OpenWater
RENEWABLES LTD

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# Steel vs Concrete for Floating Offshore Wind

How hull material shapes floating offshore wind — from track record and supply chain to moorings and end of life.

## BY THE NUMBERS

**124**
Floating and Hybrid concepts tracked in the OpenWater database

**85**
concepts proposed in steel

**29**
concepts proposed in concrete

**10**
concepts combining steel and concrete

*Source: OpenWater Renewables Mara-Data database — 117 floating and seven hybrid deepwater concepts.*

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## 1.0 Introduction

A multitude of concepts for deep-water offshore wind are being proposed, and OpenWater Renewables Limited (OpenWater) are presently tracking 117 floating offshore wind and seven hybrid deepwater concepts in our in-house database Mara-Data. Of these, 85 are proposed in steel, 29 in concrete, and 10 comprise a mixture of both steel and concrete elements. The summary of materials for different hull forms is shown in Figure 1 below.

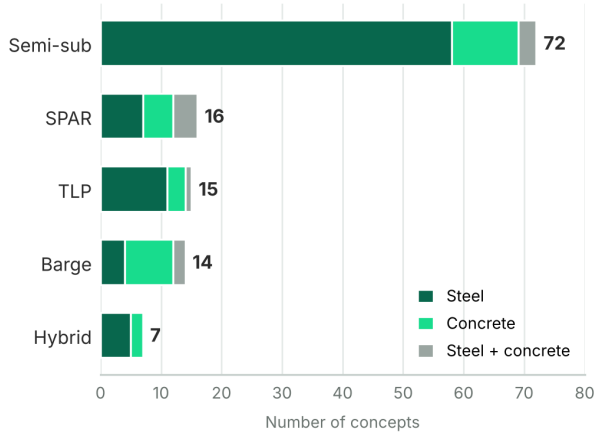



**Figure 1** Hull type by material

Steel floating structures, including tankers, bulk carriers, FPSOs, drilling semi-subs and tension leg platforms, have a long service history, and many participants in the deepwater wind industry have assumed that steel is the obvious choice for floating wind hulls. However, concrete, while less common for floating structures, has a long history of use in the marine environment and can offer advantages over steel in some circumstances.

This newsletter is not intended to promote the use of concrete over steel, but rather to compare the use of different materials for marine structures and to identify the qualities that may lead to the selection of a floating wind concept based on either material.

It should be noted that selecting a floating wind hull concept for a project depends on many factors, not just material choice, and OpenWater's concept selection tool (Mara-Rank) considers 39 criteria across the life cycle of a project. Material choice affects a number of these criteria, but others, such as TRL or the use of QCDC mooring connectors, are independent of material choice.

## 2.0 Historical Use of Steel and Concrete in the Marine Environment

Steel and concrete have been used as structural materials in coastal and offshore engineering for more than a century. Whilst there is no authoritative registry of offshore platforms, estimates for platforms in service today range from 7,000 [1] to over 9,000 [2], with more than 10,000 platforms having been installed to date. The majority of these platforms are steel jackets, with major concrete structures accounting for over 500 units, of which around 50 are oil & gas installations, and the rest are offshore wind projects. These include the 11 concrete SPARs deployed on the Hywind Tampen project, and 71 concrete gravity-based structures (GBS) deployed on the Fécamp project [3].

> **71**
>
> concrete gravity-based structures deployed on the Fécamp Offshore Wind Farm since 2022 — of fewer than 200 major concrete offshore structures [3]

Steel has dominated offshore construction since the earliest fixed jacket platforms of the 1940s and 1950s. Its high strength-to-weight ratio, weldability, and well-understood fabrication techniques made it the default choice for bottom-fixed structures and, later, for floating systems in the oil and gas industry. The first floating steel platform concepts emerged shortly after bottom-fixed structures, with semi-submersibles and tension-leg platforms (TLPs) becoming commonplace from the 1970s onward as offshore oil exploration moved into deeper water. The Hywind Demo, installed off Norway in 2009 by Equinor, was the first grid-connected floating wind turbine and used a steel SPAR – a design concept taken directly from the oil and gas sector [4].

Concrete, however, also has a long history in the marine environment. Early reinforced-concrete seawalls, jetties, and harbour structures demonstrated that, when correctly designed and using an appropriate mix specification, concrete could resist the corrosive effects of seawater and wave action. Systematic Norwegian research from the 1960s onward, documented by the Norwegian Committee on Concrete in Seawater (NUFBIS), established the technical basis for large-scale offshore concrete construction [5].

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The Ekofisk Tank, installed in 1973 by Phillips Petroleum in the Norwegian North Sea, was the first major concrete offshore platform – a prestressed, post-tensioned structure 90 metres high with a circular base 99 metres in diameter, designed by the French group C.G. Doris [6]. Its success inspired Norwegian Contractors to develop the Condeep (Concrete Deep Water Structure) gravity-based platforms. Between 1973 and 1995, Norwegian Contractors built 14 Condeep platforms, ranging from the early Beryl A and Brent B in the mid-1970s to Troll A in 1995, which had a total height of 472 metres and was constructed using 245,000 $m^3$ of concrete [7].

Floating concrete structures also emerged in the oil and gas sector. The Heidrun TLP, installed in 1995 at a water depth of 345 metres on the Norwegian shelf, was the world's first floating concrete platform and the first to use lightweight aggregate concrete as the primary structural material for an offshore hull [6]. The Troll B semi-submersible, completed in 1996, was the first catenary-anchored concrete floater. Meanwhile, concrete barge designs for LNG and LPG storage demonstrated that floating concrete structures could be constructed, outfitted, and towed over long distances. A notable example is the N'Kossa FPU, a pre-stressed concrete barge located offshore Congo since 1996. Although the unit's initial design life was 30 years, condition assessment suggests this could reasonably be extended to 40 years [8].

Despite the positive experience with concrete for oil and gas structures, steel rapidly came to dominate offshore wind substructures as the industry developed from the early 1990s. The first offshore wind farm, Vindeby in Denmark, commissioned in 1991, nevertheless used shallow-water concrete gravity bases – a natural extension of onshore practice. However, as sites moved into deeper water and turbines grew larger, steel monopiles became the most common solution, driven by cost-effective fabrication methods and structural efficiency [4]. Today, steel monopiles account for the vast majority of bottom-fixed offshore wind installations worldwide.

## 3.0 Steel for Floating Offshore Wind: Material Strengths and Weaknesses

### 3.1 STRENGTHS

Steel's principal advantage in floating wind is its proven track record as a structural material across all four main platform hull types – SPARs, semi-submersibles, barges and TLPs. The Hywind Scotland array (five 6 MW turbines, commissioned in 2017) and WindFloat Atlantic (three 8.4 MW turbines, commissioned in 2020) both use steel hulls, and the accumulated operational data from these projects underpins much of the industry's confidence. Steel's high strength-to-weight ratio enables relatively lightweight, compact designs with good hydrodynamic performance. Fabrication techniques based on plate cutting, rolling and welding allow complex geometries that can be optimised for structural efficiency. Standardised fabrication processes, a global supply of structural steel, and a mature global offshore fabrication industry mean that design, procurement and construction timelines for steel platforms can be well defined.

Steel also offers advantages during installation. Its low self-weight compared with concrete means steel floaters can be towed by light conventional vessels and do not require exceptionally deep-draught assembly areas or large dry docks. Inspection and maintenance requirements for steel are well understood, even if onerous, with visual and non-destructive testing methods well established in the industry.

### 3.2 WEAKNESSES

The principal weakness of steel in the marine environment is corrosion. Seawater, salt spray, and fluctuating humidity combine to create highly aggressive conditions, and steel requires continuous corrosion management through protective coatings, cathodic protection systems, and periodic inspection and recoating. For floating structures that will spend 25 to 30 years offshore, these maintenance requirements represent a significant and unavoidable operational cost. Offshore maintenance is logistically demanding and expensive, and any requirement for access for inspection increases the lifecycle cost of a steel platform compared with a material with inherent corrosion resistance. Oil and gas industry experience suggests that the scope of

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inspection and maintenance will increase significantly as the structure ages.

Steel is also susceptible to fatigue damage under the cyclic loading imposed by wind and waves. Welded connections are particularly prone to fatigue crack initiation, and designing welded tubular joints for fatigue is a complex and conservative process. For floating wind platforms that experience millions of load cycles over their service life, fatigue will govern the design of many structural details.

In addition, steel supply chains are global and subject to price volatility. According to the International Energy Agency, steel currently used for offshore wind support structures largely originates from coal-fired plants in a limited number of countries, raising both carbon footprint and supply security concerns [9]. The structural steel plate and sections required for floating wind fabrication are not universally available from local sources, limiting the ability to build a regional supply chain in many prospective floating wind markets.

## 4.0 Concrete for Floating Offshore Wind: Material Strengths and Weaknesses

### 4.1 STRENGTHS

Concrete's most significant advantage in the floating wind context is its inherent resistance to corrosion. Well-designed reinforced concrete with adequate cover depth and modern admixtures, including corrosion-inhibiting additives and supplementary cementitious materials (SCMs), exhibits durability superior to steel in a marine environment [10]. Unlike steel, which requires ongoing protection, concrete does not rely on a sacrificial or active corrosion management system to maintain its structural performance. This reduces operations and maintenance (O&M) costs over a 25 to 30 year asset life and raises the prospect of extending the infrastructure life beyond that of the turbine itself [11].

Concrete's high mass is an advantage for the stability of floating structures. Greater mass lowers the centre of gravity and increases the restoring moment, improving hydrostatic stability. In a comparative study, a concrete floating platform achieved a centre of gravity 1.67 metres lower than a geometrically equivalent steel design and a wind heel angle 0.8 degrees smaller [12].

Minimising platform tilt under aerodynamic loading is directly linked to improved turbine performance and reduced fatigue loading.

> **1.67 m**
>
> lower centre of gravity for a concrete floating platform than a geometrically equivalent steel design [12]

DNV has noted that for larger turbine sizes, concrete floaters are an attractive alternative to steel from both cost and carbon-footprint perspectives [13]. DNV is currently running a Joint Industry Project (Concrete FLOW JIP) to develop and refine design standards for concrete floating structures [14].

### 4.2 WEAKNESSES

The principal weakness of concrete for floating wind is its mass. While mass confers stability benefits, it also increases displacement, draft, and the demands on mooring and installation systems. Concrete platforms are heavier than steel equivalents and typically require greater water depth for assembly and tow-out, as well as deeper-draught port facilities and potentially a high quayside load-bearing capacity.

Concrete construction is inherently more time-consuming than steel fabrication. Placing reinforcement, pouring, and curing concrete are sequential steps that are less easily accelerated than steel plate cutting and welding. For large, complex floating platforms, this creates schedule risk, though prefabrication and modular construction techniques can partially address this limitation [11]. The use of ordinary Portland cement (OPC) in seawater applications poses durability challenges, as sulphate compounds and chlorides can attack the OPC paste over time. This underscores the importance of using high-performance concretes with appropriate binders – a well-established but not universally applied practice [9]. Advanced concrete formulations, including ultra-high performance concrete (UHPC) and eco-cements, are being actively developed by companies such as Saitec for floating wind applications, partly to address these durability and sustainability concerns [15].

The fatigue performance of concrete under the cyclic loads experienced by a floating wind platform also requires careful attention. While concrete is generally more fatigue-resistant than steel at equivalent stress

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levels, the design of concrete joints and connections under fatigue loading is a developing field, with ongoing research needed to reduce conservatism in design standards and improve material efficiency [11]. Water tightness to prevent leaks is a specific design consideration for concrete floaters: DNV's design standard ST-0119 [16] recognises that crack width and depth must be controlled to maintain the target buoyancy and long-term durability.

## 5.0 Project Execution: Fabrication and Local Content Opportunities

The supply chain implications of material selection are among the most commercially significant considerations for floating wind, particularly given national and regional ambitions to maximise local content in major capital investments. The two materials offer substantially different prospects in this regard.

Steel floating platforms operate within a global fabrication market dominated by a small number of large specialist yards, many of which are based in Asia. Structural plate steel for offshore applications requires controlled steelmaking processes and specific material grades that are not available from all producers. The specialist welding, dimensional control, and quality assurance required to reliably deliver a large number of hull structures effectively limit the supply chain to experienced heavy fabricators. This creates a concentration risk: supply chain bottlenecks for large-scale steel floating wind deployment are a recognised challenge in emerging markets [17]. Some efforts are underway to develop local steel supply chains - for example, a UK Innovate-funded project led by Marine Power Systems is working with Tata Steel to develop strip steel from the Port Talbot steelworks for use in floating platforms, specifically to build local supply chain content in South-West Wales [18].

Concrete presents a fundamentally different supply chain profile. The constituent materials of concrete – aggregate, cement, water, and steel reinforcement – are available in most coastal regions of the world, and the skills required for concrete construction (formwork, reinforcement fixing, concrete batching, and placing) are widely distributed across the civil engineering sector. A 2021 study by the UK's Offshore Renewable Energy (ORE) Catapult, in partnership with Arup and the Concrete Centre, assessed Scotland's readiness to manufacture concrete floating wind substructures at commercial scale. The study found that Scotland's concrete supply chain already had sufficient capacity in most areas, including the supply of lower-carbon concretes, and identified several suitable port sites, including the Cromarty Firth, Hunterston, Kishorn, and Ardersier [19]. The scale of material required is nevertheless significant: a single 15 MW concrete floating foundation would weigh more than 15,000 tonnes, and a 500 MW project would require approximately 33 such structures, but this would still represent only 0.5% of annual UK concrete construction [20].

> **0.5%**
> of annual UK concrete construction — the share a 500 MW project of 33 concrete floating foundations would represent [20]

BW Ideol has gone further, arguing that there is effectively no feasible path to gigawatt-scale floating wind deployment using steel semi-submersibles at the required speed and cost. It is partnering with cement producer Holcim to develop dedicated concrete platform manufacturing lines in southern France and north-east Scotland [21]. Saitec Offshore Technologies, whose DemoSATH concrete barge is the first floating wind unit connected to the grid in Spain, emphasises that the concrete supply chain is present worldwide, enabling on-site or near-port fabrication that reduces logistics costs and stimulates local employment and economic development [15]. The ability of concrete fabrication to leverage existing civil engineering skills and local materials means that floating wind could act as an economic catalyst in coastal communities – an important consideration for project permitting and political support.

## 6.0 Impact of Material Selection on Mooring System Design

The choice between steel and concrete for the floating substructure has direct and significant implications for mooring system design. Mooring systems for floating wind must maintain station-keeping, provide restoring forces to limit platform offset, and withstand the

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combined effects of wind, wave, and current loading over a 25 to 30 year operational life.

The higher displacement of a concrete platform compared with a steel design of similar function has two primary effects on mooring design. First, the static pretension in mooring lines must be increased to hold the heavier platform against environmental loads. Second, the greater mass and added inertia of a concrete platform shift its natural periods in surge, sway, heave, roll, pitch, and yaw. This may be an advantage where resonance is a key concern.

For catenary mooring systems – the most common configuration for floating wind – a heavier platform requires heavier or longer mooring lines to provide the required restoring force, increasing the material cost and seabed footprint of the mooring system. The COREWIND EU research project, which used concrete-based semi-submersible and SPAR reference designs, developed optimised mooring configurations for concrete floaters to reduce the levelised cost of energy by at least 15% compared with equivalent bottom-fixed offshore wind [22]. This work concluded that the mooring design should be optimised as part of the platform concept from the outset, and that concrete platforms benefit from tailor-made mooring approaches rather than direct adaptation of steel-platform designs.

The dynamic characteristics of concrete and steel platforms also differ in ways that affect mooring fatigue. In a study comparing a UHPC fibre-reinforced composite foundation with a steel equivalent for a 10 MW turbine, the concrete foundation produced peak surge motion approximately 8.6% smaller and peak pitch response 27.3% smaller than the steel equivalent under normal loading conditions [23]. Because mooring line fatigue is driven by the range and frequency of dynamic tension variation, this reduced motion translates directly into lower fatigue damage – a critical consideration given that mooring system failure is likely to be one of the primary reliability risks for floating wind farms.

**27.3%**

smaller peak pitch response for a UHPC concrete-type foundation versus a steel equivalent for a 10 MW turbine [23]

Anchor design is also affected by platform mass. Heavier platforms generate higher loads on the mooring lines. This can increase anchor costs but is generally manageable within the existing offshore mooring technology portfolio. The University of Maine VolturnUS reference platform – a concrete semi-submersible – uses a hybrid mooring system combining chain and synthetic rope segments and has become a reference case for floating wind mooring analysis under international design standards [24].

## 7.0 Decommissioning, Life Extension and Repowering: Implications of Material Selection

Material selection has significant implications for the treatment of a floating wind hull at the end of the turbine's operating life. This aspect is gaining importance as the industry approaches its first generation of commercial-scale wind farms, most of which are being designed for a 25 to 30 year service life.

For steel hulls, the prevailing industry assumption, informed by experience with fixed-bottom offshore wind, is that end-of-life will involve full removal and recycling of the hull. Current guidance for floating wind end-of-life planning notes that, given decades of loading and the consumption of any corrosion allowance built into the original design [25], a hull is unlikely to retain sufficient fatigue life margin at the end of turbine service to justify reinstallation elsewhere. Consequently, the residual value of a steel floating wind hull at end-of-life is expected to be largely limited to scrap steel value, rather than the substantially higher value of a reusable structural asset. This mirrors the experience of fixed-bottom steel foundations, where industry forecasts anticipate only limited scope for reusing existing structures, since the foundation was originally sized for a smaller turbine and is rarely a good structural match for a later-generation replacement [26].

For concrete hulls, the position is markedly different. Concrete's favourable fatigue performance relative to steel, combined with its inherent corrosion resistance (see Section 4.1), means that a well-designed concrete hull can be expected to retain substantial structural capacity beyond the 25 to 30 year design life of the turbine it originally supported. Oil and gas precedent supports this: the N'Kossa floating concrete barge,

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discussed in Section 2.0, was condition assessed as reasonably capable of a 40 year life against an original 30 year design life [8]. Fixed concrete gravity-based structures offer an even longer track record – Troll A, commissioned in 1995 (Section 2.0), remains in continuous service three decades later.

Bouygues Offshore indicates that concrete Gravity Based foundations may be suitable for up to 100 years design life [27].

This durability offers the prospect of a different end-of-life pathway for concrete floating wind hulls. Rather than decommissioning and scrapping, a concrete hull could be disconnected, inspected, and overhauled, with a new turbine, tower, and associated systems fitted for continued operation, either at the original site for life extension or, after tow to a new location, redeployed on a new wind farm. This mirrors established practice for concrete hydroelectric dam structures, where only the generating equipment, not the dam structure, is replaced at the end of the equipment's service life.

> *"Only the generating equipment, not the dam structure, is replaced at the end of the equipment's service life."*

Realising this potential is not automatic and depends on decisions made at the concept selection and design stages. A robust in-service inspection regime, aligned with emerging design standards such as DNV-ST-0119 [16], will be needed to build the evidence base required to support recertification of a hull for extended or repurposed service. The mooring and turbine interface, including the tower connection, cabling, and disconnect systems, will also need to be capable of disconnection, refurbishment, and reconnection. This should be considered as part of the system design, rather than as a retrofit.

The benefits of reusing an existing hull include avoiding fabrication costs, reducing lead time, and eliminating the embodied carbon of a new substructure. However, disconnecting, towing to a suitable facility, and overhauling a hull is itself a substantial undertaking, and the net economic benefit compared with procuring a new-build unit will be project- and site-specific.

If concrete hulls can be reliably validated for multi-generation service, this would represent a meaningful point of differentiation from steel, where the current industry expectation is that end-of-life will predominantly mean full removal and scrapping. Further development of design standards, in-service data, and life cycle assessment work, potentially building on frameworks such as DNV's Concrete FLOW JIP [14], would materially reduce uncertainty in this area and support more informed concept selection decisions.

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AT A GLANCE

## Steel vs concrete for floating offshore wind hulls

| | STEEL | CONCRETE |
|---|---|---|
| **Track record** | Proven across SPARs, semi-subs, barges and TLPs; Hywind Scotland and WindFloat Atlantic | Decades of North Sea service (Ekofisk Tank, Troll A, Heidrun TLP); fewer floating concepts to date |
| **Mass & stability** | High strength-to-weight; light, compact hulls with good hydrodynamic performance | High mass lowers centre of gravity and improves hydrostatic stability |
| **Durability** | Needs coatings, cathodic protection and inspection; fatigue at welded joints | Inherent corrosion resistance; lower O&M and potential life beyond the turbine |
| **Construction** | Mature, fast plate cutting, rolling and welding | Sequential pour and cure is slower; prefabrication and modular methods help |
| **Ports & installation** | Towed with light vessels; no deep-draught assembly areas needed | Greater draft; deeper water for assembly, tow-out and port facilities |
| **Supply chain** | Concentrated in specialist yards, many in Asia; price volatility | Materials and skills available in most coastal regions; strong local content |
| **Moorings** | Lower pretension and lighter mooring hardware | Higher pretension and heavier lines, but reduced motions and mooring fatigue |
| **End of life** | Expected full removal and recycling; scrap value | Prospect of reuse with a new turbine, at the same or a new site |

*Summary of the comparison set out in Sections 3.0 to 7.0.*

## 8.0 Summary

Steel and concrete each offer complementary advantages for floating offshore wind substructures. Steel's current dominance reflects its proven track record, lightweight properties, mature fabrication, and the direct inheritance of technology from the oil and gas sector. It is expected that steel will continue to be used for floating wind platforms, particularly compact semi-submersibles, though in some regions the steel supply chain would benefit from industry and government investment.

Concrete, however, is increasingly recognised as a strong candidate for commercial-scale floating wind deployment – particularly for barge and large semi-submersible designs, where its mass provides hydrodynamic benefits, its corrosion resistance reduces lifecycle costs, and its locally sourced supply chain delivers regional economic benefits.

Historical precedents from the North Sea oil and gas industry – from the Ekofisk Tank to Troll A Condeep and the Heidrun floating TLP – demonstrate that concrete can be designed, constructed, and deployed in some of the harshest offshore environments, performing reliably over multi-decade asset lives. The challenge for the floating wind industry is to translate this service record into scalable, cost-competitive substructure designs, supported by adequate port and fabrication infrastructure.

The mooring system should, in all cases, be designed as an integral part of the floating system concept. Concrete platforms' greater mass demands appropriately sized mooring hardware and anchor systems, but it also brings inherent benefits, including reduced dynamic response and mooring system fatigue. The optimal material choice will ultimately be site and market specific, reflecting water depth, distance to port, local supply chain capability, and overall project economics. However, the case for concrete as a serious contender at commercial scale is now well established.

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## 9.0 Glossary

| | |
|---|---|
| **DNV** | Det Norske Veritas |
| **FPSO** | Floating Production Storage and Offloading |
| **FPU** | Floating Production Unit |
| **LNG** | Liquefied Natural Gas |
| **LPG** | Liquefied Petroleum Gas |
| **O&M** | Operations and Maintenance |
| **OPC** | Ordinary Portland Cement |
| **QCDC** | Quick Connect Disconnect Coupling |
| **SCM** | Supplementary Cementitious Materials |
| **TLP** | Tension Leg Platform |
| **TRL** | Technology Readiness Level |
| **UHPC** | Ultra High Performance Concrete |

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