VATTENFALL

Kriegers Flak Offshore Wind Farm

Brainstorm for Foundation Concepts

Platform Concepts

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Helge Gravesen, HlG

VATTENFALL VINDKRAFT AB

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Author	Project name
Helge Gravesen, HIG, (VN-PT)	Platform Concepts Kriegers Flak
Customer	**Reviewed by**
Vattenfall (VN-PY)	Thomas Stalin
	Approved by

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1 Introduction

This document includes a brainstorm for potential principal foundation concepts for Kriegers Flak.

The concepts considered include:

- Conventional steel monopile
- GBS Cone
- Steel tripod
- Jacket
- Conventional GBS
- Concrete tripod (quadrapod)
- Steel monopile with concrete transition piece

A preliminary assessment is been included.

2 Platform and ice cone(s)

In general it is deemed most favourable to include an ice-breaking cone with a platform level in el. +3.5 m like on Nysted, Lillgrund and Middelgrunden. The experience on access has been extremely good on these three sites. It is very desirable to avoid a platform in a high elevation. The ice conditions require anyhow a cone so it is highly feasible to combine a cone structure with a platform.

Even though that the operational waves are somewhat larger than on the three previous wind farms, the conditions in Baltic Sea with no significant tide favour a low platform. The only technical problem is better-required water tightening and larger wave loads on the access door and it may be solved. The access door is assumed placed in el. +4.0. If deemed practical in the further evaluation, the platform allows a stair up to a door placed somewhat higher.

3 Conventional steel monopile

Main dimensions:

Diameter Monopile (transition piece):...................................... $D_1 = 7m$

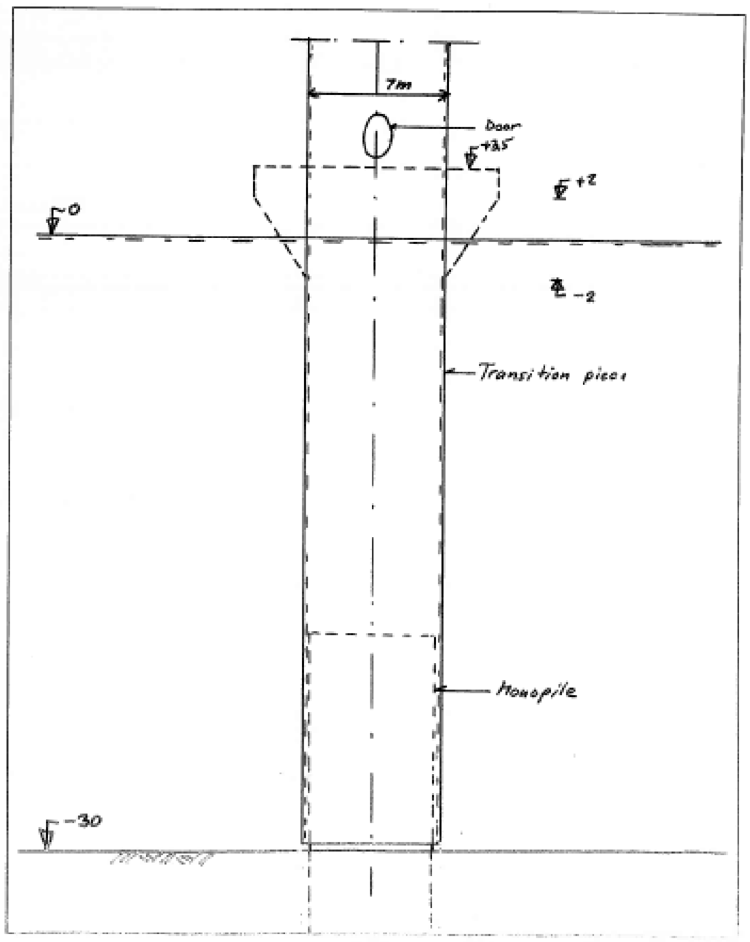

Figure 3.1 *Monopile.*

The ice cone may be a pure steel structure (empty/sand filled), a composite steel/concrete structure or a concrete structure.

The sketch shows an outer steel transition piece. The alternative is to apply an inner transition piece. This alternative allows that the grouted connection length may be located complete or partly below the sea bed.

The design of transition piece is highly integrated with the design of the cable connection.

4 GBS Cone

Main dimensions:

Diameter cylindrical section .... D_{1Top} = 7 m

Diameter bottom of cone above foot plate.........................$D_{1Bottom}$ = 22 m

Height of cone form seabed: .... H = 20 m

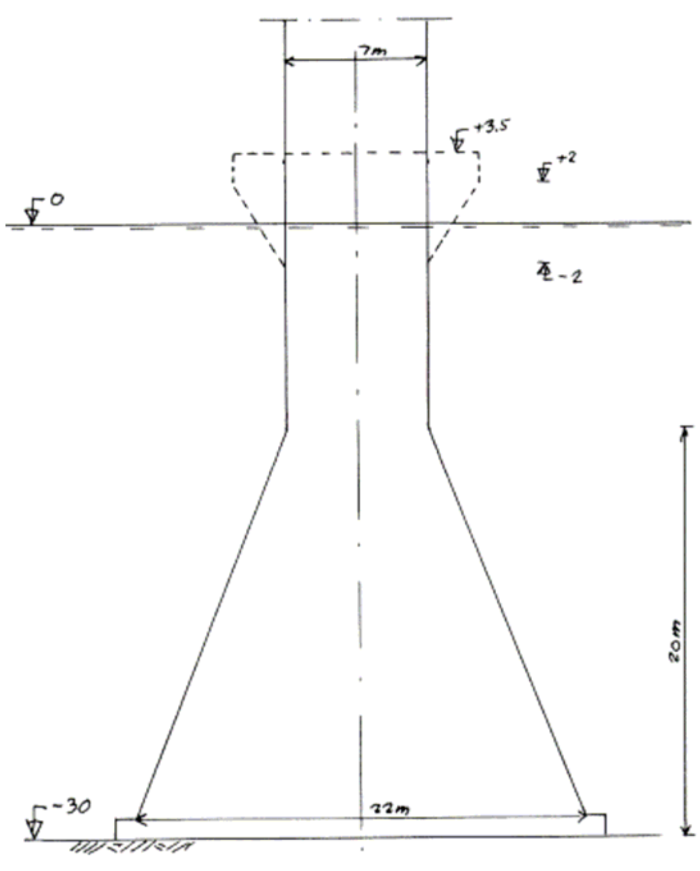

Figure 4.1 GBS (cone).

A key problem is to limit or avoid sea bed preparation. It is important that the sea bed is relatively flat before placement of the caisson. Therefore an appropriate skirt may be needed. The skirt design is an important part of the GBS design.

At deeper water this may be very expensive to carry out excavation and smoothening of the sea bed if it requires strong support from divers.

It is important to consider installation procedures with limited diver support.

There exist technological possibilities to utilize robots or other systems requiring limited diver support. One example of proven practice is the system used for up to 30 m water depth for the Great Belt West Bridge where the jack-up Buzzard was equipped with capabilities for dredging, installing and compact a gravel bed and smooth is with a very high accuracy.

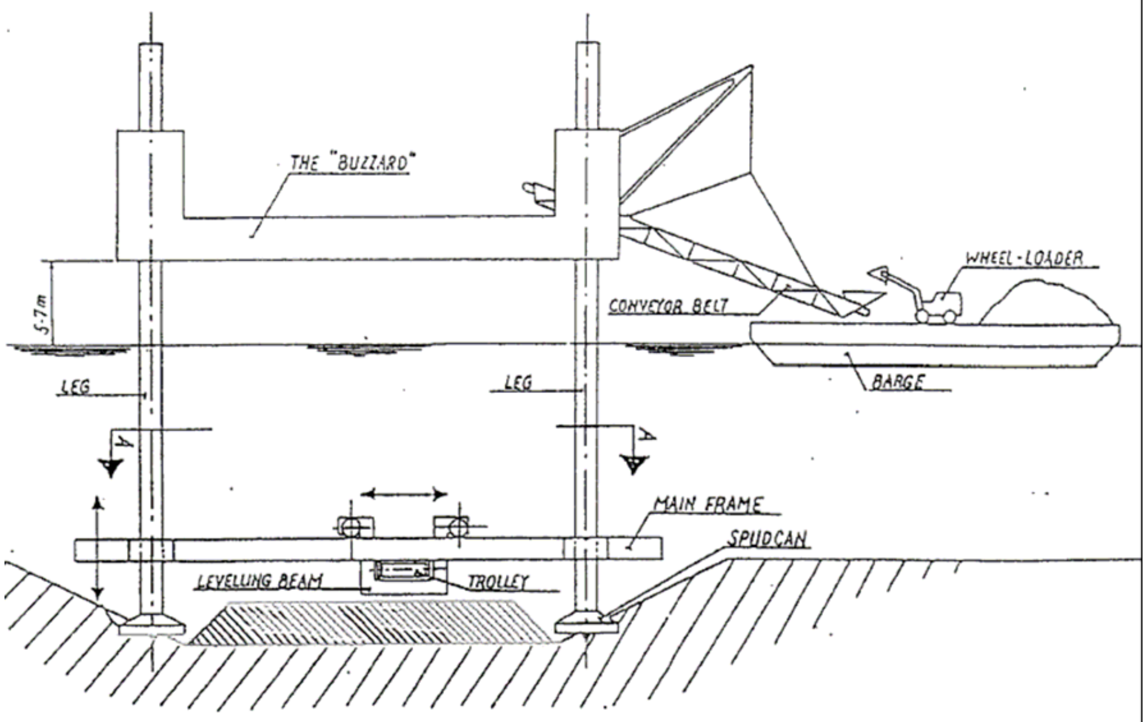

Figure 4.2 Buzzard.

Another key problem is required lifting capacity. It is vital to adjust the lifting capacity to the one of the cheapest crane vessel. This parameter is a key feasibility parameter.

5 Steel tripod

Main dimensions:

Diameter cylindrical section: ....$D_{Top} = 7$ m

Diameter of 45° stiffeners:................................. $D_{45°Stiff} = 3$ m

Diameter of base stiffeners: .... $D_{baseStiff} = 3$ m

Radius to support piles:...R = 18 m

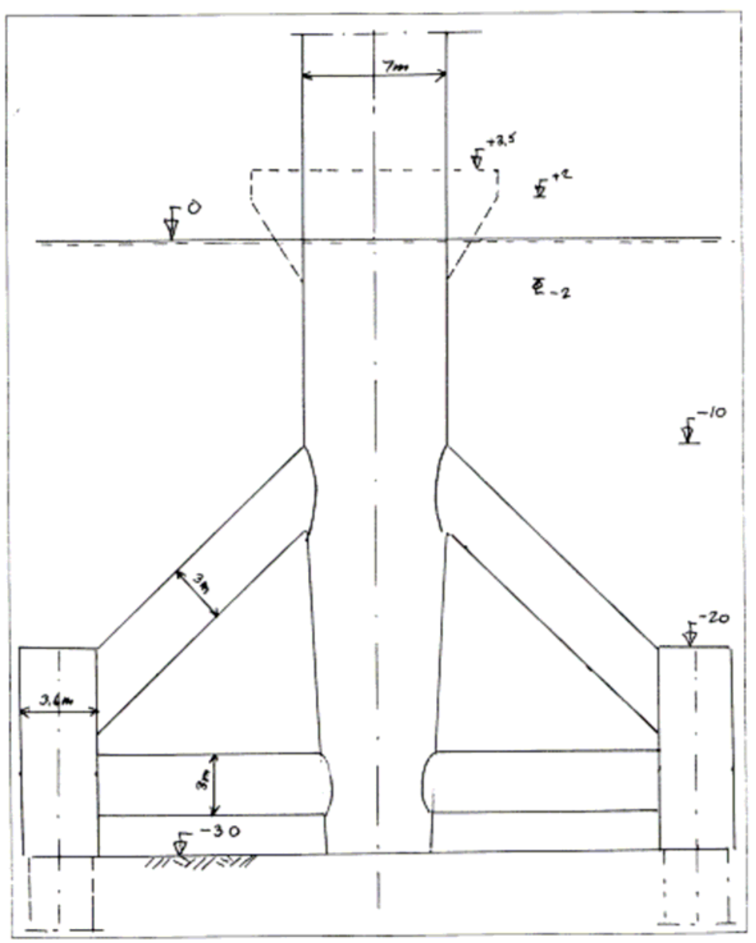

Figure 5.1 Tripod.

The structure may be installed on pre-driven piles (driven through a template) or pile may be driven after installation of tripod.

6 Jacket

Main dimensions:

Centre width of piles at top:.................................. L_{Top} = 13 m

Centre width of piles at base:............................... L_{Base} = 25 m

Diameter of main piles:......................... D_{Main} = 1.2 m/ (0.8 m)

Diameter of cross stiffeners: .... D_{Stiff} = 0.8 m / (0.4 m)

Waves load direction is diagonal to the jacket structure.

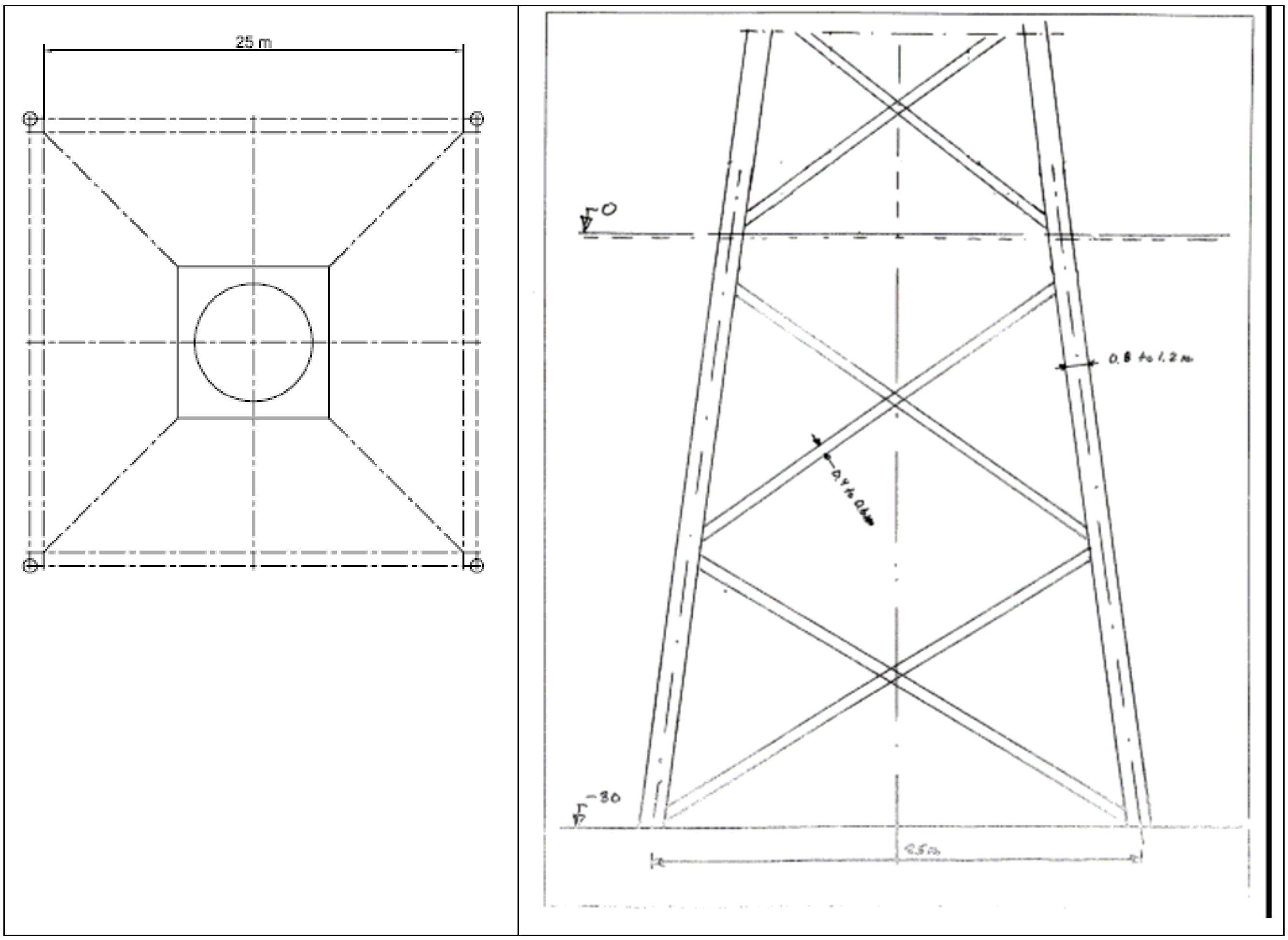

Figure 6.1 Jacket.

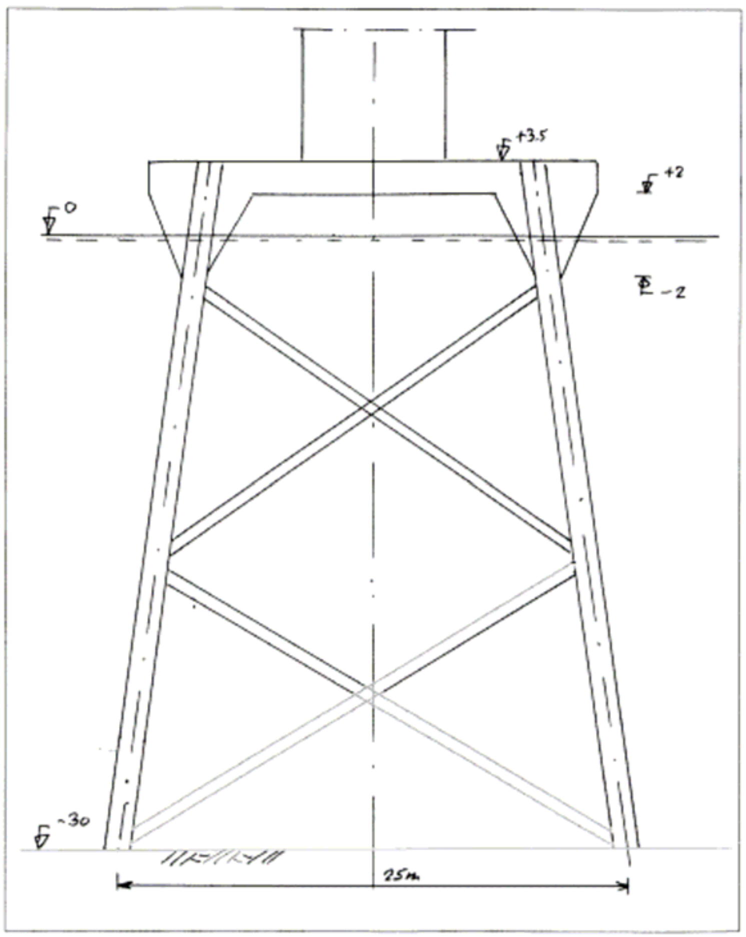

Figure 6.2 Jacket with ice cone (preliminary sketch).

The jacket structure includes some problems associated to ice cone. Individual ice cones are required at the four main legs to limit required length of tension piles. With a platform in elevation +3.5 in is unavoidable that the will occur uplifting pressure on a platform bottom in say el +2.0. This problem needs special attention. A potential solution is to design the platform with two different elevations still allowing access in say +3.5 m but with the central part supporting the tower in a higher elevation. This may take away some of the uplifting wave pressure. Part of the platform could also be non-massive allowing release of wave pressure on the bottom.

The piles may be pre-driven (through a template). In other cases vertical pile slieves are used, like the standard practice within the offshore industry. Finally, it may also be possible to drive piles through the main 4 piles after installation.

The platform may be constructed of concrete, steel or as a composite steel concrete structure. The platform may either be installed together with the jacket or a bolted flange connection may be included.

7 Conventional GBS

An alternative to the cone GBS is a “Nysted solution” extended to deeper water but in principle a simple circular structure fixed in a bottom plate which could include cells for filling with stone fill. The filling process should be considered carefully as filling with larger stones has shown to cause problems at deeper water. More solutions are possible:

- Fill is sand pumped in a closed cells.
- A concrete plate/gabion plate is placed on top after filling with material been pumped in.
- Concrete/asphalt grouting is used to close the cells

Most probably the more conventional GBS is more feasible the shallower the water depth.

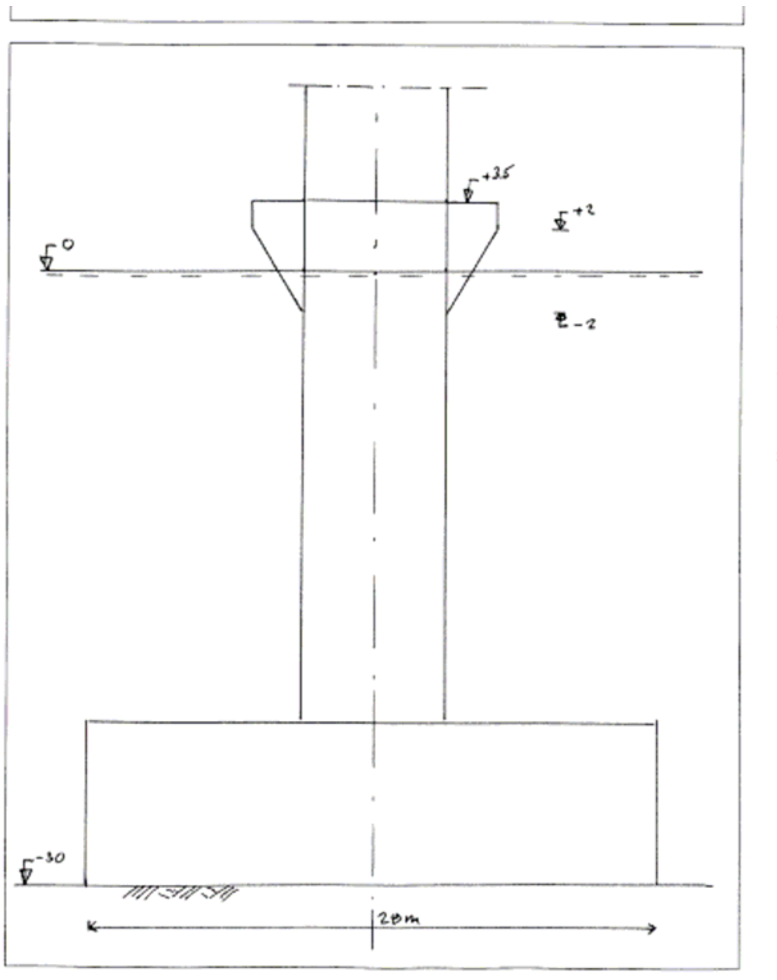

Figure 7.1 Conventional GBS.

8 Concrete tripod (quadrapod)

Previous projects has shown that a concrete tripod/quadrapod is feasible compared with the steel tripod. This alternative include also a potential hybrid between a tripod and a GBS: A gravity structure on piles with a freedom to choose if the piles should take only compression but no tension. This alternative include a large freedom to vary nearly all elements including pile forces, arm of piles, volume for gravitational infill and density of infill.

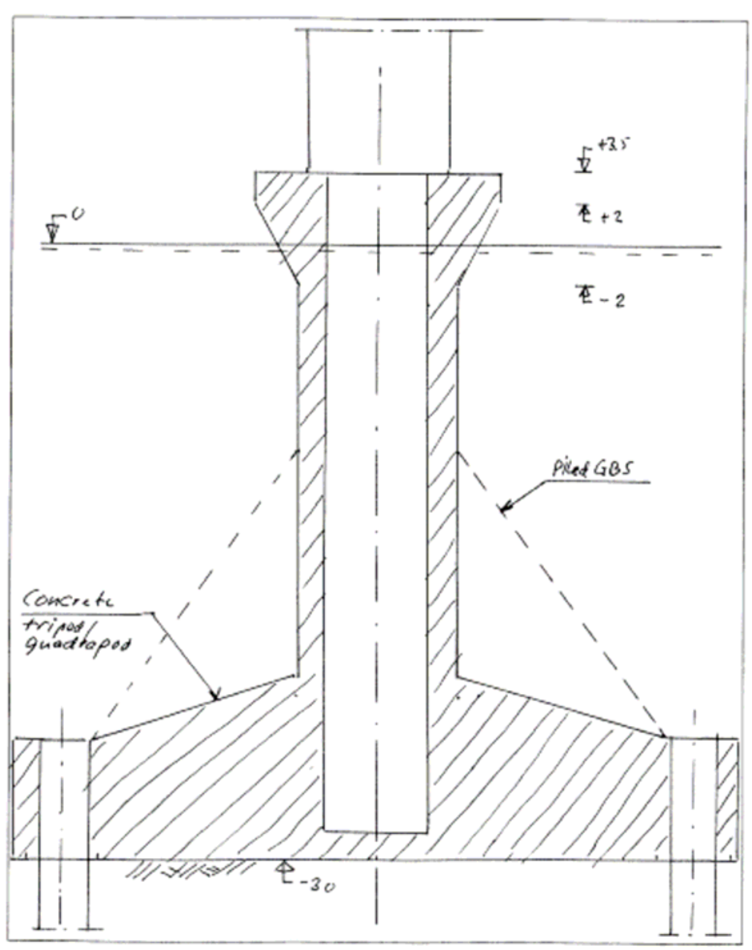

Figure 8.1 Concrete tripod/quadrapod /piled GBS.

The design could either be made as one concrete structure or it could be dived in two pieces requiring less lifting capacity.

9 Steel monopile with concrete transition piece

An alternative to a conventional monopile is to exchange the transition piece by a concrete transition piece integrated to the platform and ice cone.

There are potential patent problems related to this alternative.

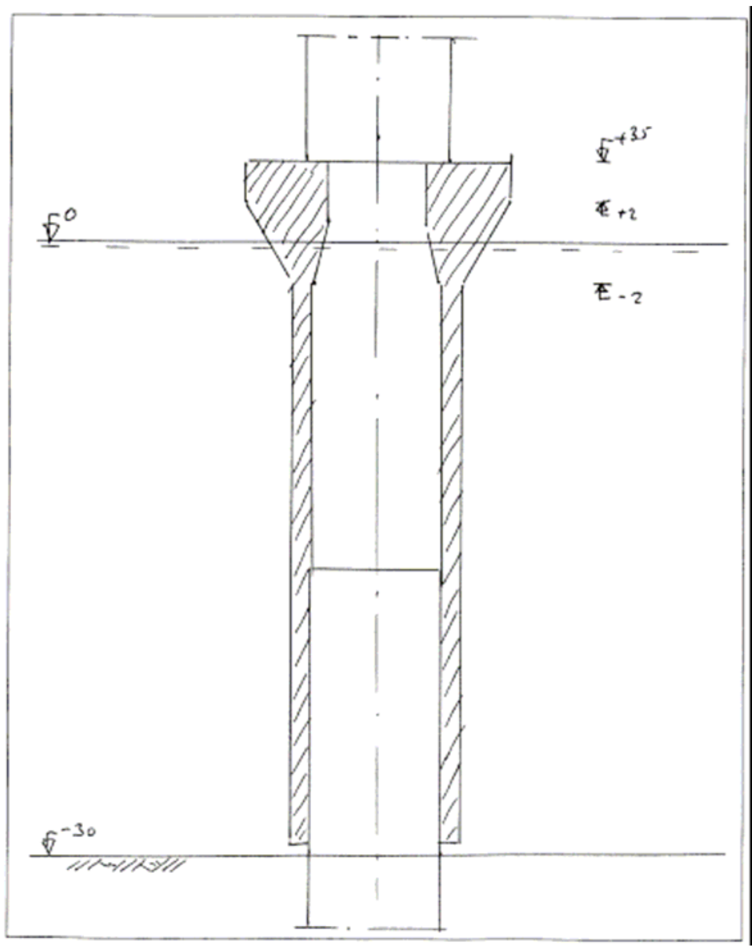

Figure 9.1 Steel monopile with concrete transition piece.