Day 1

Part 1

25 Years of Gravity Based Structures

Design, Construction and Installation

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1. A BRIEF HISTORY OF NORTH SEA EXPERIENCE

Although concrete gravity foundation type structures have been known since the beginning of the century as quay-walls, offshore light houses, bridge-piers and breakwaters, the oil and gas production in the Northern North Sea, which started in the late sixties, has initiated a new era in this type of structures.

The name 'Gravity Structures' ['Gravity Base Structures' or 'GBS' in North America] implies two main characteristics. First, the foundation is not piled, but of a gravity type, and secondly the main structural elements are of concrete. This in turn implied a break-through in a wide range of technologies poorly known before.

These technologies were mainly:

- soil mechanics for dynamically loaded gravity foundations;
- stability of thick walled shells including effects of tolerances and creep;
- durability aspects of concrete in seawater and in contact with crude oil;
- fatigue of large prestressed concrete members;
- effects of high temperatures, temperature gradients and temperature changes on thick walled concrete members;
- the impact of the use of High Strength Concrete on design and detailing;

In many countries around the North Sea, including The Netherlands, research programmes were started to deal with these subjects. In the U.K. it was "The Concrete in the Ocean programme" and in The Netherlands the "MATS" programme which included research on durability, structural analysis and fatigue.

The first Northern North Sea GBS was the Ekofisk platform ordered 25 years ago in 1970 and installed in 1973 for Phillips Petroleum. It was designed by C.G. Doris and constructed by a Joint Venture of CG Doris and a number of Norwegian Contractors. Immediately after the successful installation in 1973, within 14 months, 12 more platforms were ordered.

The Ekofisk Barrier itself has been strengthened against waves in the mean time by the so called "Ekofisk Barrier in 1989, as waves would hit the deck due to subsidence of the seabed by oil production.

Many features have been mentioned for the break through of GBS platforms in the North Sea. They include of course the favourite condition of the northern North Sea bottom profile consisting of overconsolidated clay with a shear strength of over 1 N/mm^2. The main reason for this platform galore should however be recorded as the scarcity in production capacity for conventional large scale steel jackets. Under the pressure of the 1973 oil crisis, concrete structures proved to have a great potential in the mobilisation of construction capacity.

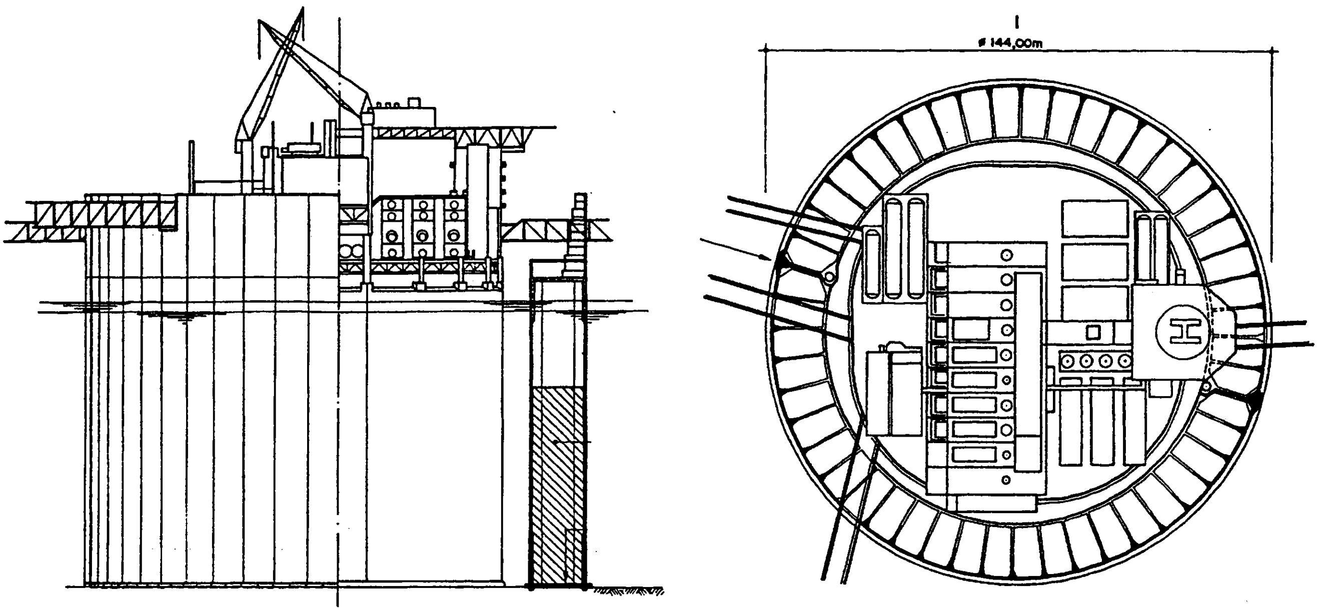


Fig. 1 Ekofisk Tank and Barrier as installed in 1973 and 1989

In the gravity type production and storage platform construction, the client required speed related to the economy. The explosive expansion of the market limiting the resources of the clients and the different restraints and advantages being encountered by different contractors has led to the situation where constructors with in-house design capability became successful. During 1973 and 1974 a contractor with a design, quality assured by a certifier, and a planning permission for a construction site, was almost sure of being awarded the construction of a platform.

The speed required by the client relates to the enormous investments from exploration to actual production. The existence of a construction window for actual offshore operations implies that a loss of a few weeks or even days could delay return of investments by 6 to 8 months.

Last but not least it has to be recognized that the resources available in the different countries where contractor groups were able to construct platforms are so diverse that they automatically resulted in different design approaches in turn resulting in different designs. Such restraints are given by draught in the construction area, conditions of dry dock, available aggregates for concrete, labour resources, availability of certain types of equipment, construction experience, etc.

This resulted in different shapes as shown in figure 2. The full caisson and the caisson tower-deck type are the best known designs. Increasing water depth at location and the allowable draft at the construction site were the usual reasons for going from one concept to the other.

The requirement for platforms in the Arctic and in oceans where icebergs occur, as in the Hibernia field, has again enriched, installed and planned shapes, as in the case of caisson retained islands and conical GBS facilities.

In the mean time the use of GBS platforms proliferated also to site conditions with poor foundation soil, types installed without pre-installed topsides and shallow waters with relatively high waves, where they could not compete before with steel jackets.

Looking to this 25-year history, contemplating why and when a GBS has to be selected for a special job, the following points remain valid.

Construction capability

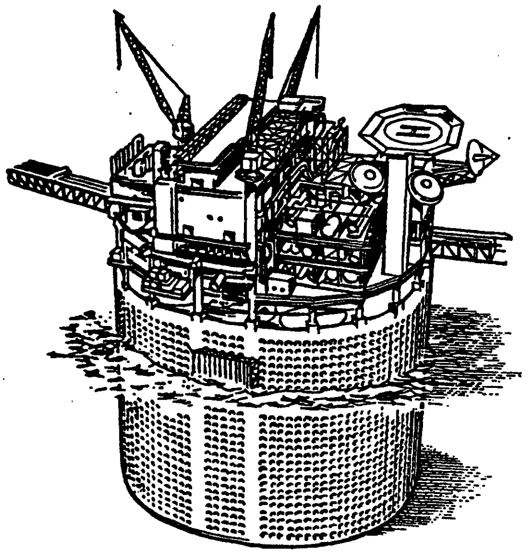
A fast development, as in the Northern North Sea in the early seventies, offers more flexible and reliable expansion in construction capability for concrete than for steel. Additionally, construction capability in concrete is usually more attractive for countries without high-technology steel construction facilities required for the construction of steel jackets and a low amount of available foreign currency.

Storage

Although a concrete GBS is not the only solution for offshore buffer oil storage, the presence of a huge hollow body used for horizontal transport during construction is, of course, a first feature to economically allow for such storage.

Reduced cost for installation

The most important reduction in installation costs is caused by the reduced number of manhours in hook-up offshore as the GBS is able to carry a completely installed and hooked-up deck to the location. In the seventies, this resulted in a cost saving of up to 0.5 - 1.0 million manhours offshore for hook-up, compared to less [due to efficiency in logistics] and cheaper [due to continuous work, without travel and expensive lodging] work onshore [25% or less]. Another cost reduction was possible in the installation phase as offshore derrick barges were not required. Towards the eighties, however, the size and operational window of derrick barges increased dramatically due to the introduction of semi-submersible barges with a lifting capacity of up to 12.000 tonnes enabling the installation integrated decks in one operation.



EKOFISK TANK

Installed :	1973	Concrete :	80000 m3
Waterdepth :	70 m	Reinforcement :	125 kg/m3
Submerged weight :	190000 t	Prestressing :	44 kg/m3
Foundation area :	6200 m2		

BRENT B

Installed :	1975
Waterdepth :	142 m
Submerged weight :	170000 t
Foundation area :	6200 m2
Concrete :	65000 m3
Reinforcement :	165 kg/m3
Prestressing :	18 kg/m3

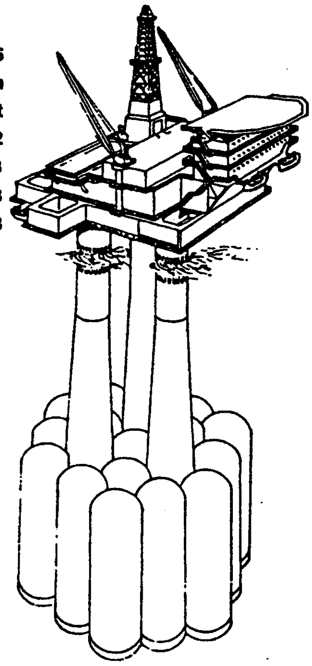
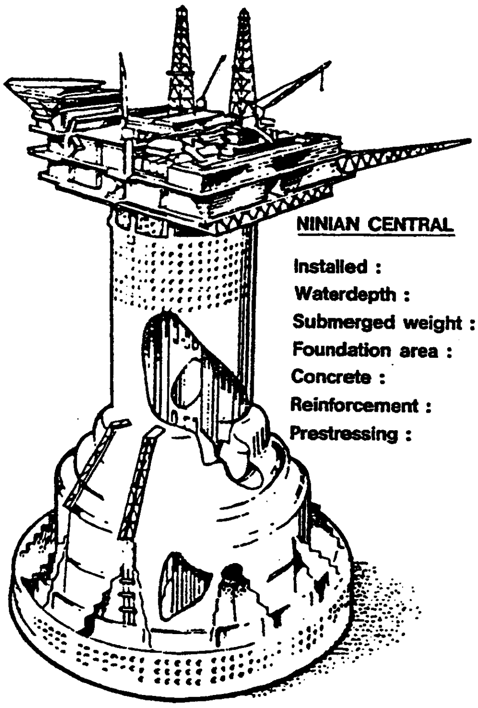
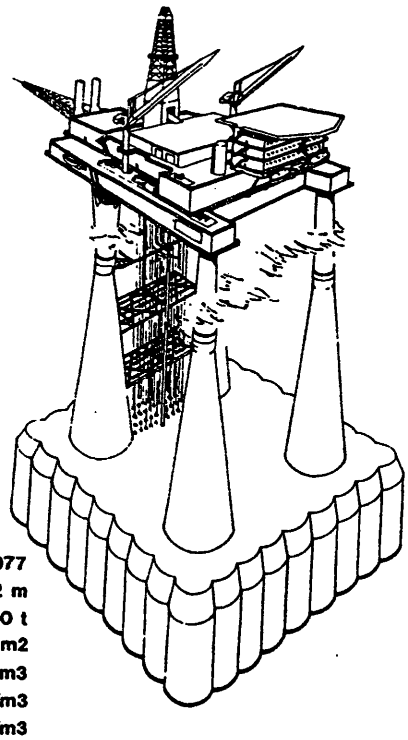


Fig. 2 Full caisson type GBS Ekofisk tank and high caisson with 3 columns type GBS Brent B



NINIAN CENTRAL

Installed :	1978
Waterdepth :	139 m
Submerged weight :	320000 t
Foundation area :	15400 m2
Concrete :	142000 m3
Reinforcement :	190 kg/m3
Prestressing :	22 kg/m3



DUNLIN A

Installed :	1977
Waterdepth :	152 m
Submerged weight :	200000 t
Foundation area :	10600 m2
Concrete :	94000 m3
Reinforcement :	132 kg/m3
Prestressing :	25.5 kg/m3

Fig. 3 Low caisson with four-legged type GBS such as Dunlin A, and semifull caisson type GBS such as Ninian Central

Special loads

GBS, when they are of concrete, are supposed to be more efficient in resisting special impact loads. This is, for instance, the case where ice loads are carried due to ice-ridges and ice-bergs. It is also a feature for structures in busy ship channels and other places where collisions with floating solid bodies are likely to occur. Other accidental loads, such as fire and explosions, are assumed to be better resisted by a GBS than by a steel jacket. In case very high deck loads, of for example over 20.000 tonnes, have to be supported, a GBS is in favour.

SUMMARY LIST
GRAVITY BASE STRUCTURES

OPERATOR	LOCATION	DESIGN	WATERDEPTH	CONCRETE VOL m^3	INSTALL YEAR
Phillips	Ekofisk	Doris	70	80,000	1973
Mobil	Beryl A	Condeep	118	52,000	1975
Shell	Brent B	Condeep	140	64,000	1975
Elf	Frigg CDP1	Doris	104	60,000	1975
Shell	Brent D	Condeep	140	68,000	1976
Elf	Frigg TP1	Sea Tank	104	49,000	1976
Elf	Frigg MP2	Doris	94	60,000	1976
Shell	Dunlin A	Andoc	153	90,000	1977
Elf	Frigg TCP2	Condeep	104	50,000	1977
Mobil	Statfjord A	Condeep	145	87,000	1977
Shell	Cormorant A	Sea Tank	149	120,000	1978
Chevron	Ninian Cent.	Doris	136	140,000	1978
Shell	Brent C	Sea Tank	141	105,000	1978
Mobil	Statfjord B	Condeep	145	140,000	1981
Texaco	Schwedeneck A	D&W; B+B	10	3,628	1984
Texaco	Schwedeneck B	D&W; B+B	10	3,064	1983
Mobil	Statfjord C	Condeep	145	130,000	1983
Statoil	Gullfaks A	Condeep	135	125,000	1986
Statoil	Gullfaks B	Condeep	141	100,000	1987
Hamilton	Ravenspurn	Arup/Laing	42	10,000	1987
Norsk Hydro	Oseberg A	Condeep	109	120,000	1988
Statoil	Gullfaks C	Condeep	216	240,000	1989
Phillips	Ekofisk PB	Doris	75	105,000	1989
Statoil	Sleipner A	Condeep	82	75,000	1993
Shell	Draugen	Condeep	251	85,000	1993
* Shell	Troll	Condeep	303	220,000	1995
* Conoco	Heidrun	Condeep	345	**65,000	1995
* Norsk Hydro	Troll Oil	KDOC	325	42,000	1995
* BP	Forth	CTW/TEL	106	**35,000	1995
NAM	F3	HBW/VSCI	42	20,000	1992
* Esso	West Tuna	Kinhill/Doris	61	27,000	1995
* Esso	Bream B	Kinhill/Doris	61	12,000	1995
* Mobil	Hibernia	Doris	80	200,000	1997

* Under construction ** Light weight aggregate concrete *** Second platform

Fig. 4 Table showing GBS structures installed or under construction since 1970

Special foundation conditions

In case the soil consists of rock or coral, generally meaning soil in which it is difficult to drive piles and to find resistance for tensile piles, a GBS is an ideal topside foundation.

2. FUNCTIONAL REQUIREMENTS

Some understanding of the functional requirements of a GBS type production platform is essential for the global design. The different systems serving the functional requirements are listed below as far as they have impact on the geometrical and structural aspects of the design.

2.1 Deck

The platform deck structure houses most of the functional requirements of the platform. These can be divided into three groups:

- The drilling equipment, including one or two drilling rigs, storage of drilling casings, mud plant etc. These functions can, however, be executed by a temporary installed adjacent platform as was the case with the F3 platform. Advance drilling and installation of the platform on top a subsea completed wellhead may also be considered.

- Oil [c.q. gas] processing systems, including depressurization equipment, cooling equipment, gas injection, water injection flare, etc. The amount of equipment is different from case to case as it depends on the composition, volume and composition of the liquid to be produced.

- Living quarters including helideck, live saving systems, etc.
  These facilities may, for reasons of safety, be installed on a special living quarter platform.

In case of a GBS for deep water and a large deck, it is important to sail out with all equipment on board. The total dry weight of the systems, including the weight of the deck, is a most important figure for the design of the platform as it controls the stability during tow.

2.2 Conductors

To guide the drill casings into the mud line, Ø 30" - 36" casings have to be provided in a pattern suitable to accommodate Christmas trees at the top of each well.