Ice protection structures

ICE BARRIERS For over 25 years IMPaC Offshore Engineering has gained substantial knowledge and experience in numerous ice engineering projects. One area of special expertise is the design of ice protection structures.

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The increasing demand for hydrocarbons requires offshore exploration and production drilling activities in ice infested areas. In shallow water areas like the North Caspian Sea, purpose-designed ice protection structures also called ice barriers can lead to solutions that provide technical and economical advantages compared to field developments without ice protection measures.

For the protection of offshore production facilities in shallow water areas permanent ice barriers made from rock or concrete structures are often the appropriate solution. For drilling exploration facilities, which usually have to change their location after they have sunk the well, ice barriers made from steel are mostly the better solution as they are easier to install and de-install.

Ice barriers can also be used to protect offshore wind parks or harbour installations.

Advantages

Ice barriers allow designing of an exploration platform or other offshore facility for reduced ice loads. The ice load reduction is a function of the type and number of ice barriers.

Less expenditure for the protected platform requires additional costs for the design construction, installation and operation of the ice barriers. However ice barrier structures also considerably improve the conditions under which supply of the offshore unit is possible. In some cases platforms can only be operated during the winter season with ice barriers in place. Also during the non-ice season ice barriers can improve the platform supply conditions by reducing wave heights in the vicinity of the offshore installation. Thus, ice barriers can considerably extend the availability of the platform with large positive effect on the overall economics of the offshore field operation.

Ice barriers can also be required to facilitate evacuation of the crew from the platform under ice conditions. Production on offshore platforms has to be stopped under extreme environmental conditions where rubble ice piles prevent the emergency evacuation of personnel. Therefore, ice barriers whilst protecting the integrity of the offshore platform structure also increase the availability of the platform's production, thus improving the economics of the project.

Requirements

An ice protection structure has to be a simple, yet robust structure as it is exposed to harsh environmental conditions and has to withstand large ice loads. The main requirement on ice barriers is a high technical reliability at a minimum material expenditure.

For the protection of mobile units like offshore exploration drilling rigs the de-installation and re-use of an ice barrier are also of importance.

Full compliance with environmental protection requirements is mandatory for all ice barriers.

Determination of design loads

The technical reliability of an ice protection structure is strongly dependent on the correct ice load. In some cases especially in deeper water areas the hydrodynamic forces due to waves and current can become the dominating load situation.

Deterministic methods are mostly applied to predict the ice loads as the data basis for a probabilistic approach is often insufficient.

When the ice protection structure is of simple geometry analytical methods can be applied to establish the ice loads. When the shape of the ice barrier is too complicated for analytical methods ice model tests have to be carried out.

In practice, the prediction of ice loads is not the major challenge but the determination of realistic full-scale ice conditions from which the ice loads will be derived. The uncertainty in the ice load conditions and the lack of full-scale data often require a conservative design approach and do not allow full design optimisation of the ice barrier structure.

Due to the lack of ice data satellite imaging has been utilised to determine ice conditions. The satellite images allow a fairly good estimate of the ice coverage and the thickness of sheet ice. But in many

Fig. 1: Drilling unit with driven piles as ice protection structure

Fig. 2: Ice protection piles, view from drilling unit

Fig. 3: Drilling unit with barge type ice barriers to protect against excessive ice loads

cases the dominating ice loads for an ice protection structure result from the interaction with pressure ridges, which cannot be identified from the satellite pictures. In such cases field observations and surveys are of particular importance.

Driven piles as ice protection structure

Driven piles have been used as ice protection means at the first two exploration sites of a mobile drilling barge, which has been operating since 1998 in the shallow water areas of the North Caspian Sea. The piles also serve as berthing and mooring piles for the supply vessels. The optimum pile arrangement has been determined in ice model tests. The main parameters influencing the ice load reduction for a given ice thickness are pile diameter and pile spacing. With the optimised pile arrangement the ice loads could be reduced by 60 percent compared to the solution without any piles.

Simple pontoons as ice protection structures

As a larger number of wells had to be drilled as originally anticipated the piles have been replaced at later sites by pontoons, which have the advantage of easy re-usage.

After de-ballasting and refloating the ice barrier barge can be towed to the next exploration site of the drilling unit. At the drilling site the ice barrier barge needs to be ballasted with sea water in order to create sufficient sliding resistance. In some cases concrete can be used as fixed ballast. However, due to draft limitations fixed ballast cannot always be used. Due to the simple geometrical form of the barge type ice barriers the ice loads could be established by analytical methods. However, for establishing the minimum number of ice barrier barges and their optimal arrangement relative to the drilling unit ice model tests have been carried out.

In future, ice model tests may only be required for verifications purposes as latest developments of computer models allow a relatively good analytical simulation of the interaction of drifting ice with ice barriers of different arrangement. ▶

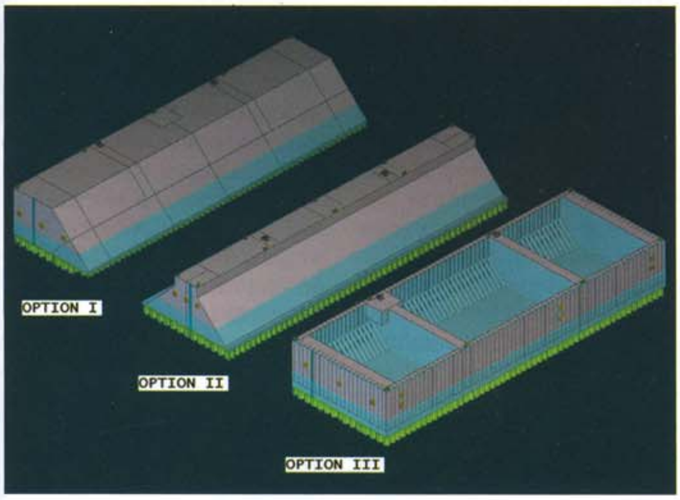

Fig. 4: Design options for optimised barge type ice barriers structures

Fig. 5: Ice barrier structure providing shelter for a supply vessel

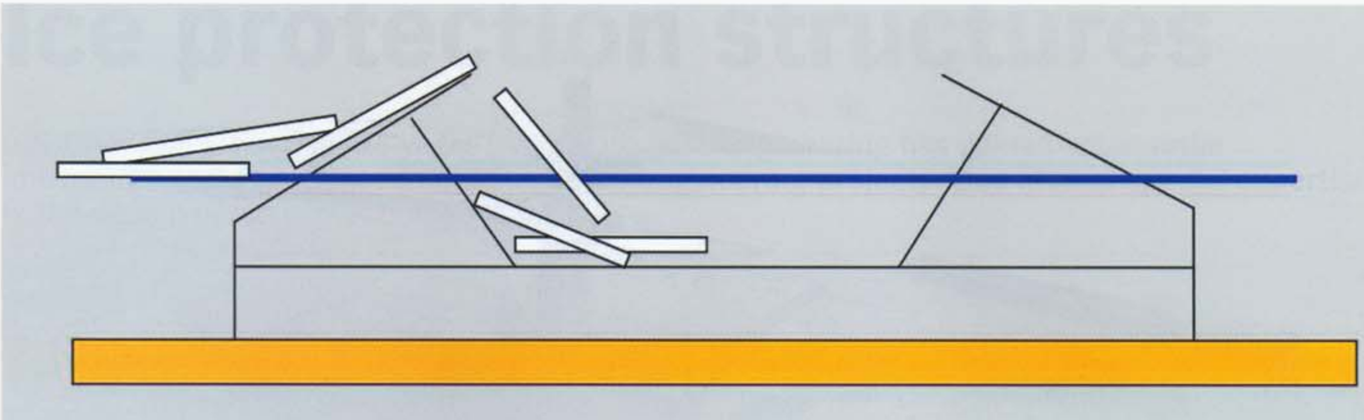

Fig. 6: Sketch of a light-weight ice barrier © IMPaC

Purpose-designed ice protection barges

Various types of barges have been developed by IMPaC aimed to optimise performance as an ice barrier.

The vertical wall design has been compared to sloped walls with different slope angles. For sheet ice the sloped surface has advantages but often the interaction with pressure ridges is the dominating load scenario for which the slope angle of the wall is of lesser importance.

Ice protection barges with one vertical long wall have advantages during site installation and de-installation or when the barge needs to be moored in a harbour or yard for inspection purposes. During operation the vertical wall normally facing towards to the drilling unit has the advantage of providing a berthing and mooring place for marine boats and barges.

Sloped walls also have the advantage of smaller local ice loads compared to vertical walls. The weight of the steel shell of a barge type ice barrier strongly depends on the size and distribution of the local ice loads. The smaller the ice load exposed area considered in the stress analysis the larger the local design ice load to be applied. The distribution of the local ice loads including so-called "ice background pressures" acting on the sloped or vertical shell usually leads to a vertical stiffening of the shell. For economical reasons plastic deformations of the outer steel plate and the stiffening bulb profiles are normally accepted while stresses in frames and bulkheads have to remain within the elastic range.

In Figure 5, a barge type ice barrier with one sloped and one vertical wall is shown, providing shelter for an ice breaking supply vessel.

While the local ice loads have a large impact on the design of the steel shell the global ice loads usually dictate the overall height and bottom width of barge type ice protection structure.

Fig. 7: Light-weight ice barrier with accumulated rubble ice and indicated ice drift direction

The ice barrier has to provide sufficient sliding and overturning resistance. In very shallow water areas sliding failure is more of a risk than overturning.

When the seabed is of the non-cohesive type (sand) the overall design of the ice barrier is weight driven. The larger the contact pressure from the bottom plate to the top layer of the seabed, the larger the sliding resistance of the ice protection barge. The sliding resistance can be further improved by using skirts. Spray ice could also be used to increase the weight of the barrier. The larger weight of the barrier structure leads to larger sliding resistance.

When the seabed is of the cohesive type (clay) the footprint of the ice barrier becomes important while the weight has less impact on the sliding resistance. At sites with cohesive seabed material, underwater berms or backberms can lead to an improvement of the sliding resistance.

Light-weight ice protection structure

IMPaC has developed a light weight ice barrier structure, which is based on the idea that the broken ice pieces will be collected and the mass of the accumulated rubble ice contributes to the overall resistance of the barrier.

The principle of the light-weight ice barrier can be seen in Figure 6. It shows the first stage of the interaction with drifting ice in early winter when relative thin ice has failed at the sloped wall and the broken ice piece start to accumulate.

Various ice model tests have been carried out to verify the function of the light-weight ice barrier. The ice model tests were also performed to measure the ice forces acting on the structure during the different phases of the interaction with drifting ice features. Also the mass of the accumulated ice was determined which allowed checking the sliding stability of the light-weight barrier structure.

Figure 7 shows the situation after the light-weight ice barrier has been filled-up with rubble ice.

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Outlook

Future exploration and production activities in the North Caspian Sea and other ice infested shallow water areas will require a considerable amount of ice protection structures, which need to be designed, built and operated.

IMPaC Offshore Engineering will continue to play a leading role in the realisation of these projects and also in the future development of new ice protection technologies.

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