FUNDATIONS & ANCHORS

Foundations and gravity anchors

They are large and heavy structures that are placed on the ground. Their capacity to resist tensile, sliding and overturning forces is proportional to their weight. One way of optimising lateral loads is to take into account the frictional resistance, which depends on the nature of the soil. Gravity anchors are commonly referred to as "dead bodies".
In the field of land-based wind energy, these foundations are often conical with diameters greater than 15 m, their structure is made of pre-stressed concrete and the interior is ballasted with a material denser than concrete such as olivine, thus increasing its capacity. The cost of these technologies is directly conditioned by the large quantity of material needed for the desired resistance capacity, as well as the means of transport to the site.

Pile foundations and anchors

Piles are deep cylindrical foundations driven into the ground. They are able to adapt to very different soil profiles (clay, sand, soft rock). They are steel tubes driven into the sea bed by an average of 30 m. Their dimensions (diameter, depth, steel thickness) depend on the type of soil and the forces transmitted:

- the resistance to horizontal forces and overturning moment is strongly linked to the diameter and wall thickness,
- the vertical resistance depends on the friction involved in the pile-soil interaction as well as the surface of the pile tip.

In the field of wind turbines, monopile foundations are commonly used. Their diameter currently reaches 9 to 10 m for 12 MW machines. The low burial height/diameter ratio, which is about 3, does not allow the elasticity of the pile to be influenced in bending, which then behaves like a rigid pile. However, these piles are essentially subject to lateral cyclic forces (wind turbine thrust, waves, current) for which they must be correctly dimensioned without being able to relieve the stresses by axial deformation.

Jacket-type foundations consisting of at least three piles driven into the seabed and secured at the top by a metal lattice structure are also very common. These piles are mainly subjected to vertical forces, the lateral resistance being very high because it is distributed over all the piles.

The cost of these technologies is directly conditioned by the installation method, which is either by driving or by drilling and then filling with concrete. Depending on the hardness of the soil, this operation can be complicated or even impossible.

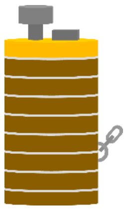
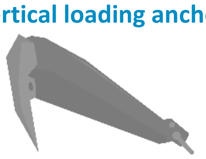
Embedded anchors

These foundations are only used for floating systems. In the group of buried anchors, we find:

- **drag anchors**, which are the most traditional, and have always been used in the maritime sector. These anchors only withstand horizontal forces and do not support any vertical forces. They are designed to sink as the tension increases, but require soft to very soft ground. Therefore, it is not possible to consider tensioned anchor lines,
- **vertical loading anchors (VLA)** are derived from drag anchors and are adapted to withstand tension at angles of up to 30° to the horizontal. This allows them to accommodate the wide variations in anchor line angles encountered in shallow waters such as floating wind sites
- **suction anchors** are low-slung piles (driving height close to the diameter) that behave like rigid piles. Their capacity is increased by sucking out the water contained in the sediment trapped inside. These anchors can support very high vertical loads and are therefore particularly suitable for tensioned anchor lines. They can only be used in very loose environments (mud, coarse sand, clay). When the soil allows it, the suction anchor remains a very efficient and inexpensive solution.

The cost of embedded anchors lies mainly in the installation, which consists of tensioning the anchor to 80% of its ultimate strength load in order to drive it sufficiently into the ground. These loading ranges require very powerful tugs and the increase in unit turbine power implies loading ranges on the anchors that may require the construction of a more powerful tug fleet than at present or alternative installation methods.

In summary

Technology	Fabricat° cost	Installat° cost	Installat° procedure	Advantages and limits
Drag anchor 	€	€€	☺☺☺	• Simple installation and dismantling • Position correction possible • More suitable for cohesive soils • Does not tolerate vertical load
Suction anchor 	€€€	€€	☺☺	• Tolerates horizontal and vertical loads • Simple installation and dismantling • Low noise impact on installation • Highly constrained by the nature of the soil • High construction and installation costs
Directed pile 	€€	€€€	☺	• Accepts almost all types of soil • Tolerates horizontal and vertical loads • Noise at installation • Need for detailed geotechnical data • Difficult recovery at dismantling
Gravity anchor 	€	€€	☺	• Very good tolerance of horizontal and vertical loads • Only for medium to hard floors • Large mass and size • Difficult to recover when dismantled
Vertical loading anchor 	€	€€	☺☺	• Standard flat anchor design method • Combines the advantages of the flat anchor with vertical strength • Precise positioning of the anchor • Tensile strength must be qualified
Dynamically installed anchor 	€	€	☺☺☺	• Simple and inexpensive construction and installation • Precise positioning of the anchor • Little feedback