# SPUN PRE-STRESSED CONCRETE POLES: ALTERNATIVE TO WOODEN AND STEEL POLES FOR LOW, MEDIUM, AND HIGH VOLTAGE

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## ABSTRACT

*This paper presents the advantages of spun pre-stressed concrete poles. Key benefits include greater life expectancy, minimized maintenance costs, greater stability, major environmental benefits, protection from vandalism, health and safety advantages, and lower costs over the entire life cycle of the product.*

## 1. INTRODUCTION

As manufacturer and engineering service-provider, Europoles has gained experience for 130 years in pole construction from a great variety of materials. The company provides all its own calculations and shop drawings and is a member of the National and European Standardisation Group. The concrete from the resulting state-of-the-art prestressing and spinning technology represents a major transformation. The use of wooden and steel poles is widespread for overhead lines. The pre-stressed spun-concrete poles technology, as an alternative, is environmentally driven. However, not all utility companies apply standards related to concrete poles. The applied solution must fit the global costing target. The present treatment describes the design, production, and market performance of such poles. It elaborates in detail on the properties of various pole materials in overhead-line construction, as well as on the state of the art in concrete poles, and shows how concrete is a viable alternative to other materials such as wood and steel.

## 2. NORMATIVE BASICS

Concrete poles produced with ultra-high-strength prestressed spun concrete are normatively regulated in Europe [1], [2], [3], [4], [5], [6], [7]. This ensures complete adherence to fundamental standards for raw materials, design, and production, and enables ideal conditions for market entry. CE marking evidences thorough adherence to quality and safety stipulations.

## 3. LIFE EXPECTANCY

### 3.1 Resistance

In spun-concrete pole technology, the spinning and the tensioning of the steel strands produce a dense and pore-free surface that is extremely resistant to aggressive environmental media such as air and frost, and to other influences such as fire and mechanical damage. The results are based on intensive work in this technology for over 50 years. The oldest concrete poles still in use date from 1957. CDF tests (freeze-thaw resistance in concrete tests with sodium chloride solution) and tests for carbonisation provide additional evidence of extreme resistance to chlorine action, carbonisation, weathering, and mechanical impacts according to EN standards.

Fig. 1: MV angle section pole in the desert of Oman.

Impressive examples are shown in the use of pre-stressed spun concrete poles for 33-kV and 132-kV overhead lines in Oman, with extreme conditions of temperatures up to 60° C, sandstorms, termites, fire, and sun. The customer Petroleum Development Oman required a high-quality, reliable pole with a life span of 50+ years. These spun-concrete poles have been in use for three years and have successfully survived two 170-km/h cyclones.

Fig. 2: HV poles in service in Oman.

### 3.2 Maintenance

The long life expectancy of these poles (80 years) results from the advanced design and superior production processes. The spinning process compacts the concrete at 20 *g* and results in concrete with very low water-cement ratios, down to 0.28[-]. This results in high compressive strengths and virtually pore-free surfaces. The smooth and practically pore-free, highly compressed surface requires no special inspection, coatings, nor any additional protection against corrosion. To maintain standards, it is necessary to implement a highly efficient quality system. Pre-stressing prevents cracks and contributes to optimized utilization of steel and concrete. During their service lives, these concrete poles and bolted connections require only visual inspections. The material will not shrink as wood does, and mounted fittings will accordingly not become loose, once properly mounted. The high-quality stainless steel inserts do not produce the brown marks that typically run down conventional poles. The lack of stays prevents farmers from unintentionally damaging the poles. The security of a grid is one of the key aims of network owners. In salty or dusty air, flashovers readily occur and set fire to wooden poles.

Fig. 3: Remains of a wooden pole after a fire.

Overall costs for maintenance are therefore reduced significantly, as a result of minimum pole refurbishment and longer inspection windows, with savings of around €20 for each pole per year. This saves the owner's money, increases profits, and secures assets.

## 4. STATIC PERFORMANCE

Poles made of high-performance concrete (C55/67 to C100/115) were developed to enable greater loading capacities, higher tensile and compressive strengths, lower wall thickness and diameters. The occurring deformations are reduced due to the high e-modulus (up to 60,000 N/mm²).

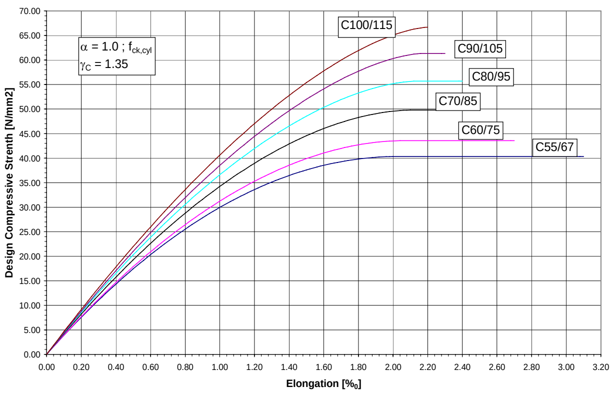


Fig. 4: Parabola-rectangle diagram for concrete under compression in accordance with DIN 1045-1.

The production processes in this case enable safety factors lower than for natural products with their inherent inconsistencies. Early pole failures are also eliminated – a problem that increasingly occurs in rotting of conventional wooden poles. Pre-stressed spun concrete pole design has far fewer constraints, and these poles maintain full strength capacity over the expected lifetime of 80 years.

| *According to FOS homologation | Resistance | Permanent loads | Variable loads | Global FOS |
|---|---|---|---|---|
| Wood | – | – | – | 2.5 |
| Pre-stressed spun concrete poles | $\gamma_C = 1.35$* $\gamma_S = 1.15$ | $\gamma_g = 1.35$ | $\gamma_q = 1.35$ | – |
| Concrete poles | $\gamma_C = 1.5$ $\gamma_S = 1.15$ | $\gamma_g = 1.35$ | $\gamma_q = 1.35$ | – |
| Steel | $\gamma_S = 1.1$ | $\gamma_g = 1.35$ | $\gamma_q = 1.35$ | – |

Fig. 5: Overview of **F**actor **O**f **S**afety according to the majority of European standards.

The polished moulds create a smooth surface, at an equivalent roughness of less than 0.1 mm (5 times smoother than steel). The increase of moment values is virtually equivalent to the increase in the moment of inertia. The combination of circular cross sections and a very slender silhouette results in wind effects far weaker than with poles of other materials or types of cross sections.

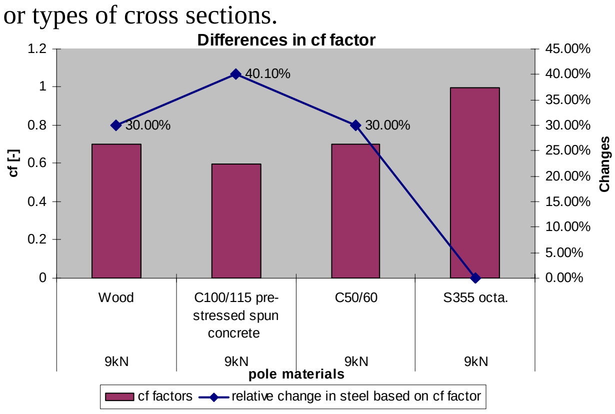


Fig. 6: Low cf factor (aerodynamic factor) of pres-stressed spun concrete poles (DIBt homologation).

Fig. 6 shows the effect of smoothness of the surface. Fig. 7 reveals the savings of moment due to wind on a 14-m pole shaft. The total bending moment is reduced by approx. 7 kNm compared to steel and 3 kNm compared to wood.

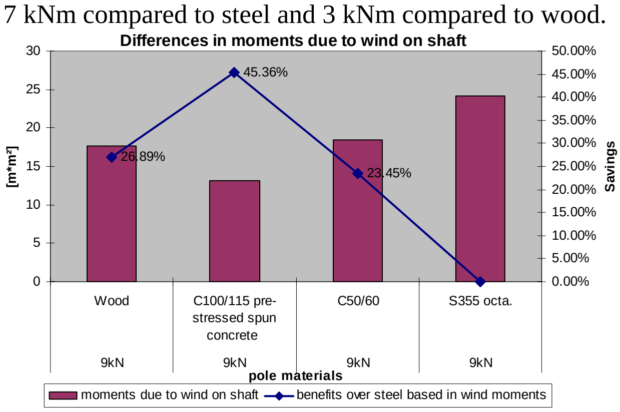


Fig. 7: Benefits in moment due to wind on shaft.

## 5. FOUNDATION

Installation of spun pre-stressed concrete poles requires no special foundation systems. The poles can be simply embedded in the ground, as is the case for other monopole types, or can be installed on a base plate. The pole base will not rot in aggressive soil. For higher voltages and loads, special foundation solutions can be designed: e.g., drop-in foundations or anchor cages.

## 6. LOCAL PRODUCTION

Construction of local production facilities is highly advantageous owing to ease of access to the required resources, which are practically universally available. Numerous benefits result. Proximity to the raw materials, local labour, and short distances to the installation sites enable short, flexible, and dependable delivery times. Logistical expenses are minimized in comparison to distant production sites. This eliminates expensive import of raw materials. All these factors result in an enormous degree of planning and supply security – and the satisfaction of using resource-saving alternatives.

## 7. ENVIRONMENT

DIN EN ISO 14001:2009-certified manufacture of pre-stressed concrete poles, long life expectancy, use of local raw materials and resources, and minimal maintenance all reduce the $CO_2$ footprint. In 2008, a study by LCEE (Life Cycle Engineering Experts), in Darmstadt, Germany, verified these benefits. Over its total life, a C100/115 concrete pole has around twice the carbon footprint of a wooden pole – but does not contain hazardous material. All materials in a pre-stressed spun concrete pole are 100 % recyclable. After manufacture, concrete is neutral and does not react with other substances. A study [8] has concluded that creosote has a greater carcinogenic potential than previously known. In the near future, further restrictions on conventional impregnation substances can be expected. Pre-stressed spun concrete poles are designed to resist high loads without stays, which avoids clutter and optical pollution. These benefits enable economic use of raw materials and protect the environment. Resource-conserving spun-concrete technology also offers greater possibilities in selection of pole location, since the inert material allows installation of poles near sensitive sites (playgrounds, kindergartens, etc.).

## 8. SECURITY

### 8.1 Vandalism

Vandalism has become a major concern with poles. The theft of earthing cables and copper conductors by felling poles is not possible with spun concrete. Pre-stressed spun concrete poles have the earthing systems on their interiors, and the hollow cores can be used to install pole infrastructure: which protects sensitive systems from possible vandalism and theft. These poles cannot be climbed without special equipment, which enhances security.

### 8.2 Durability and flexibility

The surprising flexibility and exceptional reactions of concrete poles are major aspects. Installed in a grid at angles, with section and terminal poles exposed to storms or heavy ice loads, concrete poles are far better capable of bending in the direction of the loads without being damaged – unlike stayed poles or lattice towers. As soon as conductor tension abates, pole displacement balances the line and reduces the load on the poles.


Fig. 8: A 15-m intermediate pole under bending test with a displacement of 10 %.

In rocky soil the bottoms of wooden poles are often cut during installation process to save expenses in excavation. On a concrete pole the mark and ID plate cannot be removed, which guarantees for the owner the correct embedment length.

### 8.3 Health

Contrary to other materials, concrete poles avoid potential health concerns. Stocking and handling are safer thanks to the smooth surfaces.

## 9. ECONOMY OF A PRE-STRESSED SPUN CONCRETE POLE

Studies reveal that a pre-stressed concrete pole costs half as much as a steel pole. Considering life expectancy and additional inspection or disposal costs, it is cheaper than a wood pole. Additionally, short times for delivery lower inventories and logistics expenses, which help to reduce working capital.
A pre-stressed spun concrete pole has a steel share of max. 2-4 %, which provides independence from fluctuating steel prices. The pole structure enables application of high loads at one single point, without the requirement for special measures.

## 10. HYBRID POLES: FURTHER ALTERNATIVES TO WOOD AND STEEL

Hybrid poles entail a combination of two different materials, such as concrete and steel or concrete and fibreglass. The extraordinary success of concrete-base poles, topped with galvanized steel components, is due to the lower environmental impact of the right-of-way, as well as to savings in comparison to all-steel or all-concrete structures in specific soil conditions. Additional material combinations are possible: base sections of concrete and upper sections of steel or glass-fibre reinforced plastic (FRP), which reduces total weight. Long life cycles in aggressive soils are not affected by the direct connection of various materials. The spun-concrete pole combined with an upper FRP section offers the possibility of pole use as an insulated system. FRP cross arms can also be part of this solution. With the hybrid variation of steel at the bottom and FRP at the top, the focus of optimisation is primarily on reduction of overall weight: which enables total weight comparable to wooden poles.

## 11. SUMMARY

The following diagram shows key parameters in the selection of pole materials:

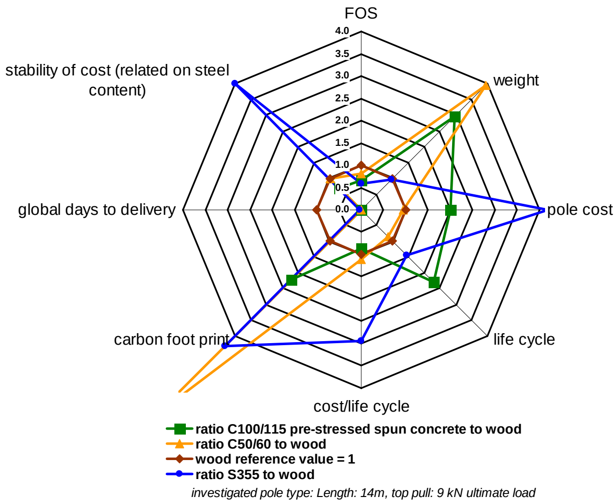


Fig. 9: Comparison of various pole materials

The diagram above is based on the wooden pole (value = 1) as the basis for evaluation of the various pole materials. Industrial production enables reduction of safety factors without lessening security.

With respect to weight, wood and steel are approximately the same.

Life cycles are the longest for pre-stressed spun concrete poles for the materials considered here. Inspection intervals can be increased without disadvantage.

Concrete poles are considerably more expensive than wooden poles – but far less than steel poles.
The concrete pole is far more favourable than wood with inclusion of service life, inspection costs, and disposal. The carbon footprint of concrete poles is far lower than of steel or conventional concrete poles – but does not achieve the low level of wooden poles. However, this does not take into account the potential health issues associated with the use of other pole materials (it must be noted that the $CO_2$ balance does not consider the use of hazardous materials). A concrete pole can be returned 100 % to the raw materials cycle, with the user thus satisfying his ecological responsibility.
With local production, concrete poles achieve the best delivery quality of all materials, and enhance the local economy. Unlike all other poles, pre-stressed spun concrete poles can be stored for unlimited periods of time.

All the aspects of life expectancy, maintenance, environment, health, foundation aspects, global cost, and safety result in superior performance for pre-stressed spun concrete poles.

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[5] DIN EN 50423-1, 2005-05: *Overhead electrical lines exceeding AC 1 kV up to and including AC 45 kV*

[6] DIBt (German Institute for Civil Engineering), notification of approval Z-15.13-257: *Masts, Columns and linear Elements of Spun Concrete*

[7] DIBt (German Institute for Civil Engineering), notification of approval Z-13.1-117, *Pre-stressing of Strands*

[8] Commission Directive 2001/90/EC, 2001, *adapting to technical progress for the seventh time Annex I to Council Directive 76/769/EEC on the approximation of the laws, regulations and administrative provisions of the Member States relating to restrictions on the marketing and use of certain dangerous substances and preparations (creosote)*