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Ship Impact on a Shaft of a Concrete Gravity Platform

Collision d'un bateau avec une plate-forme en béton

Schiffsstoß gegen eine »Offshore« - Konstruktion aus Beton

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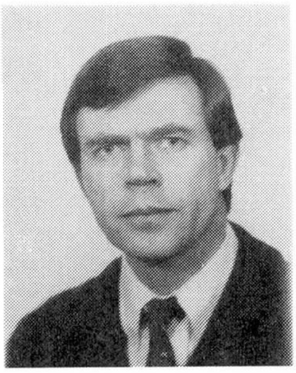
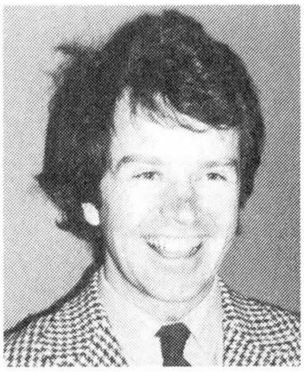
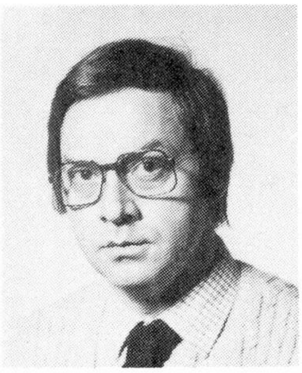


After graduation in 1968, Bernt Jakobsen born 1944, had 5 years of consulting practice before receiving his Dr. ing-degree in 1980, also at the Norwegian Institute of Technology. He is at present working with Norwegian Contractors in Oslo.

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Einar Skåre, born 1943, graduated with a degree in structural engineering from University of Minnesota. For seven years involved in engineering and construction of concrete gravity platforms for the North Sea. At present project engineer and responsible for engineering of steel jackets riser platforms for Statoil.

SUMMARY

An impact between a 150 000 dtw tanker and the shaft of a concrete gravity platform is investigated. Although several uncertainties are present, the main conclusion is that the platform may be designed to resist such impacts.

RÉSUMÉ

L'impact d'un pétrolier de 150 000 tdw contre la colonne d'une plate-forme de production type gravitaire en béton est étudié. Malgré certaines incertitudes, il est possible de conclure que la plate-forme peut être conçu de façon à résister des impacts de cette envergure.

ZUSAMMENFASSUNG

Stoßbeanspruchung zwischen einem 150 000 tdw Tankschiff und dem Turm einer »Offshore« - Konstruktion wurde untersucht. Trotz gewisser Unsicherheiten ist es möglich zu schließen, daß die Konstruktion so entworfen und gebaut werden kann, daß sie solchen Zusammenstößen widerstehen kann.

1. INTRODUCTION

Experience has shown that ship collisions with offshore platforms do occur and must be considered in design.

Previously it has been shown, ref. (1), that concrete platforms have, or may be designed to have, sufficient strength to sustain the loads resulting from present day ship collision criteria without damage.

With offshore loading of oiltankers being more and more common, the impact behaviour between a 150 000 tdw tanker and a concrete shaft is of increasing interest. Detailed static and dynamic analyses have been performed to investigate this question. The impact velocity chosen is 2 m/s; for a tanker this is extreme and should not be considered as an ordinary design situation.

The intention of this paper is to show that the concrete platforms may also be designed to have sufficient strength to sustain the loads resulting from a tanker collision without unacceptable damage.

2. DESIGN FOR SHIP IMPACT

Design criteria for offshore structures are given in (2) and (3). Design practice for collision as accidental loads is summerized by S.Fjeld (4) and in (1). DnV's Technical Note TNA 202 (5) "Impact loads from boats" specifies load-indentation characteristics for a 5000 t supply ship, and forms a useful design aid.

Essential for concrete design is the impact load area. This is derived from simple geometry, such as height of ship, radius of shaft and ship indentation.

To summarize briefly:

$$E_s = 1/2\ (m + \Delta m)\ v^2$$

where E_s is kinetic energy of the ship

m is mass of ship

Δm is added hydrodynamic mass

v is velocity of ship

The absorbed energy of concrete gravity platforms is negligible compared to the energy absorbed by the ship.

For the supply ship considered in TNA 202 (5) the following characteristics are used:

$$m = 5000\ t$$

$$\Delta m = \begin{cases} 0,1\ m \text{ for bow and stern impacts} \\ 0,4\ m \text{ for sideway impact} \end{cases}$$

v = impact velocity to be taken as the drifting velocity in the out-of-control condition. $v = 0{,}5H_s \geqslant 2$ m/s, where H_s is the maximum significant wave height for operation of ship near the platform.

Knowing the load-indentation relationship the impact load P is found by equating the kinetic energy and the energy absorbed by the ship.

To account for local and uneven distribution of the contact stresses TNA 202 (5) suggests a reduction factor (= 0,4 for sideway, = 0,7 for bow and stern) on the contact area.

Applying this procedure for the 5000 t supply ship on a typical offshore platform showed that, regardless of ship impact velocity, the shaft would not be destroyed. The main findings from (1) are included here, as local flexural strength (fig.1) and punching strength (table 1), both related to applied loads. Note that the entire load-indentation curve is included to velocities many times the corresponding accidental design condition. The design values of strength are used.

TYPE	P	Q	Q_d	Q_d/Q
	7.5	.66	1.54	2.36
	7.91	.64	1.56	2.44
BROAD	8.31	.65	1.57	2.41
SIDE	9.51	.70	1.60	2.28
	11.5	.80	1.65	2.07
	6.	.71	1.55	2.18
	6.68	.66	1.57	2.40
STERN	7.69	.69	1.61	2.34
	9.34	.76	1.66	2.19
	2.8	1.08	1.48	1.37
BOW	4.8	.41	1.55	3.77
	8.2	.51	1.65	3.23
	13.7	.69	1.78	2.59

Table 1 Shear Strength

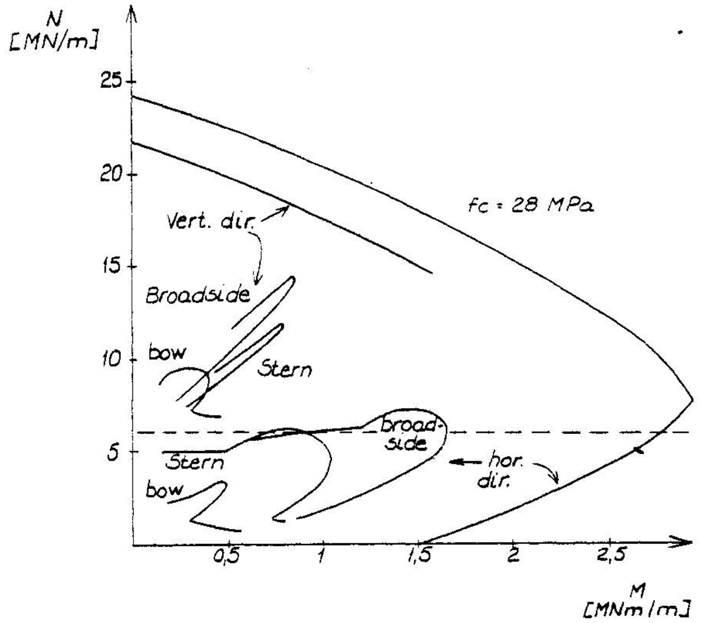

Fig. 1 Flexural response and strength

The load-indentation relationship is in reality a description of the strength of the ship. If the strength had been expressed in terms of load per unit area it would not have varied much from ship to ship and from shaftdiametre to shaftdiamtre. This is not surprising, since most ships are designed for similar loadings.

3. IMPACT RESPONSE

It is convenient to distinguish between global and local response.

3.1 Global response

The dynamic ship impact is carried out using the structural model shown in Fig.2.

The 150 000 tdw tanker colliding broadside with the platform is represented by two stiff beam elements, as seen in Fig. 2. The distribution of mass at the three nodes of the "ship" is chosen to represent the translation as well as the rotational inertia of the ship. Included in these mass quantities is a hydrodynamic mass corresponding to an added mass coefficient of 0.4 as expressed in section 2.

A ship velocity of 2.0 m/s is chosen for the case presented. This has been evaluated to represent a reasonable upper limit corresponding to an accidental impact case.

Only one impact direction has been considered, see Fig. 2. The eccentricity of the tanker relative to the shaft has been varied to examine the effect of eccentric impact.

The deformations in the tanker during the impact is represented by a non-linear spring having the load-indentation characteristics as shown in Fig.3. This curve is obtained as described in (1). The curve is only applicable in the compression stage before the tanker starts to move away from the platform. However, the maximum platform response for the cases presented is reached during or immediately after the compression stage. The corresponding inaccuracies in the results are thus expected to be of minor importance.

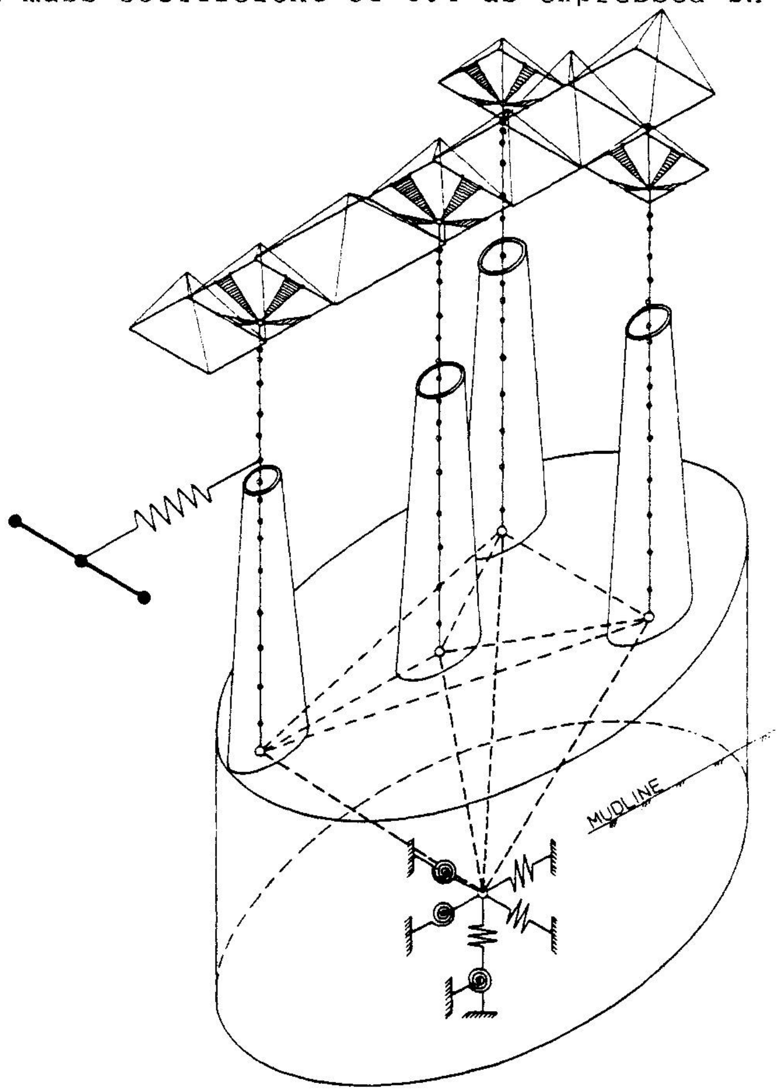

Fig. 2 Space frame model

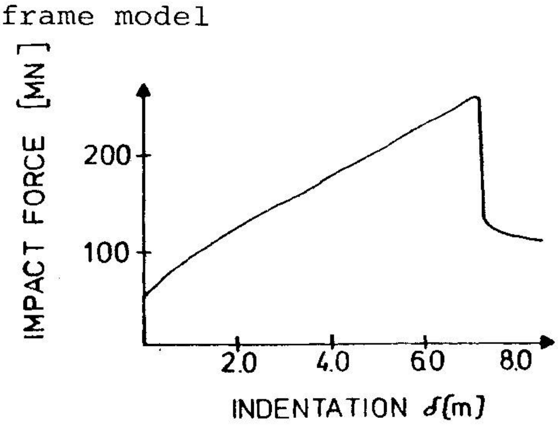

Fig. 3 Load-indentation relationship for tanker in broad side impact.

The dynamic analysis is carried out by direct time-integration using the constant acceleration method of the Newmark family. The tanker-platform system is allowed to perform free vibrations with initial conditions corresponding to the tanker velocity of 2.0 m/s.

Table 2 presents some typical response quantities for the central impact together with the time for occurence of the maximum response.

In Fig.4 the maximum impact force, shear force in shaft below the impact point, bending moments at the load and at the shaft base are given as function of the eccentricity. The curves should be interpreted as indicative only since the maximum response in several cases occurs after the maximum impact has been reached. Further, influence of nonlinear platform response is not considered.

	RESPONSE QUANTITY							
LOCATION	M (MNm)	t (s)	Q (MN)	t (s)	N (MN)	t (s)	δ (m)	t (s)
Base of shaft	7274	3.09	131.6	3.12	22.5	0.76	0.021	3.51
At/under point of impact	2153	3.09	127.0	2.97	20.3	0.33	0.169	3.09
At intersection with deck	528	3.00	77.4	2.07	19.9	0.33	0.159	3.03
Mudline	30238	3.09	225.6	3.12	18.5	0.81	-	-
Impact load/ tanker	-	-	-	-	153.9	2.70	3.17	2.76

Nomenclature: M : Bending moment
Q : Shear force
N : Axial force
δ : Displacement in impact direction
t : Time for occurrence of maximum response

Table 2 Maximum response quantities, central impact.

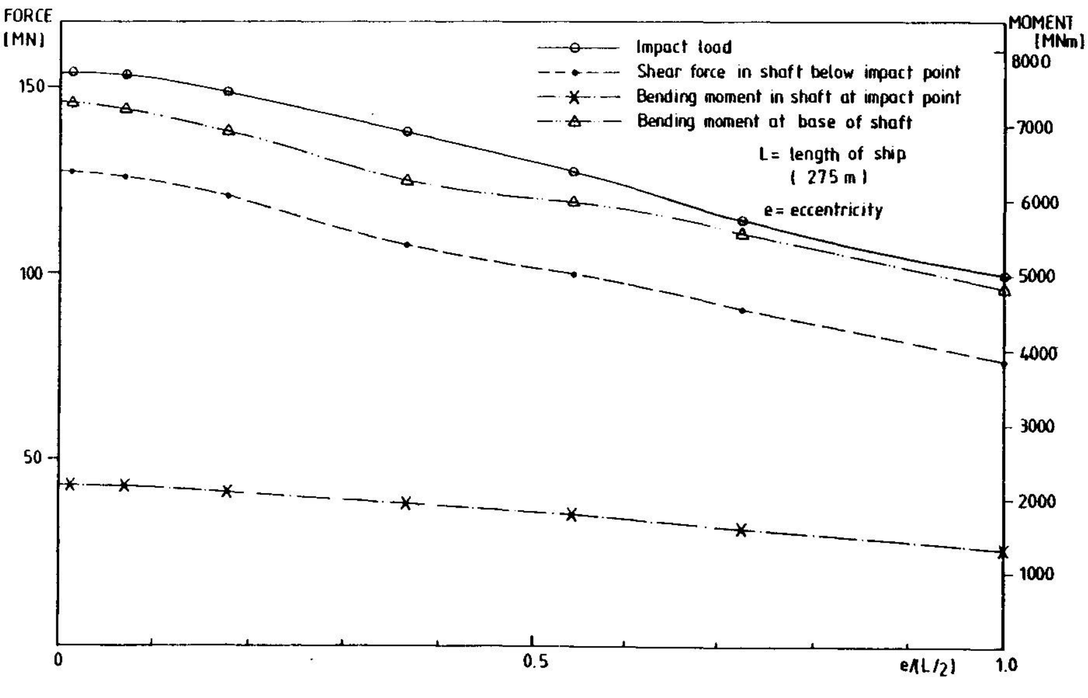

Fig. 4 Impact load and typical response quantities as function of eccentricity.

3.2 Local response

A linearly elastic analysis, as described in (1), is adopted to calculate the stress resultants in the vicinity of the load. The geometry of the shell investigated is shown in fig.5. The length of the cylindre is determined from the global moment, a length of 75m was chosen, corresponding to the maximum moment.

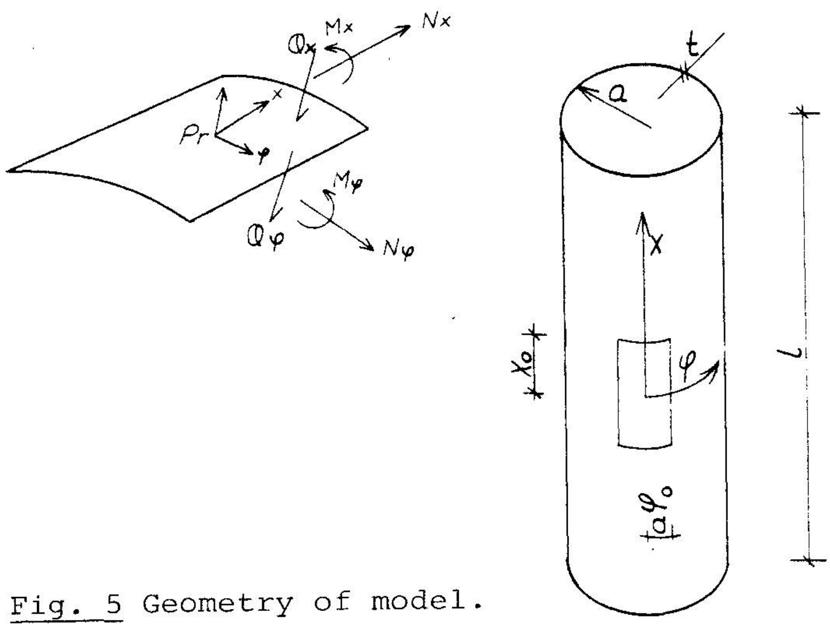

Fig. 5 Geometry of model.

To account for the possible uneveness the 0.4 reduction factor on contact area is used, as suggested for the supply ship. How appropriate this is for tanker is not known. Most likely it will be smaller in the early phase. However, then the width is very small, since $P \neq 0$ when $\delta = 0$.

Unfortunately load-deformation characteristics are not available for corner impact. This is of particular interest when the shaft is conical, which is sometimes the case. Most likely this geometric aspect should be considered during design.

There are indications, however, that the strength of the corner, in terms of load per unit area, is not so different from broadside strength at bulkhead.

4. IMPACT STRENGTH

4.1 Material properties

When investigating the extreme accidental tanker impact realistic values of strength should be used:

Concrete:

The compressive strength according to DnV Rules (3) with material factor of 1.0 is thus chosen:

$$f_c = 0,85 \times f_{cyl} = 0,85 \times 0,80 \times f_{cube}$$

A 20% increase due to aging is assumed. Thus, for C60

$$f_c = 0,85 \times 0,80 \times 1,2 \times 60 = 49 \text{ MPa}$$

Shear strength is assumed $0,33\sqrt{f_{cyl}} = 2,5$ MPa

Core tests have shown the structural strength to be $0,9 \times f_{cube}$ at an average for slipformed parts of a platform. Also the relatively high rate of loading will tend to increase the strength, such that the adopted values should be conservative.

Reinforcement:

longitudinal bars:	KS50	f_s	= 480 MPa
stirrups :	KS40S	f_s	= 400 MPa
Cables :		f_{ps}	= 1575 MPa
		T_s	= 4,29 MN
At stressing		T	= 2,9 MN

4.2 Global strength

At the mudline the loading due to tanker impact is smaller than due to environmental loads, thus evaluation of global strengths may be limited to the shaft.

At the top of the shaft the load effects are very small, and need not be considered.

At the base of the shaft the load effects are considerably larger than those caused by environmental loads. However, the design criteria are very different, as membrane tension should be avoided for the latter loads.

The flexural strength of the shaft base is shown in fig.6. The vertical compression due to deck weight is approx.200 MN.

It is seen that the applied load is far below the capacity. In fact the strength is so high that the failure load of the tanker (=265 MN) is not likely to damage the shaft base.

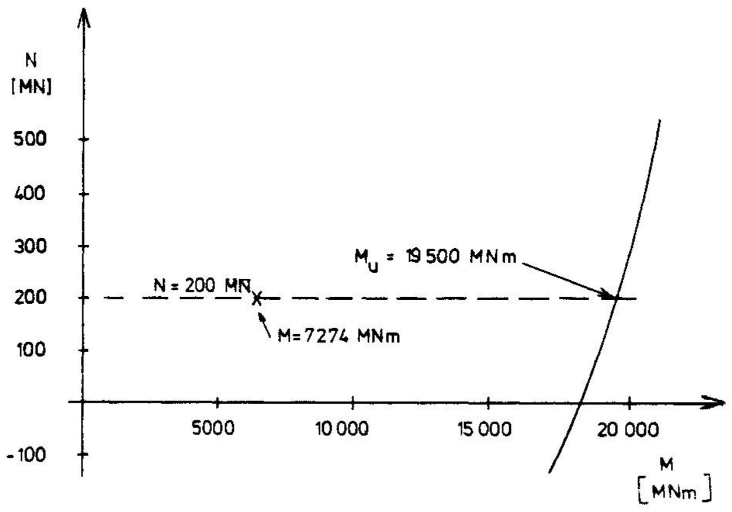

Fig. 6 Response and strength of shaft base.

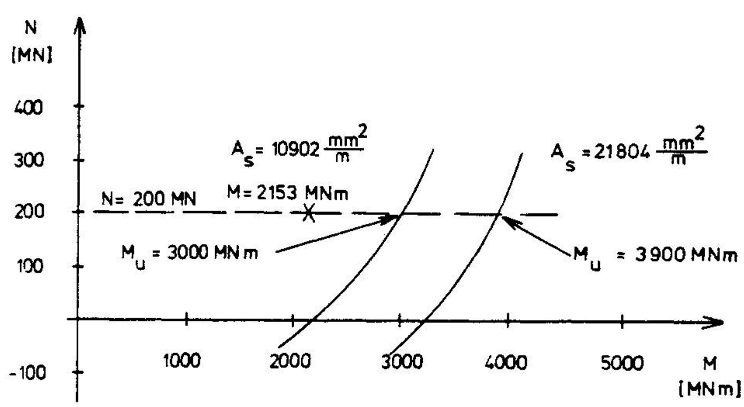

Fig. 7 Strength of shaft at waterlevel.

Also the section at the level of impact has sufficient capacity (fig. 7) to resist accidental impact without any damage. The reserves are, however, smaller than for the section at base of shaft.

4.3 Local strength

The flexural strength of shaft wall at the level of impact is shown in fig. 8.
The shear strength is expressed

$$Q_u = .33 \sqrt{f_{cyl}} \times d + A_{sv} \times f_s \times h' + N/6$$

For
$A_{sv} = 3095\ mm^2/m^2$
$d = .65 - .0625 = .5875\ m$
$h' = .65 - .125 = .525\ m$
$f_s = 400\ MPa$

$$Q_u = 2.5 \times .5875 + 3095 \times 10^{-6} \times 400 \times .525 + N/6$$

$$= 1.47 + .65 + N/6 = 2.12 + N/6$$

The local response is plotted on fig. 8. The applied shear and shear strength are shown in table 3. Thus, both flexural and shear strength compare favourably with the applied load, also for velocities in excess of 2m/s.

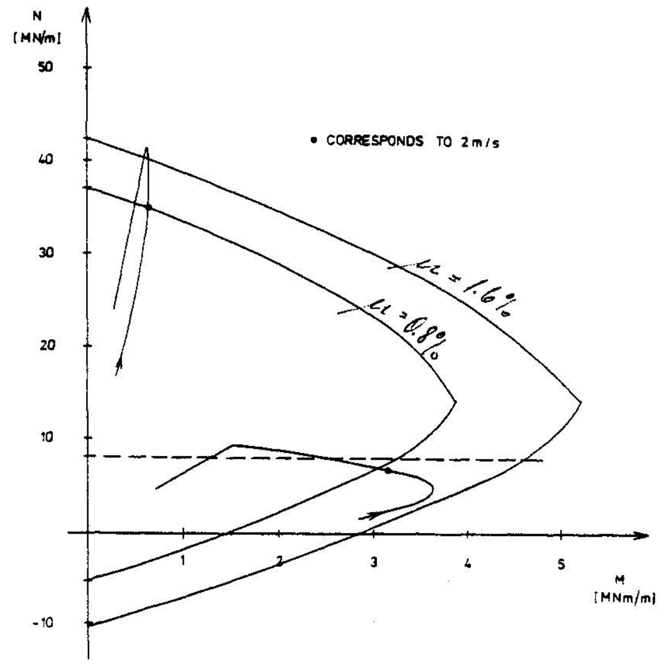

Fig. 8 Strength of shaftwall at waterlevel.

Q	N	Q_u	Qu/Q
1.42	1.72	2.41	1.69
1.46	2.32	2.51	1.71
1.49	2.60	2.55	1.71
1.51	2.79	2.59	1.72
1.50	2.92	2.61	1.74
1.49	3.26	2.66	1.79
1.51	3.55	2.71	1.79
1.49	3.93	2.77	1.87
1.46	4.70	2.82	1.93
1.42	4.50	2.87	2.03
1.31	5.02	2.96	2.26
1.23	4.60	2.89	2.35
1.21	4.67	2.90	2.40
1.19	4.70	2.90	2.43
1.02	5.63	3.06	3.00
.90	4.88	2.93	3.24
.71	6.14	3.14	4.44
.55	6.29	3.17	5.81

Table 3
Shear strength.

5. CONCLUSIONS

It has previously been demonstrated, ref.(1), that supply ships up to 5000 t do not have sufficient strength to overstress the concrete shaft, regardless of ship velocity.

The present investigation of the impact behaviour between a 150 000 tdw tanker and the concrete shaft can be summarized as follows, bearing in mind the uncertainties in the various assumptions:

At the mudline, the loading due to tanker impact is smaller than those caused by environmental loads.

At the base of shaft, the loading due to tanker impact exceeds those due to environmental actions. However, design criteria are widely different, thus strength is adequate for the 2 m/s velocity. Most likely the rupture load of the tanker may also be resisted by adequate design.

At the top of the shaft the loading due to tanker impact is very small.

The highest strained area seems to be at the level of the impact. Nevertheless, it is possible to design this area such that failure of the shaft is avoided, even for the extreme accidental case of a 2 m/s impact from a 150 000 tdw tanker.

6. REFERENCES

1. RØLAND, SKÅRE AND OLSEN, Ship Impact on Concrete Shafts. Nordisk Betong 2-4, 1982.

2. NPD., Regulations for the Structural Design of Fixed Structure on the Norwegian Continental Shelf, 1977.

3. VERITAS., Rules for the Design Construction and Inspection of Offshore Structures, 1977.

4. SVEIN FJELD, Design Assumptions and Influence on Design of Offshore Structures, IABSE Report Volume 41, 1983

5. VERITAS., Impact Loads from Boats TNA 202, 1982.

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