Institution of Civil Engineers

# Engineering for offshore fish farming

14

# Engineering for offshore fish farming

Proceedings of the conference organized by the Institution of Civil Engineers, and held in Glasgow on 17-18 October 1990

Thomas Telford, London

Conference organized by the Institution of Civil Engineers, and co-sponsored by the Royal Institution of Naval Architects

Organizing Committee: H. D. Osborn (Chairman), H. S. Eadie, C. Funnell, Professor C. Kuo and B. T. Linfoot

A CIP catalogue record for this book is available from the British Library.

ISBN 0-7277-1601-8

First published 1990



Published on behalf of the Institution of Civil Engineers by Thomas Telford Ltd, Thomas Telford House, 1 Heron Quay, London E14 9XF.

Printed and bound in Great Britain by Mackays of Chatham.

# Contents

## Insurance and legal aspects



## Environmental aspects



## Design and construction

# 1. Insurance and risk control

G. FINDLAY, Director, Sedgwick Marine & Cargo Limited, UK

INSURANCE AND RISK CONTROL

1. Insurers generally have a pretty good track record of responding to the continually developing needs of industry and commerce. This means that they are often asked to try and assess and assume risk for new ventures or areas of industry that have little or no history, and they do so without the benefit of statistics and other underwriting information that they might normally use.

2. In the world of shipping, for example, detailed statistics are available illustrating the pattern of losses measured against a range of criteria such as the type, age, size and flag vessels, all of which might assist an underwriter in assessing risk. In addition to assessing risk, underwriters continually strive to work with assureds to reduce risk. They will seek to achieve this in many different ways, for example the fire insurer that insists on the installation of a sprinkler system, the insurer of war risk on merchant ships trading in a hostile area who might encourage the ship to be equipped with chaff to act as a decoy to a missile, or the fish farm insurer who might recommend or require that the stock is kept within certain density limits.

3. Whilst aquaculture has been pursued in one form or another for many many years, the industry that we know to-day has grown out of all recognition from that that we knew only a few years ago.

4. Looking at the salmon farming industry the success and the rate of expansion has been so phenomenal that for those countries involved it is a very significant industry. Of course, for the industry to expand, the various services that support the fish farmers also need to expand. The insurance industry is one such service. Insurers have responded well, notwithstanding that in recent years they have generally found it very difficult to produce an underwriting profit which is therefore likely to be a factor in limiting the supply of insurance. In reacting to this situation, insurers may

well review the price at which they are willing to sell insurance but an equally important part of the corrective measures that they are likely to focus on is the risk reduction that I referred to earlier. This risk reduction effort may well take a number of different routes. Significant loss of stock has arisen from disease and algal bloom, and in response to losses caused by disease insurers will look to see what can be done to improve standards of husbandry and so on, whereas the response to the threat of bloom must focus on some sort of early warning system combined with other measures such as the Norwegian system where all farms have a second site 'reserved' which might be in a different current system and to which the farm can be moved if necessary.

5. In addition to those perils significant losses have arisen from damage to or failure of equipment. In many cases the loss has been a result of the extreme weather conditions which seem to be becoming a regular feature of our increasingly unpredictable environment. This is at a time when the majority of sea sites are currently located in areas that have the benefit of some sort of protection from the coastline and when the possibility of larger and more sophisticated units exploiting what the oceans have to offer by being located some miles away from the coast will bring new benefits combined with new or increased risks.

6. Such a development might be a result of the increasingly limited supply of good coastal sites that remain, combined with advantages to a fish farming business with the ability of one unit to farm an enormous number of fish. In addition, environmental factors may also influence this development. Of course, the values of these larger and more sophisticated units would in most cases dwarf the value of the 'traditional' pens or blocks of pens that we are all familiar with, and when faced with insuring these units, underwriters may well begin to think of the risk reduction measures that they rely upon when insuring shipping. These measures place great emphasis upon surveys of vessels qualifying the vessel for class issued by one of a number of Classification Societies. Of course, different Classification Societies have different standards and therefore give underwrites different levels of comfort which ultimately expresses itself along with all the other underwriting considerations, in different levels of premium. It is certainly the case that there is a wealth of experience in the marine surveying world that brings great benefit to the world of shipping from the pooling and subsequent distribution of knowledge focussing primarily upon risk reduction. Of course work of this type is sometimes carried out by aquaculture insurers anyway. Different insurers have different policies towards surveying. These policies range from

insurers attempting to assess risk without the benefit of surveys, even though this is becoming increasingly rare, to insurers who not only insist upon surveys to assess risk, but who use those surveys to reduce risk at the outset by insisting that certain things should, or should not be done, and who then hope that such a relationship between farmers and surveyors can develop whereby the communication between the two is an on-going feature the objective of which is to reduce risk to the benefit of both parties.

7. In carrying out such surveys veterinarian, oceanographic, engineering, and probably other skills will all be called upon, and I would imagine that with the advance of fishfarming into the offshore environment, the demands that will be placed upon the surveyor will only increase. From the engineering point of view, larger more sophisticated units will certainly be developed - indeed the next generation of offshore farming units is already appearing.

8. If both the insurer and the surveyor knew that important aspects of the design and construction method had already been looked at by someone who, as in the shipping world, spends his time analysing these aspects at some sort of central body that can draw on the wide experience of the industry as a whole to the ultimate benefit of all, then the surveyor would have his rather daunting burden reduced. Insurers may then feel comforted that the lessons that are so often there to be learnt from past losses, are actually being learnt not only by the party who unfortunately suffered the loss, but also by others.

9. Of course, I realise that this concept introduces problems with confidentiality, but I'm sure that the benefits of a system that might help to strengthen the industry would assist the fishfarmer as these measures may contribute towards:-

- achieving a minimum level of losses
- insurance cost reflecting any reduction in losses
- stabilisation of some of the risks leading to a healthier underwriting environment.

10. These factors could only have a beneficial effect on the supply of insurance available to an industry which has a recent history of unrivalled growth and which will be hampered in any further expansion if its support services, including insurance, do not expand with it.

# 2. Risk assessment of offshore fish-farming cages

B. L. SMITH, Consultant, Aquaculture Risk Control Ltd, UK

1. In fish farming of salmonids, losses due to storm damage are usually blamed on extreme weather conditions. As fish farmers move to more exposed sites for ongrowing, extreme weather conditions must be regarded as a normal environmental condition.

2. Loss of stock by physical damage or disease are common even in sheltered sites. The basic causes often seem to boil down to two familiar words stress and Husbandry.

3. Few fish farmers believe they exercise anything less than perfect husbandry but all recognise that reduction in fish stress is desirable. Inshore sites suffer temperature, water exchange and salinity variations which are believed to be stress factors.

4. For these and other well recognised reasons, farmers are moving offshore and into an area which is very different to that with which the industry has grown up. This will stretch the husbandry capabilities of many an operator and will demand good piers, good boats, good crew, good moorings and good cages.

5. Assessing these new risks for the benefit of the industry and its insurers will mean focussing attention on all the normal husbandry factors plus those noted above. Heavy weather damage and cage and/or mooring failure is a prime consideration.

6. Cages available for offshore use are basically of steel, plastic or elastic materials - some notes on these may be of interest.

Steel

7. There are 3 main types of cage in this material, square cages with steel gratings on box or channel rails using normally foam filled plastic or GRP tanks or drums for flotation having steel handrails. This type of cage is either fully articulated (ie., having several short sections all hinged together) or aim to be flexible by their own elasticity but still require short sections to be welded or bolted together.

8. These types of cage, 15m square steel walkways on plastic flotation are the current industry standard - even in

fairly sheltered sites failures have occurred, most due to metal fatigue emanating from the heat-affected zones of weldments.

9. This is not to say that poor welding causes all such failures. The causative agent is metal fatigue which, to exist, requires a cyclic loading and a stress raiser.

10. Now in the case of a rigid steel structure which depends on the flexibility of the entire steel walkway or connected lengths of walkways; as the bending moment is proportional to the square of the section length $Bm \propto L^2$ we must look carefully at L. At first sight L = cage size (ie) 12m, 15m, 20m therefore $L^2$ = 144, 225 or 400, but L is the effective length between points of suspension which is of course dependant on the superimposed wave pattern and the damping effect of the net.

11. In all the computer models I have seen there are some fairly dramatic assumptions made about "L" hence for all practical purposes I would suggest that L should be taken as the length between hinges or in the case of the Undertun cage, the length between 3 floats. It's not so silly therefore to consider the cage size to be a good guide to bending moments (ie) a 12m cage has Bm = Kx144 a 15m cage Bm = Kx225 and a 20m cage has Bm = Kx400. In even simpler terms a 20m cage is likely to experience bending moments twice those of a 15m cage.

12. The only 20m cage which I have seen which seems to have been designed up to these levels of bending moments is the 20m Poseidon cage which appears enormous in scantlings at first sight and I certainly hope it is, but I just wish I had a pound for every time a competent engineer said to me "I wouldn't believe what the sea could do until I'd seen it with my own eyes".

13. I have to say that as a Marine Surveyor for nearly 20 years having seen large ships broken in two by weather, having seen bulwarks and even handrails flattened on deck by seas, and having read of the loss of several ships unexpectedly and for no apparent reason, I hear what all the academics tell me about what the computer confirmed it would stand then I listen to the "old salts" who seem to know better. Certainly when we look back at early buildings, bridges and ships etc., we see overdesign as opposed to the minimum necessary scantlings for estimated strength requirements. Fish farm cage manufacturers should take note.

14. Hinging short sections of metal walkway thus appears to be the answer but there has to be some stability of the platform and flotation so one can't go too far, and at present the 5-10m length of walkway between hinges seems to withstand quite a lot but not if one then tries to limit the movement at certain hinges by introducing locking bars, levelling braces or similar restraints which defeat the purpose of articulation.

15. From the static analysis point of view these fittings may be quite acceptable but in dynamics these areas are simply stress-raisers and as expected fatigue takes place at the heat affected zones of welds or any local stress concentration eg., where loading is localised (Wavemaster lock-bars, Adams levelling braces etc).

16. I have yet to see a proper written guarantee from a steel cage manufacturer who specifies wave heights up to which the cage is considered suitable.

17. I have some sympathy here because in a cage group where there is interaction between cages, too many variables are involved, eg., damping effects of nets in some cages connected to others with no nets must create huge dynamic forces between the two dynamically quite dissimilar, but connected, forces, so what happens at the connection point is impossible to calculate.

18. Mooring forces can alter with mooring drag. This need not be massive drag to seriously alter forces on a previously well tuned mooring system on a cage group.

19. Much can be said for separating steel cages rather than grouping them together. Perhaps such separation should be by long heavy chain to provide sufficient inter-cage damping. This does require very heavy moorings at each end of each group, but there is established technology available on moorings, so it is an avenue little investigated in my opinion.

20. The only metal cage which is designed for stand-alone offshore use is the Farmocean unit which is a serious attempt to provide a safe working platform which acknowledges the fact that weather conditions on offshore sites can be so bad that boarding <u>any</u> structure can be impossible for a period of days. There are, however, numerous bolted connections associated with the Farmocean cage and these have given trouble in the past. It is also a complicated structure which interacts awkwardly with the fish enclosure, namely a relatively flimsy net and reports of chafe, especially at cage/net connections are another problem which causes some concern.

21. The ship-type cage which is essentially a rigid honey-comb structure may be structurally fine but it still relies on nets and again the net/cage interface is the problem in my opinion - chafe and net tear are one of the problems most relevant in these cases. There is also an underlying worry about the sheer value of stock and equipment relying on what is essentially a single shackle pin, one length of chain etc.

<u>Plastic</u>

22. The types of plastic used in cages are much more flexible than steel and sections are commonly tubular, a shape which naturally permits more even stress distributions. For the same applied stress, plastic strains (deforms) much more than steel hence at any discontinuity in the structure, this strain causes high local stresses. A hexagonal plastic cage when compressed will almost certainly fail at the welded connections where the hex sides meet. A circular cage provides better stress distribution because the strain is distributed over a greater length of section but at connection points (handrails, tube cross connections etc) there is a weakness and these are usual points of failure.

23. Everyone who has walked round a plastic cage in bad weather will know how dangerous they can be. Fixed walkways cause more connections and limit the strain distribution

leading to higher local stress and also greatly increased wave resistance hence overall loading and deformity.

24. The larger the circumference of a circular plastic cage with vertical stanchions and circular handrail, the less resistance the circular shape provides to prevent handrail stiffness which when handling nets in particular can lead to handrail immersion, also in heavy weather. Lack of handrail stiffness makes difficulties in maintaining bird nets taught leading to problems and generally acts as a disincentive to good husbandry and prolonged fish study especially during feeding. Swimming and feeding behaviour and response are one of the most important factors in early detection of possible disease commencement - a most important risk factor.

25. Because of the need to maintain a reasonably constant circular shape and yet utilise the flexibility of the material, more mooring points are required leading to difficulty of access by service boats and the possibility of mooring rope damage by propellers and mooring breakage in bad weather/currents etc.

26. Plastic cages are normally tied to each other in "strings" preventing walking from end to end thus individual access by boat increases the risk of rope cuts, increases time spent (or labour required) to feed etc., thus decreases time spent in studying fish behaviour.

27. The very fact that cage groups are connected by quite long ropes however, reduces intercage forces and virtually eliminates shock loading which explains why plastic cage failures even in exposed sites are less common than failures at or near intercage connections in groups of steel cages.

28. To obtain equivalent cubic capacity using plastic cages versus steel cages requires either very many small cages, each requiring individual access by boat or a lesser number of large individual plastic cages with the handrail weaknesses these entail.

29. A prototype 3 tube plastic cage has been tested with encouraging results, the outer tube of large diameter section being used to take mooring forces and provide buoyancy. Hinged to this is a standard 2-tube circular cage of large circumference which still suffers from handrail flexibility but this is currently subject to possible design change and it is also intended to commence service trials using a novel form of walkway having hinged flap sections which will allow waves to pass through yet still provide a platform. These and other developments will undoubtedly lead to plastic cages becoming more user-friendly and utilised in sites increasingly advancing offshore.

30. There is always a downside however, one factor being the extra precision required during manufacture and assembly of a multi-tube structure and of course, additional cost.

31. There is a question mark over the acceptability of many basic plastic cages to farm workers unions, Government safety officers and of course fish farm insurance company inspectors who don't like getting wet!

Elastic Cages

32. Currently cages of neoprene or rubber type material with metal connections are most used for truly offshore production units.

33. The Bridgestone Hi-Seas cage is the leader in this field and has seen minor but significant developments over the years. These developments concern alterations to the steelwork and the buoyancy at the metal connection points.

34. In general, elastic cages whilst being extremely flexible, do of course require precise mooring arrangements in order to maintain the shape.

35. This of course leads to some difficulty of access around mooring ropes and the inherent flexibility makes constant tension of bird nets difficult to achieve.

36. The handrail is simply rope loops and the walkway is the elastic hose tubing - the combination of which leads to a most dangerous platform from which to work thus feeding and servicing is normally carried out from boats leading to a basic inability to study stock performance especially during feeding and necessitates diving regularly to check stock and of course net condition.

37. Other single tube makes exhibit similar problems and all require careful buoyancy control and flexibility control by internal pressurisation of the tube and maintaining this pressure.

38. The two tube elastic cage is much more difficult to construct such that the tubes are truly concentric and interaction between the tubes must be reduced to a minimum as elastic materials are subject to chafe which once established, is progressive.

39. In all elastic cages, net design and the connection points onto the flotation collar are very important - this also applies to the bird nets.

General

40. There is a tendency to underestimate the strength requirements of the net with an offshore cage. This can lead to net tears and ropes tearing out of the net which in turn leads to fish loss and the cage maker tends to collect the blame.

41. The feature common to all cages and the most important part of all fish enclosures is the net.

42. Netting material is compatible with smooth plastic collars but can snag and tear at discontinuities and where the mesh is connected to rope under tension so, spreading the distribution of support loads over a large number of meshes makes sense and avoids point loading.

43. Net/Elastic connections are fine but the net is invariably attached to a metal part with which material, vulnerable netting is incompatible especially if the metal is sharp edged and the netting weak and forced to be drawn across such a protuberance in a seaway.

44. A quick study of any fishing boat shows that those areas

where nets are likely to be drawn over are smooth, profiled, metal, shaped plastic or elastic.

45. Even in a well designed net/collar system there is a need to scrape off fouling by mussels and barnacles on a regular basis because these can accumulate on the buoyancy and steel-work then in rough weather nets can be forced against this surface causing wear and fish loss. "Tuning" fish nets by suitable weights to suit the wave characteristics of the collar and to counteract the currents at the site coupled with fine tuning the moorings to maintain collar shape in a seaway and keep the bird nets or lines tight is something of an art - one which bears study from a safe boat in a rough sea. In such situations, taking a video film is not easy but very educational when studied in warm, still conditions ashore later.

46. At time of writing this report several farmers are preparing to move offshore in the Spring. By the date of the talk the writer would hope to have visited all of these offshore farms and it is intended to show a number of slides of different cage types in different locations and hopefully in varying weather conditions.

47. Fish farmers venturing offshore will require the best of equipment and boats. The sea is a hostile environment, strict safety codes must be observed.

48. It makes sense to buy equipment from reputable suppliers who are prepared to state wave heights which their cages will endure without failure. It is sensible to demand inspection of cages during manufacture and if it is a new cage design, to employ qualified and experienced people to study drawings and proposals and build inspections. It is false policy to economise on ropes, nets and moorings, go for the heaviest best quality, these sums represent a small part of the eventual stock value.

49. Last but not least, it makes sense to select an Insurer who understands the differences which offshore sites represent - a far remove from the Kames cages tucked in a bay near the local harbour.

# 3. Controls and legal provisions governing offshore fish-farm developments

J. SIDE, Director, International Centre for Island Technology, Heriot-Watt University, UK

SYNOPSIS. The legal controls that apply to offshore fish farm developments are numerous and stem from many differing requirements under UK law. This paper provides an overview of the principal legislative controls and practical procedures that apply to the siting and operation of offshore fish farms in UK waters, focusing particularly on Scottish Waters where the majority of such developments has occurred. The term "offshore" is taken to include all marine farm developments but specifically to exclude associated onshore facilities and freshwater operations. This in particular the planning requirements under the Town and Country Planning Acts which apply to developments above the low water mark are not included. The review of UK law and practice examines provisions for the siting of fish farms, requirements for environmental assessment and protection, provisions applying in the event of outbreak of disease, to veterinary treatments and to the control of predators. The paper examines European law which will have increasingly a determining influence on aspects of water quality and product quality. Finally, recent developments for the certification and classification of offshore structures for fish farming are briefly discussed.

SITING: PERMITS AND LEASES

1. Section 1(2) of the Crown Estates Act 1961 empowers the Crown Estate Commissioners to manage the Crown Estate, which includes the seabed of the territorial sea and by Section 1(1) of the Continental Shelf Act 1964 any rights exercisable by the UK outside territorial waters with respect to the seabed (except for coal) are vested also in the Crown. The Crown also has all rights over the foreshore - the land between high and low water marks - unless at some time the Crown has granted rights to a particular area of foreshore to someone else.

2. The Crown Estate Commissioners (CEC) is thus the sole UK agency which has the authority to grant seabed leases for fish farming on the Crown Estate and to obtain rents from lease holders. A lease for mariculture purposes provides the holder with a right to occupy the seabed involved and security of tenure to initiate and exploit the fish farming enterprise. A lease is granted normally for 15 years and is conditional on

farming being established within 2 years and that there is no subletting. The lease cannot be transferred.

3. Although the CEC is the sole agency with the authority to grant leases, a permit must also be obtained from the Department of Transport under Section 34 of the Coast Protection Act 1949, though this is now done by the CEC as part of the leasing procedure. It should also be noted that in Shetland, Orkney and the Western Isles there are additional statutory provisions which may require an authorisation be obtained from the Islands Council for the siting of a fish farm (eg. The Zetland County Council Act 1974 requires a works authorisation is obtained from Shetland Islands Council). The Crown's right of ownership of the seabed in the northern isles is a matter of some dispute and no leases have been issued in Shetland in the past 2 years pending settlement of this issue.

4. In 1987 the Crown Estate Commissioners issued Guidelines on the siting and design of marine fish farms in Scotland (Crown Estate, 1987) which introduced the concepts of separation distances and Very Sensitive Areas (VSAs) as features of development control. In their most recent Guidelines (Crown Estate, 1989) the Commissioners have adopted a development strategy which includes a presumption in favour of new fish farm developments in certain areas and a presumption against in others. The Guidelines specify a set of three geographical areas:

i) Specified Very Sensitive Areas (VSAs). These are listed in Appendix A. There is a general presumption against further fish farm development in VSAs and a presumption in favour of improvement and innovation at existing fish farms;

ii) Loch Areas outwith VSAs. An indicative list of these is reproduced in Appendix A. Here there is a general presumption in favour of small and medium scale fish farms "compatible with other interests". There is a general presumption against further large scale farms (cages/rafts/lines occupying more than 12,000 $m^2$) in Loch Areas;

iii) Open Coasts. An indicative list of these is reproduced in Appendix A. There is a general presumption in favour of fish farms compatible with other interests on sites off the open coasts.

5. The areas listed in Appendix A do not include the Western and Northern Isles but this addition is expected shortly. To ensure that a particular farm development will not have significant impacts on other interests and users of the sea the Crown Estate have since October 1986 operated a formal consultation and appraisal procedure.

6. Applicants are asked to submit information about their proposal including the position and size of the site, the type and dimensions of any installations, output, onshore facilities and other relevant information. On receipt of an application