from SLS, ULS and FAT are applied on the top of the steel tower part, which is modeled as a stiff cylinder.



FE load model for the transition piece

The transition piece is designed as a stiff plane, which is able to transfer a large post tension force to the UHPFRC material underneath the transition piece.



Stress analysis of maximal principal stresses for the steel part

The transition piece has been designed for ULS, SLS and Fatigue loads in accordance to Vestas Tower Loads for Forida Steel-Concrete Hybrid Tower for a V112-3.0 MW hh 94m ICE2 turbine on the basis of the Eurocode standards:

- EN 1993-1-1 Design of steel structures Part 1-1: Design requirements.
- EN 1993-1-9 Fatigue analysis according to Eurocode 3: Design of steel structures – part 1-9: Fatigue.

4.2 The UHPFRC Tower

The challenge of designing UHPFRC tower in a way that certification from an accredited certification agency can be achieved, is the absence of a Eurocode standards or a national standards for steel fiber reinforced ultra high performance concrete. (UHPFRC)

4.2.1 Design guide

A set of calculation rules that partly was based on accepted standards (Eurocode, DNV standards etc.) and partly took UHPFRC concrete properties sufficient to account was established

For that purpose a design guide was made.

The aim of the Design Guide is to establish the underlying rules for design a hybrid wind-turbine tower, where the lower part is made of Ultra High Performance Fiber Reinforced Concrete (UHPFRC) and the

upper part is a more traditional steel tower. In the design guideline it is assumed that a Vestas wind turbine is used.
The Design Guide only cower the Hybrid Towers and the post-tensioned cables. The post-tensioned cables will be anchored in the foundation, and this has to be accounted for in the Foundation Design. The transition between the concrete part and the upper steel tower is made by a so-called transition piece which should be able to resist both the forces from the post-tensioned cables and the forces from the wind turbine. Finally the transition piece has to secure a uniform distribution of stresses to the concrete tower part.

The tower will primarily be designed according to the Eurocode and DNV OS C502, and reference will be made to:

- [EC 0] Eurocode 0, EN 1990:2002/A1:2005, Basis of structural design: In this design guideline, the general concepts and definitions, basic requirements and principles set out in EN 1990 Chapter 1 – 6 are used. The rules in Annex A1 - Application for Buildings are used for combining actions. The rules in Annex D7 static determination of a single property are used to statistically evaluate the specific characteristics of the laboratory tests for the current UHPFRC.
- [EC 1-1] Eurocode 1-1, EN 1991-1-1:2002, Actions on structures Part 1-1: General actions - Densities, self-weight, imposed loads for buildings. The standard is used to determine self-weight and imposed load on internals.
- [EC 1-4] Eurocode 1-4, EN 1991-1-4:2005, Actions on structures - Part 1-4: General actions - Wind actions. In general wind load on the turbine will be determined according to the rules in IEC 61400. Wind load on the Tower shaft and in the intermediate stages will be determined according to EN 1991-1-4.
- [EC 1-5] Eurocode 1-5, EN 1991-1-4:2005, Actions on structures - Part 1-5: General actions - Thermal actions. The standard is used to determine the climatic actions on the tower and the foundation. Temperature changes in the foundation will be determined in accordance to section 5 Temperature changes in buildings. Temperature changes in the UHPFRC tower will be determined in accordance to section 7 temperature changes in industrial chimneys, pipelines, silos, tanks and cooling towers
- [EC 1-6] Eurocode 1-6, EN 1991-1-6:2007, Actions on structures - Part 1-4: General actions – Action during execution.
- [EC 2-1]Eurocode 2, EN 1992-1:2005: Design of concrete structures – part 1-1: General rules and rules for buildings.
  This standard is generally used but with certain deviations due to the particular material properties of UHPFRC.
- [EC 2-2] Eurocode 2, EN 1992-2:2005 Design of concrete structures – concrete bridges. Annex L-L is used for concrete shell elements
- [EC 3] Eurocode 3, EN 1993-3-2:2006 Design of steel structures, Tower masts and chimneys – Chimneys is used to determine the circumference moments from un-uniform wind load
- [EN 61400] DS/EN 61400-1: 2006 Wind turbines – Part 1: Design requirements. Concerning partial load and safety factors the DS/EN IEC 61400-1 overrules the Eurocode.

Furthermore reference will be made to the following DNV recommendations:

- [DNV1] DNV OS C502 Offshore standard, offshore concrete structures, September 2012.
  This standard is used for shear capacity of non-shear reinforced steel fiber reinforced concrete, the minimum amount of reinforcement in steel fiber concrete and the fatigue capacity of the steel fiber reinforced concrete and the grout.

4.2.2 Material properties for the design of UHPFRC constructions

A key point in understanding the design methods for UHPFRC is related to the mechanical properties of the material. Traditional concrete, for which most standards are developed, have unstable properties for tensile stress and acts as a brittle material for concrete with a high compressive strength.

UHPFRC materials have much better properties of tensile stresses as the steel fibers are activated and bridges the cracks, like the steel fibers gives the material a considerable toughness.

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To include those better material properties in the design a considerable series of test has been conducted

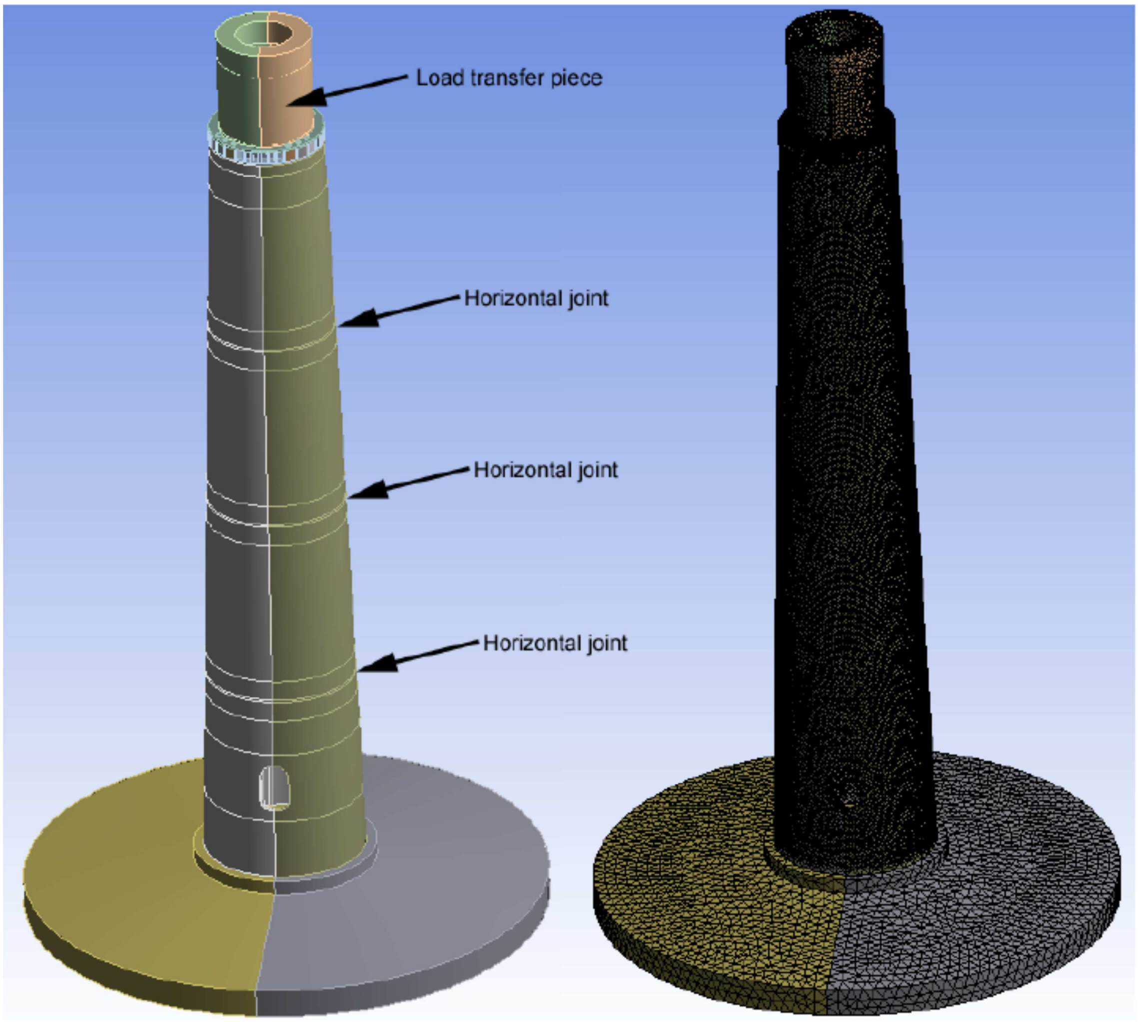
See further description in section 5

4.2.3 Load data

Load calculations for the tower are conducted by Vestas. The loads are simulated in accordance with IEC61400-1 Edition3.
The load specifications include Fatigue loads, Extreme loads, Steel-Concrete transition extreme loads, own weight contribution and tower frequency ranges.

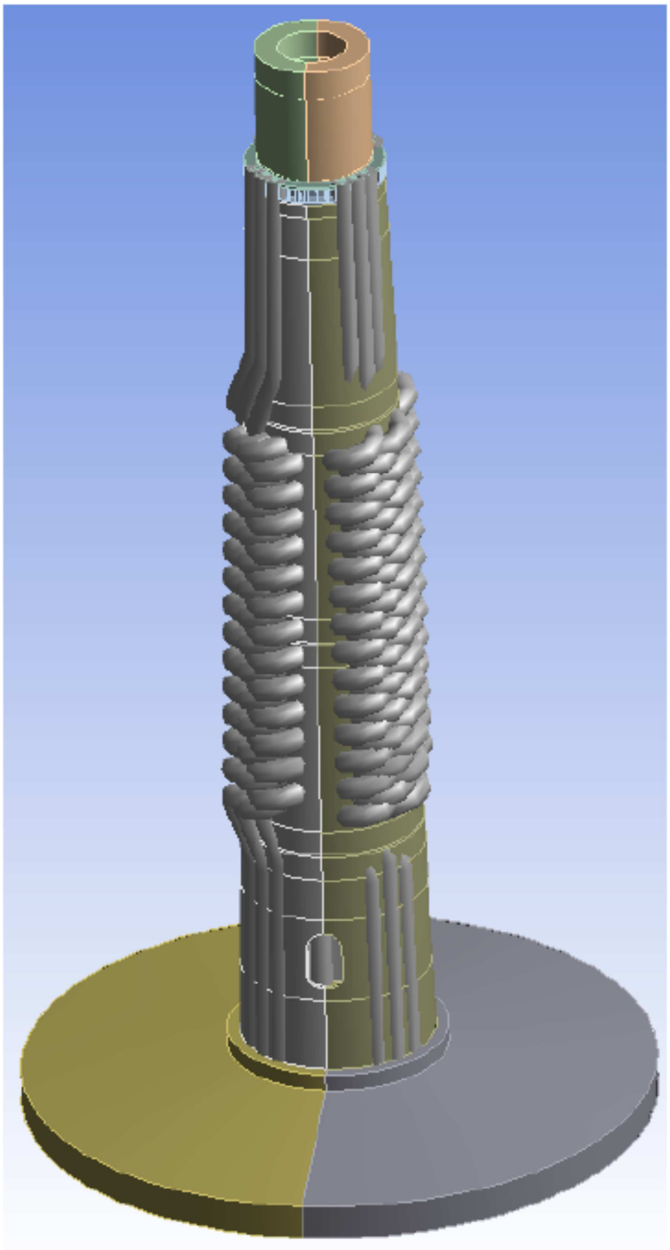
4.2.4 FE calculations for the UHPFRC Tower

The UHPFRC tower is modeled as a solid FE model imported directly from Autodesk inventor. Consequently the model is an exact representation of the tower. The discretized model consists of elements with mid-side nodes, to give a better representation of the stresses trough the thickness.



Overview of imported model and meshed model

The post tension cables is modeled as body- ground spring elements from the top side of the transition piece to the foundation



Overview of spring elements.

The detailed calculations is reported in "Forida towers Analyses of UHPFRC Tower" rev 1.0 February 2014.

This report is a detailed analysis of the UHPFRC tower and includes a validation of the Service Limit State (SLS), for both characteristic and frequent load cases, the Ultimate Limit state (ULS) and the fatigue load state (FAT).

- SLS frequent loading – crack limitation
- SLS characteristic loading – stress limitation
- ULS extreme loading – plastic capacity limitation

- FAT fatigue loading – damage limitation
- Installation loading – stability capacity

In the analysis, the geometry includes both a part of the tower above the transition piece, the actual transition piece the total UHPFRC part of the tower and the foundation to ensure that the forces, post tension cables, shrinkage and temperature variations are represented correct.

4.3 Foundation

The foundation was established in connection to the Gingsholm wind turbine farm in 2012.

The foundation is made so in the beginning a traditional Vestas steel tower can be installed on this and later this can be replaced with the developed UHPFRC element tower.

The foundation is constructed in plain concrete and the foundation design is mostly in accordance to Vestas standard foundation for a V112 3,0 MW HH 94 m IEC 2a turbines, only with that modification that the post tension cables for the hybrid tower is installed.

The hybrid tower has a larger own weight compared to the tubular steel tower used which increases safety against overturning.

The hybrid tower uses a larger diameter in the bottom section which distributes the forces from the tower in a better way so the section forces of the foundation will be smaller compared to the tubular steel tower.

This gives the opportunity for price reductions in the future for foundations where only one type of tower (the UHPFRC) shall be installed.

Foundation with both anchor bolts for a steel tower and post tension cables for a UHPFRC Hybrid tower

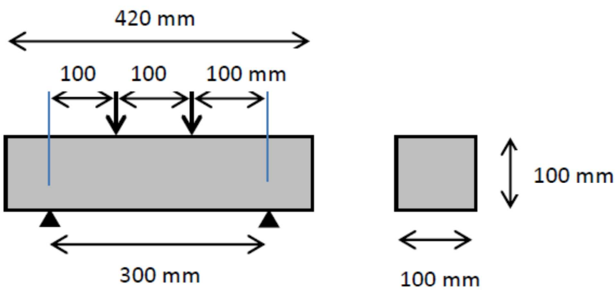
5. Technical documentation of the UHPC-material:

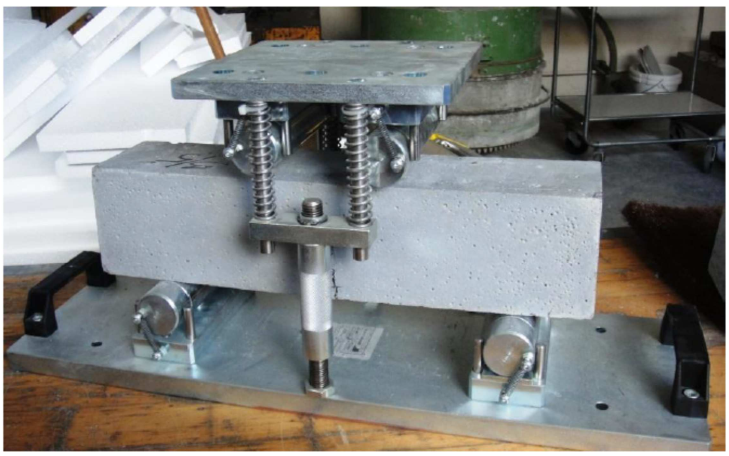
Baced on previous experience a new type of steel fiber reinforced ultra-high performance concrete, Forida CRC Mix, is composed. In contrast to previous applications it includes a stone boundary of crushed granite in the fraction 4-8 mm, making the material economically and environmentally more attractive.
The material is documented by tests at AAU laboratory so that all key parameters are defined (workability, compressive strength, tensile strength, elastic modulus, shear capacity, fiber distribution, shrinkage creep and fatigue conditions), furthermore full-scale tests for panels concerning fiber distribution as well as full scale tests of joints for static as well as fatigue loads has been made.

5.1 The Material tests

The tests conducted are listed in the below.

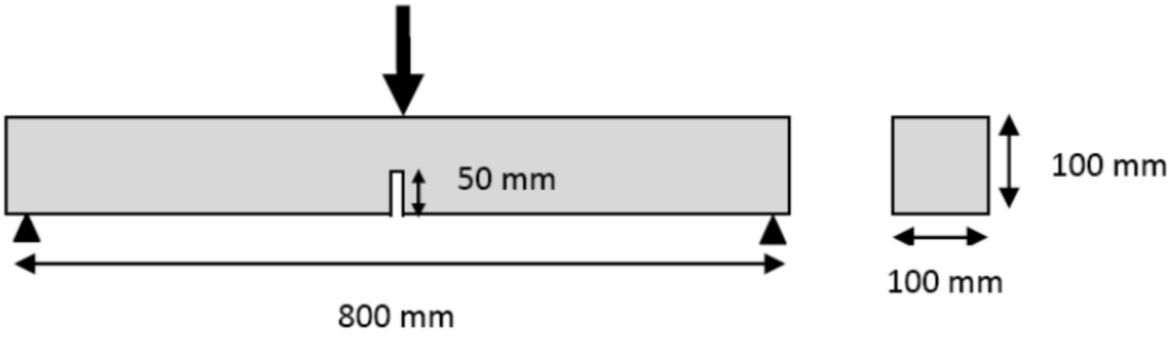
- Pre-test of workability in terms of fiber content and aggregate types produced by component supplier Hi-Con A/S
- Workability of the freshly mixed material using a flow crone according to EN 12350-5
- Setting time on a heat insulated sample to determine when the hydration of the binder starts. – from this the maturity is calculated.
- Compressive strength made on cylinders (d/h) 100/200 mm cylinders in accordance to EN 12390-3
- Flexural strength on 100x100x420 mm beams in accordance to EN 12390-5





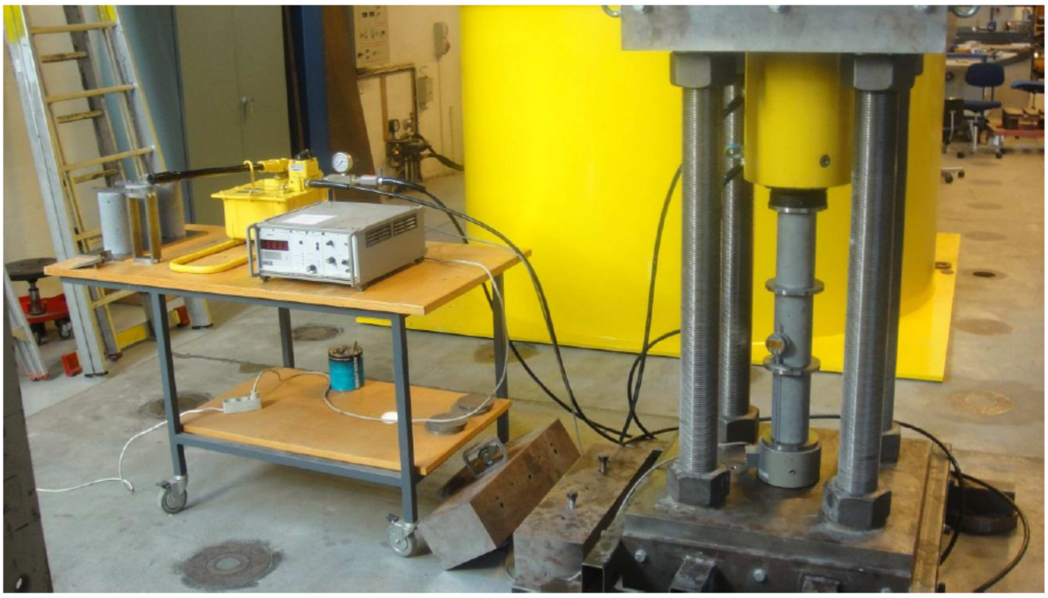
Flexural test set up

- Modulus of elasticity made on cylinders (d/h) 100/200 mm in accordance to EN 12412
- Fracture energy was measured using notched beams 100x100x840 mm with a sawn 50 mm deep notch sawn in the mid-point of the beam. The beam was simple supported and loaded with a single force at the mid-span of the beam.



Set-up for specific fracture energy measurement

- Shrinkage – both autogenous shrinkage alone, and total shrinkage during drying was measured to establish the dimensional stability of the materials.
  The autogenous shrinkage was determined on sealed specimens
  The total shrinkage was measured at two levels of relative humidity by placing the specimens in different containers containing a saturated salt solution giving relative humidity of 33% respectively 55%.
- Creep – the test uses a hydraulic cylinder jack to apply the force. Three test cylinders, each (d/h)100x200 mm were used. The stress level was kept constant at 30% of the ultimate compression stress of the material.
  The displacement was regularly measured with electronic displacement gauges and compared to un-loaded cylinders over a period of more than one year.

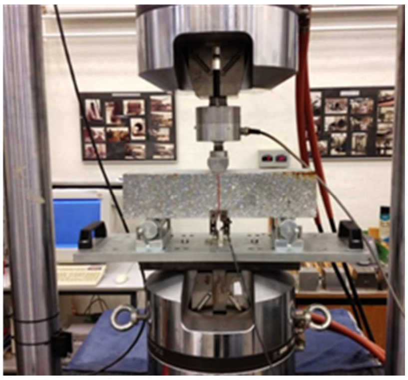


Creep test set-up

- Fatigue in compression for UHPFRC
  The behavior of the material under cyclic loading was studied using cylindrical specimens (d/h) 60x120 mm.
  The specimens were water cured for 28 days before testing. The maximal stress applied was 70%, 75 % and 80% of the static compression strength. The minimum stress level was 5 % of the static compression strength.
- Fatigue in compression for Epoxy mortar
  To evaluate the properties of an epoxy mortar (Mapai mapoxy L) in order to use this in the horizontal joints fatigue tests was conducted in a similar way to the compression fatigue test of the UHPFRC The maximal stress applied was 50%, 60 % and 70% of the static compression strength. The minimum stress level was 5 % of the static compression strength.

Cylindrical specimens with epoxy joints before and after testing

- Influence of fibre distribution and orientation on tensile strength
  Ideally, the fibres in the UHPFRC mixture should be evenly distributed and randomly oriented in the hardened UHPFRC material. A test series was performed to investigate if this was the case or if there was an effect of fibre distribution and fibre orientation on the tensile strength of the material.
  The test is conducted as three-point bending on sawn out beams from a full scale test panel cast under the same conditions as for fabrication of the elements for the wind turbine tower and compared to three point bending tests conducted on beams cast in mould. From this the value of the fiber orientation factors K_{global} and K_{local} can be calculated.



Three point bending tests on sawn out beams for determination of K factors

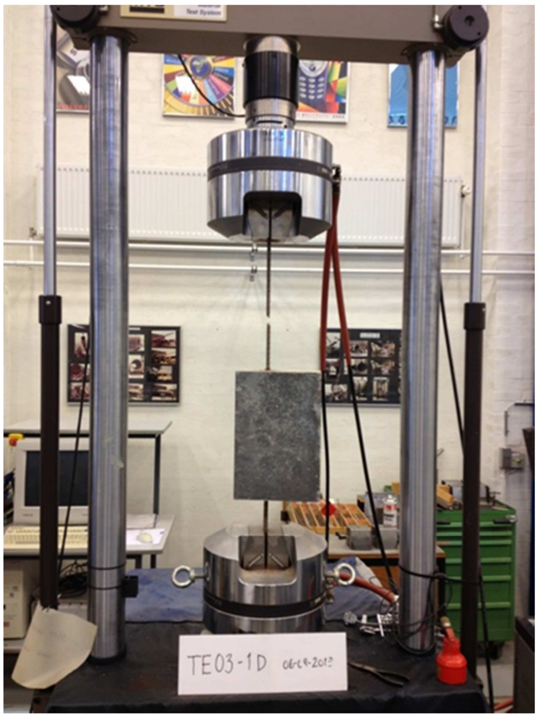
- Flexural strength determination by force vs. deflection relationship
  As an alternative to the flexural bending tests conducted in accordance to EN12390-5 we have carried out a test series in accordance to the French (AFGC) recommendation for ultra high performance fibre-reinforced concrete.
  The tests are conducted as a four point bending test where the relation between force and deflection is recorded.
- Shear capacity of non-shear-reinforced concrete
  The static shear capacity for a beam without shear reinforcement may be determined in a four-point bending test according to DNV OS C502 section 4, clause D115.
  Beams, 125 x 210 x 2350 mm, longitudinally reinforced with 2 Y 25 mm rebar, were produced for determination of the shear capacity of the Forida CRC mix. The capacity at first crack and the ultimate capacity were recorded.

Test set up for Shear capacity test of non-shear reinforced beams.

- Lap lengths of reinforcement bars in CRC JointCast

In order to demonstrate that the intended lap length of the reinforcement bars in vertical joints of the tower structure will secure the full static capacity of the joint, a series of tests were performed, comprising both static tests of reinforcement bars, and static and dynamic tests of JointCast specimens containing embedded reinforcement. Test specimens of CRC JointCast material were made with embedded reinforcement. In the one end of the specimen reinforcement bars in the current dimension were embedded with an anchorage length as intended in the real construction (less tolerance). In the other end of the specimen a reinforcement bar with a larger embedment length and diameter was used to ensure that the fracture would occur in the (thinner) current rebar. The two protruding rebar were located in line so that no moment would be introduced during pulling of the rebar by the testing machine. In order to minimize the occurrence of stress concentrations from the jaws of the testing machine the end of the rebar were provided with aluminum caps which could more efficiently distribute the force from the jaws over the surface of the rebar.

The tensile loading of the specimen (rebar) was displacement controlled at a rate of 0.05 mm/s. During the test the force and the crosshead displacement were recorded



Test set up for determination of lap lengths

- Fatigue strength of lapped reinforcement in CRC JointCast joints
  Similar to the static tests of the lap lengths for the reinforcement anchored in the CRC JointCast a test series for fatigue testing of the joint was conducted. The specimens TE 04-2 were subjected to cyclic loading at a frequency of 5 Hz. The minimum force applied was 7.7 kN, and the maximum force was 60 %, 70 %, and 80 % of the “yield force” for the reinforcement . If a rebar fractured at the jaws of the testing machine the new rebar end was inserted into the testing machine and the test was continued. The number of cycles to failure was then taken as the sum of the cycles survived in each part of the test. In all instances the test consisted of two parts at the most.

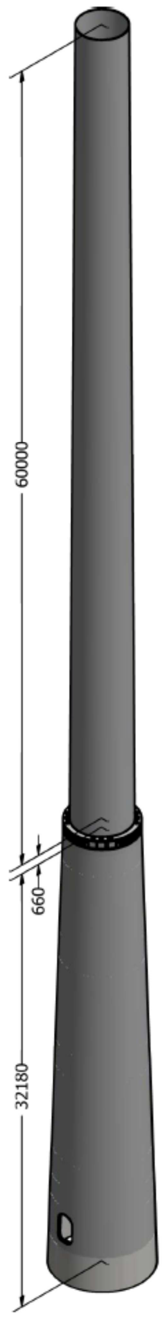
The material tests have been reported in:

- DCE contract report no. 140, “Mechanical Properties of UHPFRC Materials for FORIDA Wind Turbine Towers – Supplementary tests”, Aalborg University, Department of Civil Engineering January 2014
- DCE technical report no. 126, “Mechanical Properties of UHPFRC Materials for FORIDA Wind Turbine Towers”, Aalborg University, Department of Civil Engineering October 2012.

6. Detailed design of a Prototype tower with Hub Height 94 m

An overall design for a hybrid wind turbine tower for a Vestas V112 94m HH IEC class2a wind has been made.

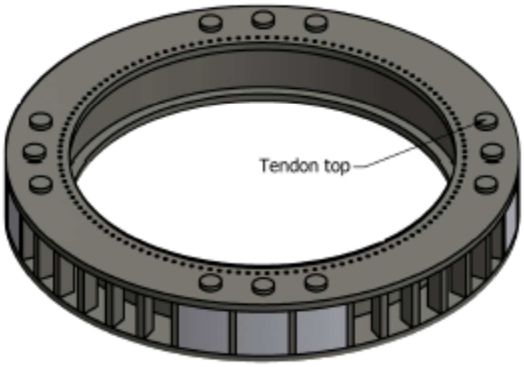
The design consists of a steel tower part primarily designed and documented by Vestas, a transition piece from steel tower section to the UHPFRC Tower part and a component divided UHPFRC concrete tower part, made in Forida CRC mix. These items are designed and documented by Forida and AAU based on load information from Vestas.



General presentation of the 94 m HH Hybrid tower

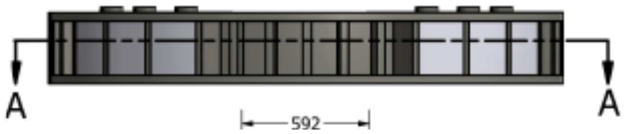
6.1 Steel transition piece

The steel transition piece transfers the forces from the steel tower and from the post tension cables as a compression force to the UHPFRC part of the tower.

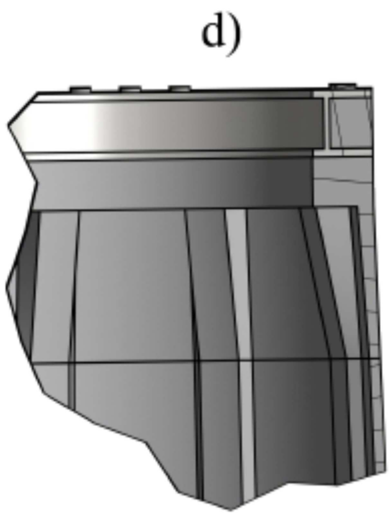


Steel transition piece with bolt holes for steel tower flange

and anchor plates for the tendon tops.



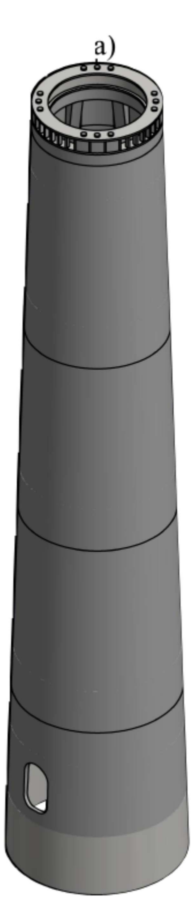
Elevation of steel transition piece



Detail of transition piece connection to UHPFRC tower top

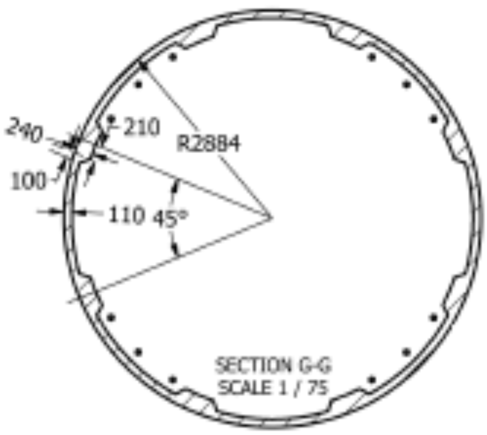
6.2 UHPFRC tower

The UHPFRC tower consists of a number of sections with a length of approximate 8 meters and diameters between 4.7 and 6.6 meters.



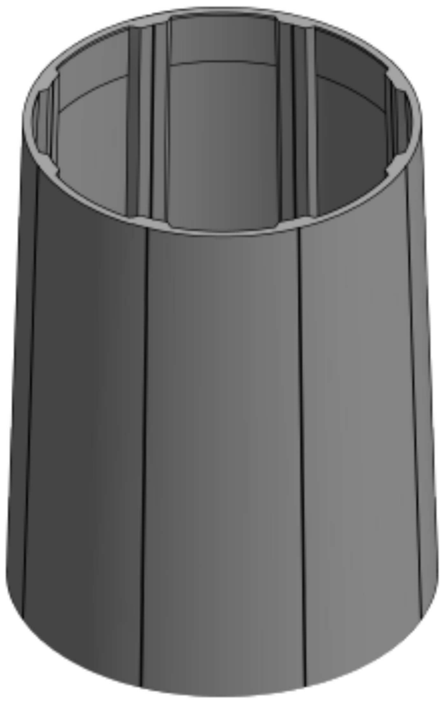
UHPFRC tower section divided in section

Elevation of the UHPFRC tower from inside



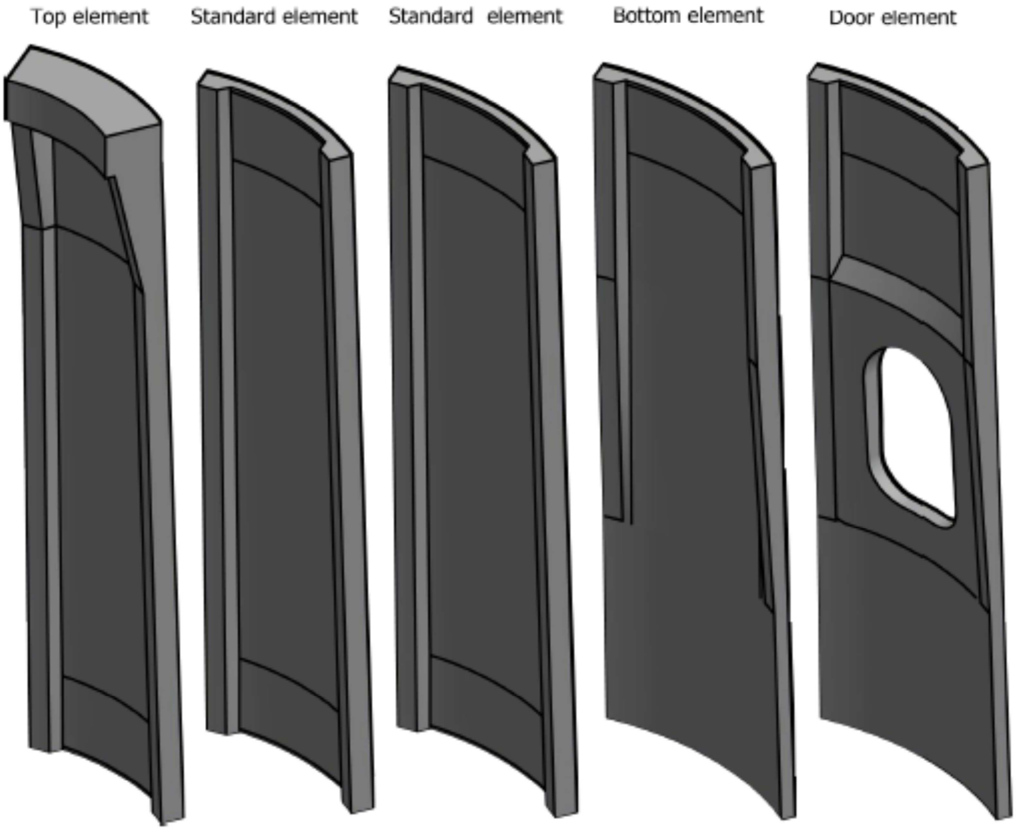
Typical cross section of the tower

The tower is made of elements which is cast together to tower sections on the construction side



Elements cast together with CRC JointCast to form a tower section

Each tower sections consiste of 4- 8 elements



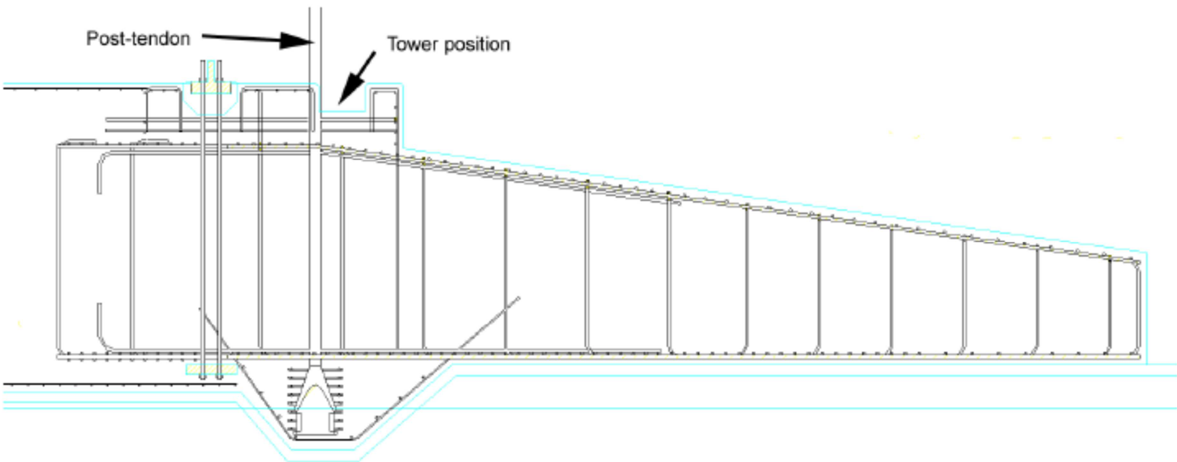
Design of element types used to form the tower sections

6.3 Foundation.

The foundation for the test side turbine has been made so it is possible to first install a traditional steel tower and later to change it to an UHPFRC tower.

The foundation for the steel tower solution was a part of Forida Energy's investments in 3 wind turbines at the Gingsholm site and is not a part of the EUDP supported project. The foundation was designed by Vestas as a part of the deliverance of those turbines.

The extension of the foundation for the UHPFRC tower was designed in cooperation between Forida, AAU and Vestas



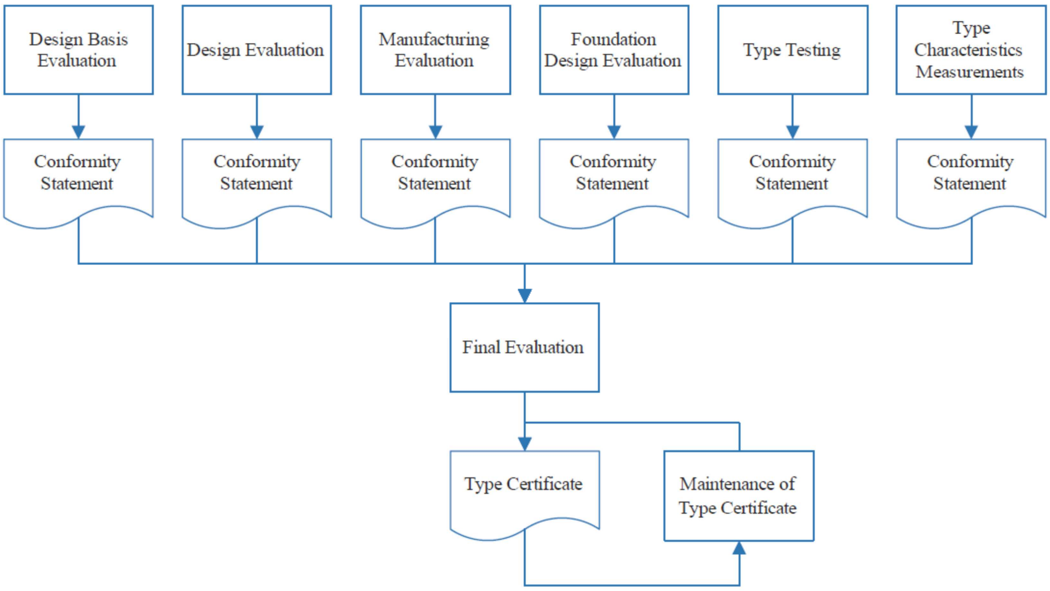
Cross section of foundation with the ability to install two types of tower.

7. Certification:

The certification process for Wind turbines shall be in accordance to a recognized standard as for instance IEC 61400-22:2010. This standard defines rules and procedures for a certification system for wind turbines (WT) that comprises both type certification and certification of wind turbine projects installed on land or off-shore. This system specifies rules for procedures and management for carrying out conformity evaluation of WT and wind farms, with respect to specific standards and other technical requirements, relating to safety, reliability, performance, testing and interaction with electrical power networks.

For the Forida Hybrid Tower system a product certification for the total Hybrid tower is applied.

To receive the final certification, the prototype of the tower inclusive the installation and operation of the wind turbine has to be executed as it involves manufacturing evaluations as well as type testing and Type characteristic measurements, see the outline of the certification process on next page.



Outline of the DNV GL certification process for a component certificate

For the certification the following design and material documentation has been evaluated by DNV.

1. Forida Towers, Analysis of steel Transition piece, rev 1.0 February 2014 - Forida and Aalborg University, Esbjerg.
2. Forida Towers, Analysis of UHPFRC Tower, rev 1.0 February2014 –Forida and Aalborg University, Esbjerg
3. Forida Towers, Gingsholm VM 2 Foundation for Vestas V 112 HH 94m, with Hybrid tower, IEC class 2a, rev 1.0 January 2014 – Forida Development A/S
4. Forida Towers, Principles for installation of the UHPFRC part of the Forida Hybrid tower, rev 1.0 January 2014 – Forida Development A/S.
5. Drawing, Forida 94 m Steel transition piece, Aalborg University Esbjerg
6. Drawing, Forida 94 m UHPFRC Tower, Aalborg University Esbjerg,
7. Mechanical Properties of UHPFRC Materials for FORIDA Wind Turbine Towers – Supplementary tests Aalborg University, Department of Civil Engineering, DCE contract report no. 140,
8. Mechanical Properties of UHPFRC Materials for FORIDA Wind Turbine Towers Aalborg University, Department of Civil Engineering, DCE technical report no. 126
9. Evaluation of supplementary tests of Mechanical properties of UHPFRC for FORIDA Wind turbine towers according to DCE Contract report No. 140,Forida Development A/S
10. Forida Towers – Material documentation for UHPFRC, Forida and Aalborg University Esbjerg

Forida development has achieved the conformity statement for the Design basis evaluation.

A copy of this statement can be seen on next page.

DNV

DET NORSKE VERITAS

DESIGN BASIS EVALUATION CONFORMITY STATEMENT

FORIDA Onshore UHPFRC Hybrid Tower, HH 94m

DB-169401-A-0	**2014-05-13**
Conformity Statement number	**Date of issue**

Manufacturer:

Forida Development A/S
Hjallerup Erhvervspark 2
9320 Hjallerup

Conformity evaluation has been carried out according to **IEC 61400-22: 2010 "Wind Turbines - Part 22: Conformity Testing and Certification"** . This conformity statement attests compliance with IEC 61400-22 concerning the design basis . Any change in the design basis is to be approved by DNV. Without approval the Statement loses its validity.

Evaluation reports:
Technical Report: PD-641694-13XJFRH-27, rev. 0

Wind Turbine specification :
IEC WT class: N/A. For further information see Appendix 1 of this Certificate.

Date: 2014-05-13		**Date: 2014-05-13**
Christer Eriksson	DANAK PROD Reg. no. 7031	**Per Enggaard Haahr**
Management Representative		**Project Manager**
Det Norske Veritas, Danmark A/S		**Det Norske Veritas, Danmark A/S**

DET NORSKE VERITAS, DANMARK A/S

8. Evaluation

With the achievement of Design Basis evaluation Compliance in conjunction with the meeting of the established economic benchmarks the reduced criteria of success are met and Forida Towers are ready to move to the next stage: construction of demonstration tower and parallel to this marketing and sale of the Tower system.

Forida Development A/S and AAU have applied for a renewed grant from EUDP for the construction of the demonstration tower as well as further development and optimization of the tower concept.