The **Concrete** Centre™

Concrete Wind Towers

CONCRETE SOLUTIONS FOR OFFSHORE AND ONSHORE WIND FARMS

There is no prescriptive plan showing how to develop a wind farm, whether onshore or offshore. Each selected or prospective site is unique, with its own mix of physical, economical, and access constraints. This document demonstrates the key role that concrete can play in realising cost efficient, sustainable and constructible energy converters, addressing the major issues relevant to any onshore or offshore wind farm development. Concrete is uniquely adaptable in terms of performance, design and constructability; making it the material of choice for wind farm developers.

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Front cover, main image:
A precast concrete wind tower in Germany, see page 11. Courtesy of The Concrete Society

INTRODUCTION

Wind energy is one of the most commercially developed and rapidly growing renewable energy technologies worldwide. In the UK, the installation of onshore and offshore windfarms supports an industry that grew by 20% in 2004 alone. The UK Government's initial target is to generate 10% of electricity from renewable sources by 2010, aspiring to a target of 20% by 2020. The next five years will see the implementation of a large programme of offshore and onshore wind farm developments nationwide, exploiting some of the best and most geographically diverse wind resources in Europe.

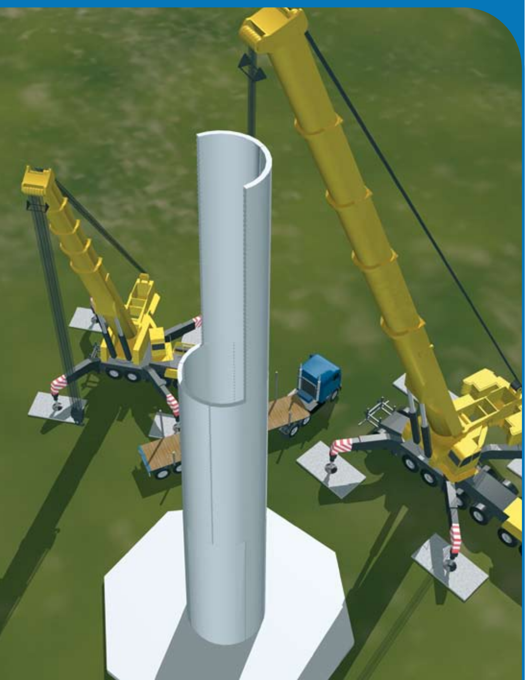
One challenge to meet these renewable energy demands is purely physical. Towers must become taller, stronger and stiffer to accommodate both future site constraints and developments in turbine technology. Demands for increasingly higher power output, coupled with a decreasing number of prime sites with high wind availability and good access, means that there is a need to use higher towers to achieve optimal performance in less windy sites. The introduction of turbines with longer blades, together with the fact that wind speeds generally tend to increase with height, mean the need for increasingly taller wind towers.

The current specifications predominantly use 1.0 to 2.5MW turbines, which require 40m long blades and 60 to 70m tall towers. These are set to change. Several wind farm developers are now introducing new generation 4.5 to 5MW turbines with rotor lengths of up to 60m. Taller towers are needed to carry these more sophisticated turbine installations.

In summary, the next generation of wind farms will demand taller, stronger towers of up to and beyond 100m. In other words, future wind power will be generated from turbines installed on wind towers that stand at twice the height of Nelson's Column.

Concrete is the serious contender for building durable 100m high wind towers with the necessary integral design flexibility.

Slender, precast concrete elements are central to the Advanced Tower System developed by Mecal and Hurks Beton.



THE BENEFITS OF CONCRETE FOR WINDFARMS

The wind industry's identified need for increased turbine sizes, rotor diameters and tower heights makes concrete a competitive option. Concrete can offer tall, strong, sophisticated wind farm structures for onshore or offshore deployment in aggressive marine or remote inland environments which require durable materials and details as a matter of course.

Low maintenance

Concrete is an inherently durable material capable of maintaining its desired engineering properties under conditions of extreme exposure. Concrete's constituent materials can easily be tailored to economically provide different degrees of durability depending on exposure, environment and the properties desired. Overall durability can be ensured by placing more sensitive structural elements such as prestressing strands in protective sheaths or if external to the concrete, then inside the pylon. With design lives for offshore wind farms in particular on the increase, concrete's inherent durability leads to reliability, resulting in wind towers with minimal maintenance requirements throughout their service life.

Design and construction flexibility

Wind farm developers require maximum power output from their sites, which can be achieved using higher-output turbines operating at heights in excess of 100m. Concrete's versatility enables design solutions with no restrictions on height or size to meet the constraints of any number of scenarios influenced by site conditions and accessibility, favoured construction methods, and availability of specialised plant.

Efficiency can be realised by optimising either in-situ or precast concrete construction methods. High quality sections can be precast in factories under controlled conditions and transported to site in units limited only by size and weight. Simple jointing details are easily achievable with precast concrete units, leading to cost effective formwork solutions and fast and efficient construction. In-situ concreting takes advantage of established construction techniques and formwork solutions to deliver quality and efficiency. With state-of-the-art mobile volumetric onsite mixing plant, in-situ construction can easily overcome transportation issues associated with more remote sites. Setting up dedicated concrete production facilities close to site can lead to significant savings in terms of both cost and efficiency. Any initial investment in formwork will be offset through its use over long production runs, giving lower unit costs.

Material flexibility

Concrete is an adaptable construction material which can be finely tuned through alterations in mix design to optimise parameters such as strength, stiffness, density and heat generation. Recent concrete technological advancements, including the use of chemical admixtures and alternative reinforcement options, allow the production of very high strength, stiff, light-weight and corrosion resistant solutions.

A recent study [1] into carbon fibre reinforced polymers (CFRP) showed that in view of enhanced material properties and reduced concrete cover requirements, the weight of a concrete wind tower prestressed with CFRP would be about 40% lower than that of an equivalent steel-prestressed structure.

As such, the range of diameters and thickness of section available to concrete wind tower designers is much greater than when working with other materials, allowing a wider range of solutions and adaptable construction methods.

Dynamic performance

As concrete has inherently higher damping properties than other materials, solutions with less noise and vibration are deliverable [2]. This is beneficial in terms of not only structural demands such as fatigue failure, but also public acceptance issues in relation to noise emissions.

Use of concrete for pylons, foundations or both can generate considerable advantages, offering design solutions that will be potentially more tolerant of occasional resonance with a reduced risk of dynamic problems. For tall offshore wind towers, for instance, the use of concrete gravity foundations instead of monopiles can offer improvements in dynamic response. For wind tower pylons, prestressing concrete offers high fatigue resistance, providing more tolerance and less risk from dynamic failure. As concrete can accommodate dimensional changes relatively easily, designs can be adapted to larger diameters to produce stronger, stiffer towers economically and avoid transport problems.

Whole life performance

Concrete can offer cost effective wind tower solutions. Recent conceptual designs and cost studies undertaken by independent consulting engineers [3,4] indicate that by taking full advantage of concrete technology and adaptable design and construction opportunities, significant cost savings for wind farm developments can be achieved. For tall towers in particular, concrete can economically deliver large diameter, low maintenance pylons with lower relative grid-connection costs and capable of generating increased levels of power. With relatively short lead-in times for concreting works and pay-as-you-pour contracts the norm, significant improvements in the way wind farms are financed may additionally be possible.

An example of concrete's versatility in delivering economic solutions has been illustrated by Mecal and Hurts Beton [2], where a 120m precast concrete wind tower was compared to an alternative 100m tower. The comparison showed that although the increase in height does require additional investment, this is offset by achieved wind speed gains; resulting in an estimated payback period of only four years.

Environmental impact

The fundamental objective of operating wind turbines is to reduce CO_2 emissions and contribute generally to a more sustainable future. Concrete's environmental credentials are excellent, with optimisation permissible through conservation of materials and the use of waste and supplementary cementing materials and recycled aggregates – all with no detrimental impact on structural performance. Concrete's ability to be manufactured locally using readily available materials and resources also impacts transportation costs, which is a key environmental consideration having significant social and economic impacts.

Recent estimates proposed by independent consulting engineers [5] have shown that for a typical 70m onshore wind tower configuration, compared to tubular steel, concrete pylon designs can deliver significant improvements in terms of:

- Embodied energy (up to 40% reductions)
- Embodied CO_2 (up to 60% reductions)

While the approximate operational time required to offset the amount of energy used to construct wind towers is relatively low (approximately 3-5 months) [6], this time can additionally be lower for concrete structures.

In terms of life-cycle design, precast concrete solutions in particular lend themselves to simple deconstruction steps and techniques. For offshore concrete gravity foundations, the employment of established flotation techniques avoid potentially complex decommissioning processes and environmental issues associated with driven monopiles in the sea bed. Reinforced concrete is additionally 100% recyclable, with options including reuse of individual concrete structural units or material crushing to provide what is now an industry-accepted aggregate source.

Upgradeable

By providing strong, stiff, durable wind tower structures with a prolonged service life, prestressed concrete design solutions introduce the option to retrofit turbines after their design life of about 20 years. Prestressing forces can easily be adapted to cope with any increased loading. Around three to four next-generation turbine life cycles could easily be accommodated in this way, thereby avoiding the financial and environmental costs of reconstruction. To fully realise this potential, the substructure would have to have similar durability; gravity concrete foundation solutions would easily meet this requirement. It is interesting to note that the current thinking in Denmark in relation to steel tower design life is limited to 50 years. Concrete tower solutions could far exceed this.

Concrete can offer high-performance wind tower solutions with improved fatigue resistance and reduced noise emissions.

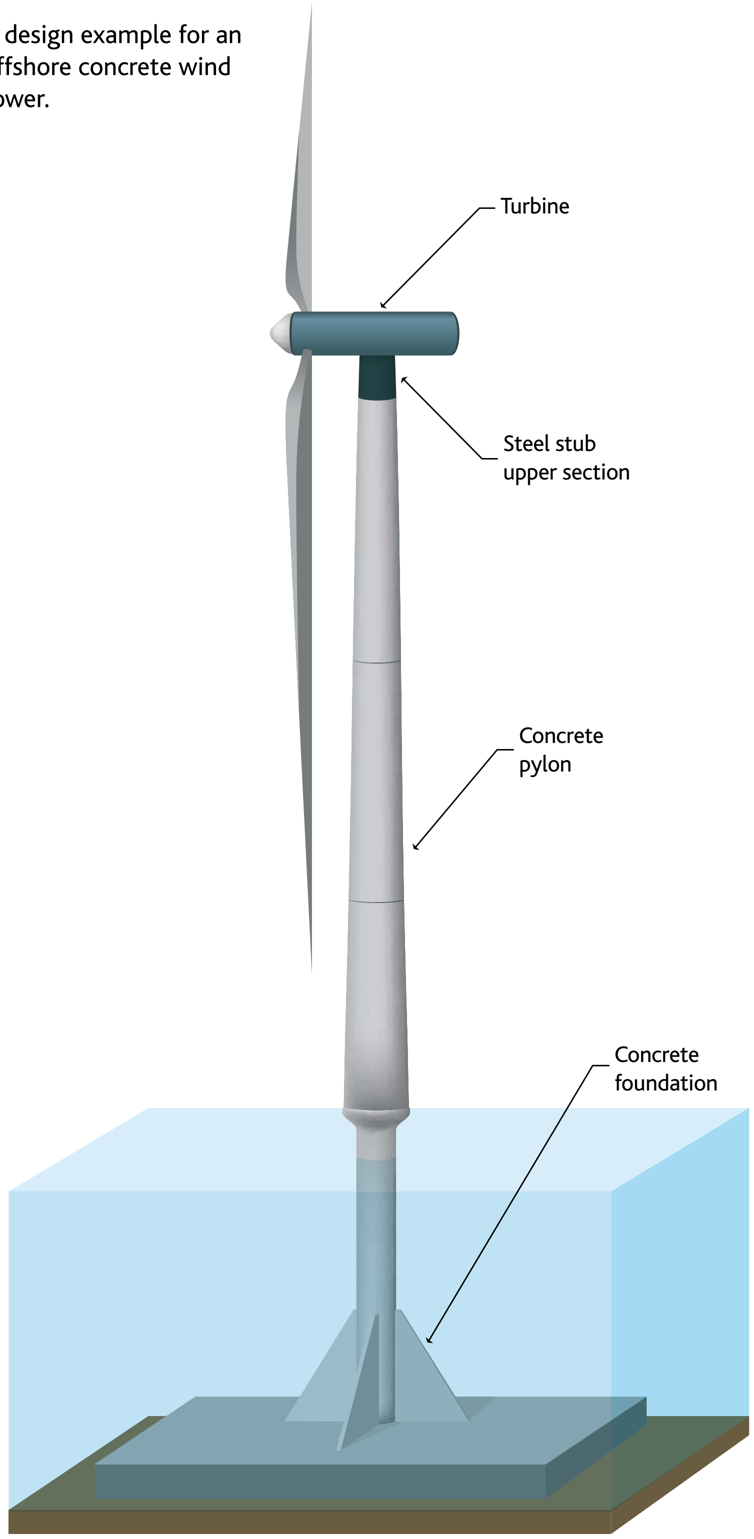
DESIGN FLEXIBILITY

As no two windfarm sites are alike, offshore and onshore wind tower designs need to be flexible enough to meet the differing needs of a wide variety of location-related constraints. Design flexibility and adaptability is central to the use of any material in wind tower solutions.

Concrete's ultimate accolade in terms of adaptability is its ability to be used in-situ to maximise benefits such as flexibility and economy, or precast under controlled factory conditions to maximise benefits such as quality of finish, repeatability and speed of erection. In-situ and precast options are valid for both foundation and pylon wind tower applications alike. Hybrid concrete construction (use of both in-situ and precast concrete) can ensure that all material benefits are realised in the optimum form.

Depending on site specifics, developers can make use of concrete's wide-ranging benefits. A generic, flexible concrete tower design concept allows each individual solution to be adapted more easily to suit local needs and conditions. Balances between wall thickness and overall pylon diameter can be calculated for individual towers to achieve uniform strength and stiffness performance.

A design example for an offshore concrete wind tower.



Concrete's design flexibility and adaptable material properties allow for tower configurations to suit all locations and construction needs.

PYLON DESIGN FLEXIBILITY

Precast Design Options

High quality precast units can be used to form both offshore and onshore pylons. This manufacturing process minimises dimensional tolerances and guarantees a high degree of fitting accuracy during erection. The size and configuration of segments can be altered to take account of lifting capacity available during construction and transportation logistics. In mainland Europe, for example, precast concrete units are being used for 98 to 124m tall pylons [7].

Precast units can be handled individually or as pre-assembled pylon sections comprising numerous precast units joined using prestressing strands. Concrete units able to flexibly accommodate detailed section changes can be constructed to large diameters without disproportionate increases in cost.

Figure 1 illustrates a typical precast unit configuration to achieve a tapered pylon profile with variable wall thickness. To accommodate project constraints, any pylon cross-section can be made up of either entire precast units, or two or three segmental units joined together. Clearly the latter option may be preferable for sites with access difficulties.

Typical joint details for precast concrete pylons units are shown in Figure 2 below. Simplicity of connection and accuracy of level are central to keeping formwork costs to a minimum and speeding up construction time on site.

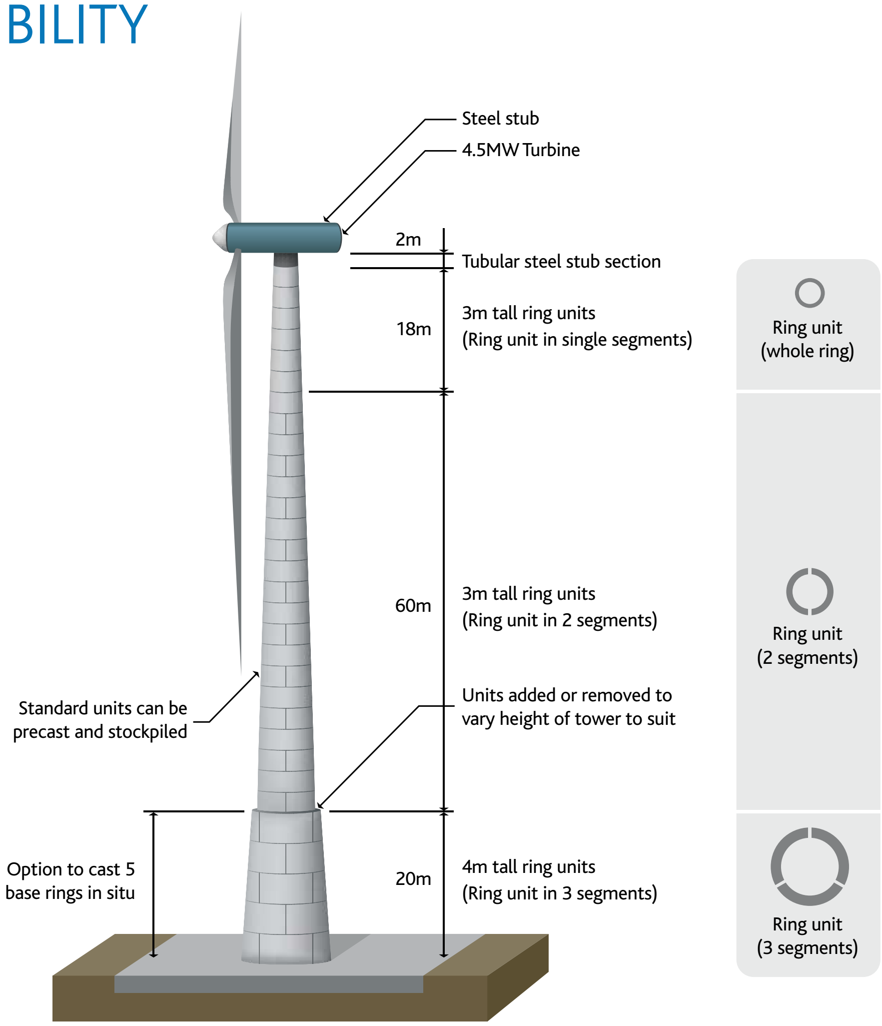
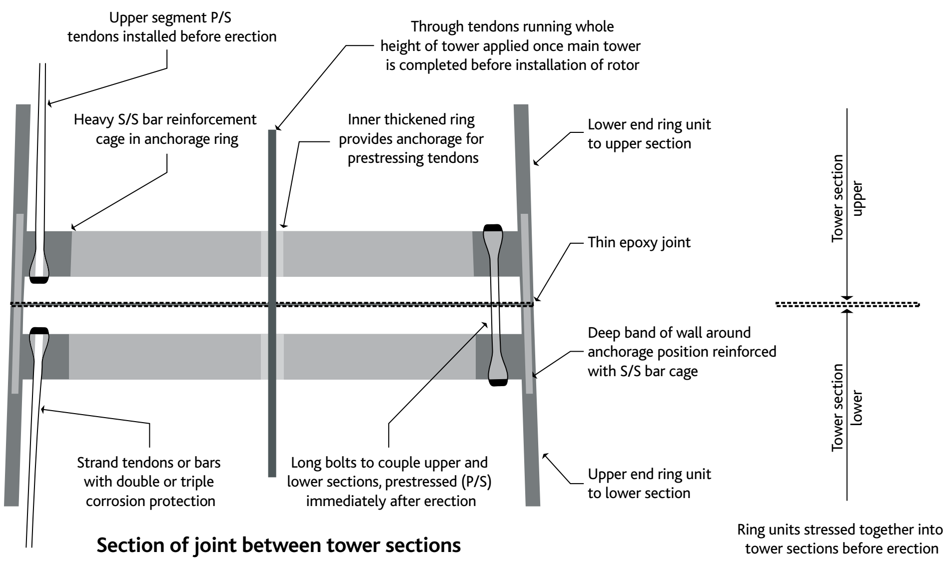
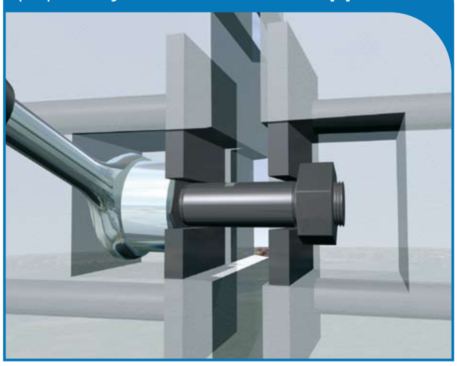


Figure 1: Typical precast concrete configuration

Figure 2: Typical precast joint unit detail



Example of precast element jointing detail proposed by Mecal and Hurks Beton [2].



In-situ Design Options

Wind tower pylons can equally be designed using in-situ concreting techniques, such as slipforming, to offer the ultimate balance between maximising construction capabilities and minimising cost. In-situ construction can overcome limited site access where delivery of large structural elements is difficult.

Delivering monolithically cast structures free from ties and cold joints, in-situ construction techniques require minimal form and space. Slipforming, for instance, is an entirely crane independent process. Together with accelerated construction times and low labour costs, cost-efficiency is guaranteed for developers.

As with precast, in-situ concrete structures can easily be prestressed to optimise in-service performance.

Prestressing

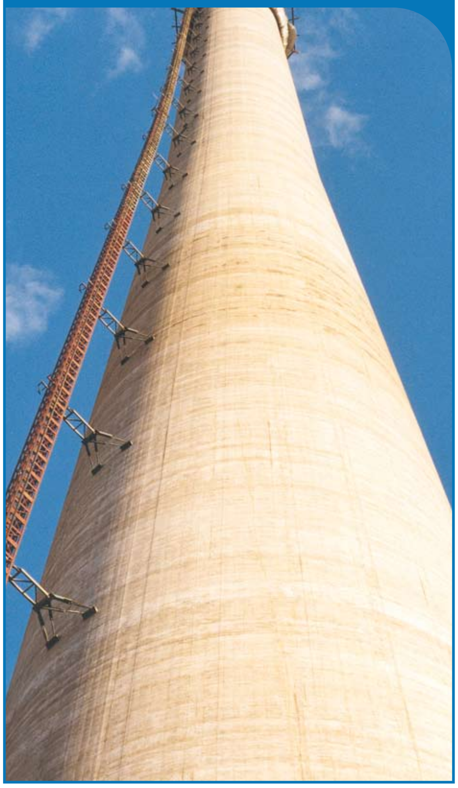
The ability to prestress concrete, coupled with concrete's inherent flexibility at the mix design stage, means that individual wind tower structures can be tailored to provide optimal levels of stiffness and dynamic performance.

A well established construction method, concrete in prestressed structures is placed under controlled compression using tensioned steel or fibre reinforced polymer cables enclosed in ducts to improve stiffness and load carrying capacity. Ducts can be incorporated into both precast concrete units (under factory conditions) and in-situ concrete (as an integral part of continuous slipforming, for instance).

Ducts can be located within pylon walls or alternatively located externally, but inside the pylon structure, to allow thin, light-weight wall construction with simple access for inspection, future capacity upgrades and decommissioning.

Both precast and in-situ concrete structures can be prestressed to optimize performance.
Images courtesy of Mecal

In-situ slipformed concrete tower.
Images courtesy of Bierrum



Prestressing ducts and tendons (on ground) for precast concrete onshore wind tower.
Images courtesy of the Concrete Society

FOUNDATION DESIGN FLEXIBILITY

Concrete is well suited for use in a range of foundation types for both onshore and offshore wind towers. As turbines become larger, foundation costs become a significant proportion of the total for wind farm developments and influence the overall cost of energy. Foundation design and selection of materials is thus critical.

Concrete can be easily and cost effectively adapted to large diameter foundations to produce stiffer towers. Monopile foundations have relatively limited structural dimensions and a restricted interface with their supporting soil. This considerably limits the overall tower stiffness achievable, particularly in poorer soils. Nevertheless, if this is the method chosen, concrete piles can offer both precast or in-situ solutions.

By increasing levels of soil interaction, concrete gravity foundations can reduce the natural oscillation period of tower systems. Concrete has high material damping properties and, particularly when prestressed, provides high levels of fatigue resistance. This is clearly advantageous for tall wind towers and provides good scope for optimising dynamic performance.

Reinforced concrete foundations can additionally be designed, through appropriate selection of materials and their mix design, to reduce costs and environmental impact while easily maintaining functionality and service life.

The gravity foundations used for the Beinn Ghlas wind farm in Argyll, for instance, were constructed using concrete containing fly ash, a by-product material produced by coal fired power stations. This not only offered a cost-effective solution, but also delivered improvements to performance parameters such as strength development and durability.

Concrete foundations can be designed in a range of sizes, shapes and densities to optimise tower stiffness, foundation pressures, and reinforcement and formwork requirements. They can be designed as ground bearing or as a pile cap and can incorporate excavated material from site to maximise foundation stability and eliminate site waste.

CASE STUDY

73 Caissons for Offshore Danish Windfarm [8]

Offshore concrete gravity foundations built in streamlined process

Casting concrete foundations on barges allowed 73 separate 1300 tonne concrete foundations to be placed ahead of schedule at Rødsand, nine kilometres off Eastern Denmark.

Contractor Per Aarsleff built the heavily reinforced foundations four at a time onto the decks of four 30 x 90m flat topped barges at a caisson yard on Poland's Baltic Sea coast.

Four lean-mix hexagonal concrete foundation mats 16.5m wide and a geotextile membrane were placed first, before the 550mm-thick caisson slab was cast in a continuous 115m^3 pour, using a C35/45 mix with 32mm aggregate. The 2.4m-high main outer and six inner cell walls and hollow central shaft followed in one continuous pour of 120m^3 of C35/45 concrete with a smaller 16mm aggregate. The next phase was the 7.2m high 55˚ inverted ice cone in a continuous 20-hour pour of the same mix.

It took up to 29 days to build four caissons. Towed to the sea bed, each caisson was lowered by a floating crane onto a specially prepared stone pad standing in 7.5 to 12.75m of water, and filled with 500 tonnes of granite boulders and sand ballast.

Client: Energi E2, Dong and Sydkraft consortium
Contractor: Per Aarsleff
Images: Courtesy of The Concrete Society

Foundations constructed on and delivered by flat top barge.

Concrete gravity foundation profiled to accept granite boulders and sand as ballast.

Foundations located on seabed using floating crane.

CONSTRUCTABILITY

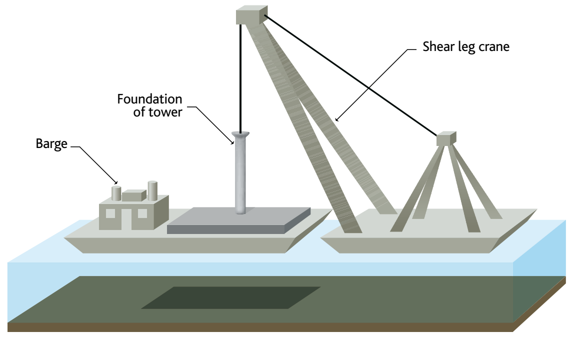
A significant portion of the capital costs associated with wind tower development is determined by installation operations and perceived levels of associated risk, particularly with regards to unpredictable environmental conditions. Concrete's versatility lends itself to a range of established construction techniques which can be easily tailored to overcome structural constraints, climatic peculiarities or architecturally-induced demands.

Offshore

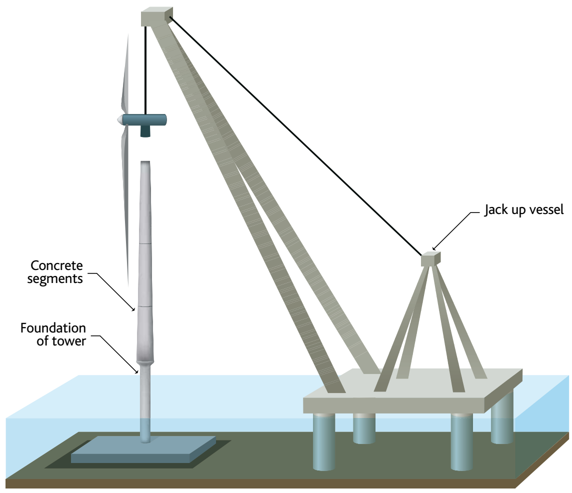
Offshore operations in particular are difficult, expensive and weather prone. Careful planning and design are required for ease and speed of erection and completion. Figure 3 illustrates typical offshore construction sequences suitable for concrete towers. Concrete gravity foundations can efficiently be constructed onshore and then installed in offshore waters using flat top barges to carry the foundations as deck cargo. Tower installation vessels can then deliver pylon sections for assembly in one or several lifts, depending upon the height of the tower. For tall pylons in excess of around 90m, delivery and assembly of concrete pylons in three sections is achievable using existing lifting plant. Concrete sections able to flexibly accommodate detailed section changes can be constructed to large diameters without disproportionate increases in cost. Individual precast units can be dimensioned to allow for easily transportable sections.

Alternatively (Figure 4), gravity concrete caisson foundations are an option, with assembly of the foundation and tower structure occurring in protected, shallow waters and then towed to site, potentially as a single entity, semi-submerged in order to increase stability. This approach would clearly offer increased efficiency by limiting offshore erection activities associated with tower superstructures. Caisson foundations in near-shore and offshore situations have a long history in civil engineering practice, and in the past few decades in the offshore oil industry in particular.

Figure 3: Onshore construction followed by independent foundation and pylon transportation and assembly

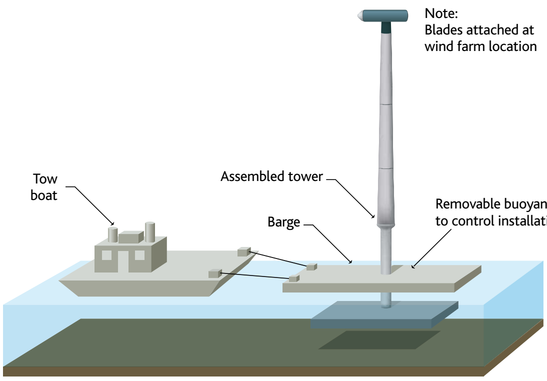


Installation of foundation

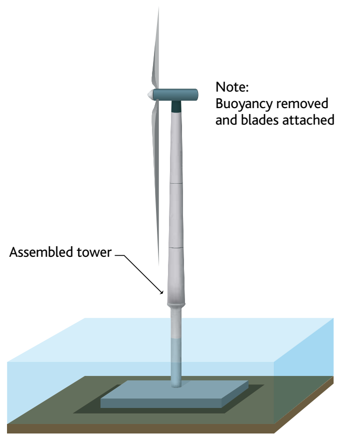


Installation of pylon segments and turbine

Figure 4: Construction of complete tower in shallow water followed by transportation and installation



Refloat assembled tower and tow out to wind farm location



Tower sunk at offshore location

Concrete wind towers are feasible structures which, in terms of performance, already fulfil the current and future requirements of the wind turbine industry.

CASE STUDY
Offshore Windfarm Middelgrunden, Copenhagen

Innovative formwork solution used for offshore gravity foundations

A state-of-the-art formwork solution was used to efficiently manufacture 20 gravity foundations onshore, prior to offshore delivery two kilometres outside Copenhagen harbour.

Egg cup-shaped to provide protection from seaborne ice, foundations with heights varying between 8.0 and 11.8m were formed using easily adjustable pre-assembled formwork units supplied by PERI.

Two PERI GRV Circular Formwork sets were used, each comprising 11 segments to form a complete formwork ring capable of withstanding tension forces up to 400kN. Completely free of formwork ties, this formwork solution enabled safe and efficient concreting speeds.

Cast into the foundations were steel rings that served both as internal formwork for the concrete and location points for the eventual 64m high pylons required for the operation of 76m diameter rotors. When the concrete had attained the desired properties, lower pylon sections were preassembled with the foundations in the dry dock prior to transportation by floating crane to the final destination in 4-5m deep waters.

The 20 turbine Middelgrunden wind farm will produce 85 million kWh of electricity per year.

Contractors: Pihl & Sohn, Kopenhagen and Monberg & Thorsen, Kopenhagen

Mass production of foundations in dry dock.

Complicated foundation profiles possible using innovative, circular formwork solution.

Concrete gravity foundations enabled onshore prefabrication of pylon sections.

Onshore

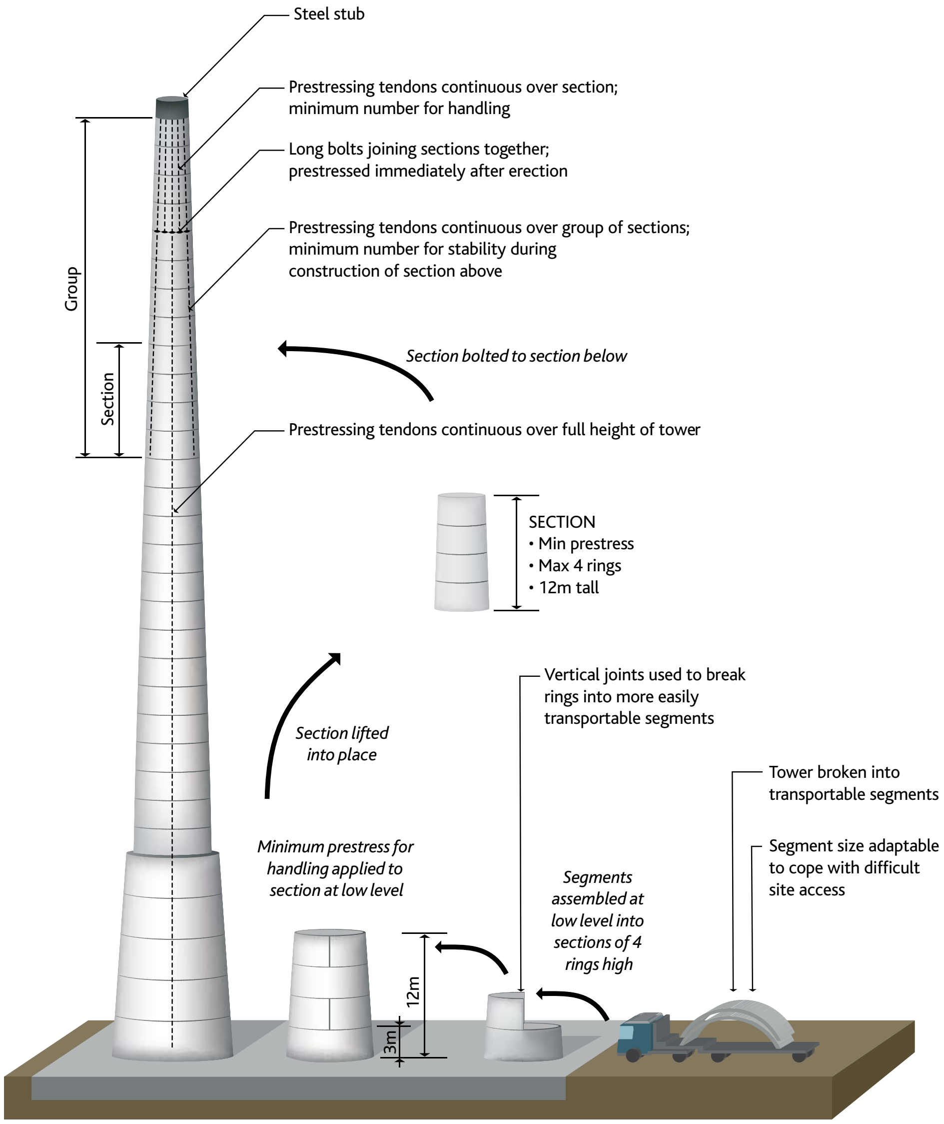
As illustrated by Figure 5, onshore wind towers can be efficiently constructed using precast concrete units. Dependent on design and any construction constraints, a monolith can be constructed by prestressing together either individual precast units or pre-assembled sections.

Onshore wind towers equally lend themselves to in-situ concrete construction, which is ideal for overcoming limited site access where access or delivery of large structural elements is difficult.

Foundations for onshore wind towers, which use weight to provide stability for the tower, are generally constructed using in-situ concrete, either as a gravity base or pile cap. Consequently, the continuation of in-situ concrete into pylons would simply be a continuation of the existing construction method, thereby avoiding any special mobilisation costs.

Established formwork solutions such as slipforming are ideally suited to in-situ concrete pylon constructions. Based on extrusion principles, slipforming uses hydraulic jacks that elevate adjustable formwork over complete structure heights in a continuous vertical sliding motion. Complicated, inclined structures with variable wall thicknesses can easily be constructed integrating prestressing strands and precast or other composite elements. Entirely crane independent, complete formwork systems are raised without opening any scaffolding or railings, there by providing optimal safety for construction crews.

Figure 5: Typical construction sequence for onshore precast concrete towers



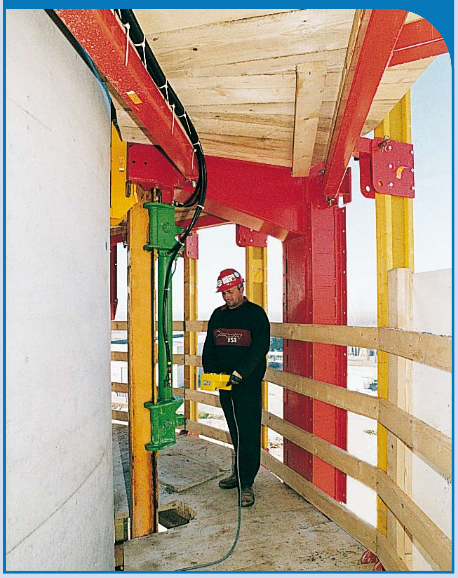
Pylons of unlimited height are deliverable by crane independent slipforming process.

SLIPFORMING

Slipforming allows construction around the clock which, on time critical projects, presents a dramatic advance in project completion times. The process enables varying wall thickness, cross sections and openings to be easily accommodated. Specialist formwork systems not only enable rapid tower construction, but limit the quantity of temporary works required and provide safe working platforms at height.

Systems such as PERI RUNDFLEX (pictured) use self-cleaning hexagonal threads on adjusting spindles to allow tight and fast adjustment of all formwork elements enabling circular formed elements with radii as low as 1m.

Safe, flexible working platform provided by slipforming formwork.



CASE STUDY

A Precast Concrete Segment Wind Farm, Lower Saxony, Germany [9]

Innovative mast climbing technique speeds up tower construction

An innovative prefabricated tower section construction technique using mast climbing work platforms enabled the fast track construction of a 14 unit wind farm in Lower Saxony.

The entire mast climbing work platform assembly worked as one unit. Two interconnecting mast climbing platforms, placed either side of the tower, were connected by two aluminium walkway bridging units. Held in a frame system, decks telescoped in and out as required, giving strength while minimising additional weight and ensuring no gap between tower and platform. Short tube anchors tied the mast to the tower at 8m intervals. After each concrete segment was placed, additional mast sections were added, and the entire system climbed to the next position.

The system provided access and a secure decked working area, while adjusting to each tower's tapering dimensions, allowing the large prefabricated segments with diameters from 2.3m to 7.5m diameter to be craned into position economically and safely using a mobile crane. The technique allowed the twenty three 3.8m high precast reinforced concrete sections required for each of the 88m high towers to be assembled quickly. A small team of six lifted seven sections into position each day.

Client: WEC Turmbau GmbH
Sub contractor: OEHM Bauuntenehmen
Images: Courtesy of The Concrete Society

Safe, rigid working platform.

Quick and efficient element construction.

CASE STUDY

Onshore Windfarm, Isle of Gigha, Scotland [10]

Mobile volumetric mixing system used to overcome access constraints

Mobile volumetric concrete mixers supplied by Armcon have enabled Cumbrian civil engineers, Ken Hope Limited, to efficiently construct concrete wind tower foundations on a relatively remote location on the Isle of Gigha.

Cementech MCD8MX-150 concrete mixing units were selected as, unlike conventional rotary mixers, they do not require a central batching plant. This approach avoided the need for concrete to be supplied via a 20 minute ferry journey from the mainland and negated the risk of wasted materials due to bad weather.

Instead, concrete constituent materials were ferried to the Isle of Gigha in bulk away from the critical timeline. The Cementech machines were then loaded on site, remaining in position until construction completion.

Armcon mobile volumetric mixers are available in a range of static and truck-mounted units ranging from 2 to 8m³ capacity and feature innovative admixture systems and replaceable components to maximise working life. With high suspension for extra ground clearance, units come complete with Globetrotter sleeper cabs enabling drivers to work at remote locations without returning to base.

Client: Isle of Gigha Island Trust
Contractor: Ken Hope Limited
Images: Courtesy of Ken Hope Limited

Ken Hope Ltd.'s Isle of Gigha project "would not have been a viable proposition" without the Armcon Cementech MCD8MX-130 volumetric mixer.

Concrete enables the construction of high-performance wind towers of unlimited height and with lower maintenance requirements.

An example of a slipformed concrete tower.
Courtesy of Bierrum

SUMMARY

In the near future, the rapidly expanding renewable wind energy market will inevitably have a requirement for the next generation of wind towers that will be up to, and beyond, 100m tall. This will keep pace with ongoing achievements in engineering design, aerodynamics, advanced materials, control systems and production engineering that have seen rotor diameters grow from 30m to 80m and power outputs from 200kW up to 5MW.

To help meet this future demand, the concrete industry can play a significant role. A variety of design and construction techniques that can easily be adapted to meet individual site conditions. Concrete can deliver economic solutions over the life cycle of a wind farm by providing a wide-range of benefits, such as:

Low maintenance – concrete is an inherently durable material capable of maintaining its desired engineering properties under extreme conditions.

Design and construction flexibility – concrete's versatility enables design solutions, with no restrictions on height or size, to meet any number of site and accessibility constraints.

Material flexibility – concrete mix designs can be finely tuned to optimise key parameters such as strength, stiffness, density and environmental impact.

Dynamic performance – concrete has inherently high dampening properties and can deliver fatigue resistance solution with less noise emissions.

Whole life performance – concrete can deliver durable, large diameter pylons of unlimited height to providing higher levels of power generation.

Environmental impact – concrete construction produces fully recyclable wind towers with significantly reduced levels of embodied energy and CO_2 in comparison to other methods.

Upgradeable – concrete can provide long life wind tower solutions capable of accommodating multiple future-generation wind turbine retrofits.

In summary, concrete is an adaptable and viable construction material which can help the wind industry meet the government's target of generating 20% of electricity from renewable sources by 2020.

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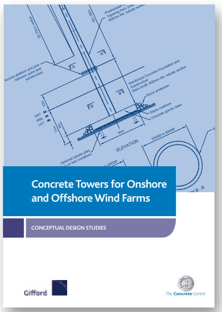

Concrete Towers for Onshore and Offshore Wind Farms – Conceptual Design Studies

TCC/02/05

The aim of this independent study is to present conceptual configurations for both onshore and offshore facilities, along with design philosophies and construction methodologies for concrete wind tower solutions. Whole life issues are accounted for, including manufacture, transportation, installation, maintenance, decommissioning, removal and disposal.

Copies of Concrete Towers for Onshore and Offshore Wind Farms can be downloaded or ordered as a hard copy from www.concretecentre.com/publications.

Onshore construction of concrete gravity foundations for 9km offshore wind farm development, Denmark.
Image courtesy of The Concrete Society

CPD presentations on concrete solutions for wind farms are available from The Concrete Centre on request. To arrange an appointment please email your details to **cpd@concretecentre.com**

If you have a general enquiry relating to the design, use and performance of cement and concrete please contact our national helpline.

The **Concrete** Centre™

Advice is free and available Monday to Friday from 8am to 6pm.
Call 0845 812 0000
Email helpline@concretecentre.com

Acknowledgements

The Concrete Centre acknowledges and appreciates the contribution to this document from the consulting engineers, Gifford.
www.gifford.uk.com

Gifford

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Computer generated image of an onshore windfarm.

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Ref. TCC/02/04
ISBN 1-904818-34-X
First published 2005

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