Precast Braced Foundation:
Towards a CoE Reduction *From the Very Base*

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1. INTRODUCTION

The wind energy sector nowadays is facing a fierce competition between the different companies on every field. In most of the countries, the energy auction system has come...and will stay. In the present conditions, any detail might be decisive.

At the same time, Wind Turbine Generator (WTG) foundations are one of the few elements within the wind technology not been subjected to relevant evolutions in the last years, mainly due to the good behaviour and adaptability to a large range of soil types as well as their construction simplicity.

Nevertheless, as a result of the increasing hub heights and rated power of the turbines, foundations loads have increased significantly, and so has done the concrete volume of regular shallow slab foundations, reaching values close to 450m^3 with some degree of regularity.

Several efforts have been made so that to reduce efficiently the concrete volume and reinforcing steel weight in WTG foundations. For this purpose, different alternative variations have come to light in recent years. However, the majority of them have not had a significant penetration in the market since effective material savings resulted in much higher execution costs as well as longer construction schedules.

The **precast braced foundation concept** comes a result of the extensive experience collected by ESTEYCO ENERGÍA and its professional team in the WTG foundation sector –up to date with more than 5,000 WTG foundations designed and already built– together with their pioneer experience as precast concrete tower designers –with more than 500 WTG towers. This background has led to come up with a patented, certified design (both by DNV-GL and TÜV SUD) and 100% owned solely by ESTEYCO concept that unites the advantages that nowadays can be found in the different techniques applied to WTG foundations state of the art.

Figure 1 – General view of the precast braced foundation during construction works

The key of the concept is based on the **strict concrete materialization of the load path** needed by the turbine loads in their way down from the tower –not a single cubic meter more, not a single cubic meter less- advantageously using at the same time the natural soil as a stabilizing self-weight. Additionally, the introduction of precast elements allows the industrialization for both manufacturing and assembling stages. All these aspects are leading to a robust and solid solution that puts significantly down the Cost of Energy (CoE)

2. CONSTRUCTION STAGES

The construction method is divided into 1+6 different stages:

- **Stage 0: Precast braces casting (1 brace per mould and day)**

  Moulds can be stocked at some existing facility in the vicinity of the WF or preferably within it, as the system doesn't need high-tech facilities. Every day the sequence is working sequence will start by demoulding the previous day casted braced, going then to cleaning the mould, putting in the reinforcement and postenssioning steel, finally casting a new brace.


Figure 2 – Construction stage 0

- **Stage 1: Excavation and blind concrete casting**

  All these operations are carried out in the same way as in a conventional foundation solution.

- **Stage 2: Lower reinforcing steel and pedestal formwork arrangement**

  Reinforcing steel can be manufactured straight at its final position or at the top of the excavation and then descended. In the latter case the excavation and steel arrangement operations are independent and may become a more industrialized process.

  The pedestal formwork acts at the same time as brace positioning template.

Figure 3 – Construction stage 2

- **Stage 3: Braces positioning and lower slab casting**

  In this stage lower slab, edge beam and central pedestal are casted.

Figure 4 – Construction stage 3

- **Stage 4: Central ring execution**

  The process has not significant differences when compared with a conventional wall execution.


Figure 5 – Construction stage 4

- **Stage 5: Upper slab execution and backfilling**

  Very light compactation requirements needs are asked for the filling as the density considered in the calculations is very low, from the safety side, so that not delaying the process.

Figure 6 – Construction stage 5

- **Stage 6: Brace's posttensioning**

  Posttensioning works are carried out with conventional, commercial and worldwide available systems, requiring just 2-3 hours per foundation.


Figure 7 – Construction stage 6

All these stages lead to a more efficient and industrialized construction, with the advantages that comes from the quality of the construction point of view. Additionally, the efficiency in the process that is achieved leads to a shorter construction schedules for wind farms from 15-20 foundations on.

3. ADVANTAGES AND RESULTS (INCLUDING TRACK RECORD)

As referred the main and primary advantage of this solution is the **significant reduction of the Cost of Energy**, which is at the end of the day the aim that currently all agents involved in the wind energy sector are actively pursuing. That advantage comes from a double source:

- The precast braced foundation **increases the Energy production AEP**, as a result of the hub height HH gain provided to the turbine with regards a traditional foundation.
- The precast braced foundation **puts down the foundation execution cost**.

As a reference, on one hand a +5m HH increase will bring an **AEP gain** between **1.5% and 2.5%** in most of the cases (depending largely obviously on the wind distribution and shear of the location), meanwhile the cost saving resulting from the comparison with a

conventional foundation with no HH increase can easily be in the range of 10%-15%. Bear in mind that **concrete and steel quantities will be around 30%-40% less** in the precast solution compared to the traditional one.

This means that considering a reference project of, say, 130MW with 65xWTG, 3,700 equivalent hours (capacity factor 0.42) and energy price of 40 USD/MWh:

- Increase in energy production will likely reach **7-9 million USD** along the lifetime of the WTG.
- Savings in foundation execution cost will totalize up to **1-1.5 million USD**.

Furthermore, there are additional advantages that are listed below:

- As noted earlier time to energy gets shortened for wind farms from 15-20 units on.
- Concrete supply becomes more rational and steady, avoiding common problems with traditional foundation executions.
- The anchor cage is needed only at the end of the execution, avoiding supply issues and therefore this usual bottle neck.
- The precast braced solution lowers down the geotechnical risk when no complete information is available at the moment of the design, since the bigger the foundation the bigger the savings it brings with respect a conventional one.

The precast brace solution provides an outstanding adaptability to different soil conditions, including piles and soil substitution if needed.

Regardless its youth, the concept track record is already remarkable:

- Up to date, 3 WWFF are already built and completely finished in Italy, India and Mexico.
- Currently, 3 additional contracts totalizing more than **230 WTG and 500MW** have been recently awarded and already in progress. Some more are likely to be signed within next weeks.

§ The concept has already left behind its validation phase and is currently on its full commercial deployment.

Finally, it is important to highlight that the concept has already been certified by DNV-GL and TÜV SUD.

4. CONCLUSIONS

1. Based on a very important track record in the wind energy sector, with over 5.000 foundations designed and built, ESTEYCO ENERGÍA has developed a solution that has started to play a significant role in the wind energy market, providing significant savings -between 10% and 15%, depending on the specific case- comparing to conventional solutions, at the same time that increases significantly the energy production. Thus, the Cost of Energy (Coe) gets notably reduced.

2. Precast braces are also suitable for manufacturing them within the wind farm, requiring only 2 simple molds. And all 100% local content, which is an obvious added value, being the solution 100% adequate for a large range of soil conditions and hub heights.

3. A large number of MW, in three different countries has already successfully experienced the system.