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Discussion and Comments

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Paper Title : Means of Reducing the Consequences of Ship Collisions with Bridges & Offshore Structures
Presented by: Mr. H. Svensson, Leonhardt, Andrä und Partner, FRG.
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Discussion by: Professor William C. Webster, Univ. of California, U.S.A.

I would like to caution against using deadweight tons as a measure of impact load. Deadweight is a measure of how much cargo the ship can carry. The ratio of this quantity to the total ship's weight varies considerably from ship type to ship type. It seems more sensible to use only the weight of the ship (that is, the displacement of the ship) when considering impact forces.

Answer by: Mr. G. Woisin, Private Consultant, F.R.G.

To the question put by Professor Webster to the paper given by R. Saul and H. Svensson as to the formula of the impact force and deadweight relationship named to me I think I should answer personally. The formula was derived by Mr. Svensson on his own on the basis of the curves of maximal and minimal impact forces given by myself acting as a consultant in connection with the project of the Store Bælt Bridge. At that time I was asked for the impact forces produced by big crude oil and coal carriers only. Of course for these types of ships the relationship easily could be changed to one with the displacement instead of the deadweight. However, there may be two objections against this:

Firstly, the relationship is meant with the size of the ship rather than with the actual displacement given with the draft while in collision; this could be misunderstood in case of a displacement relation more easily, I believe.

Secondly, the relationship does not refer to uncommon ships, as for example passenger liners, ice breakers, warships, etc., and this remains more obvious using the deadweight instead of the displacement.

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Paper Title : Modelling of Ship Collisions against Protected Structures
Presented by: Mr. O. Brink-Kjær, Danish Hydraulic Institute, Denmark.
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Discussion by: Mr. G. Woisin, Private Consultant, F.R.G.

I want to give some discussion comments on the paper presented by Mr. Brink-Kjær, Mr. Brodersen and Mr. Hasle Nielsen. It is the first paper, an introductory one, of some more papers on model tests performed on protection islands throughout the world.

As in the following papers, I miss some more thorough examination of the validity of model scales. In view of this, I think it not sufficient to produce agreement between some mathematical and physical models. If in the ship model, in the water and in the sand structure only the both types of inertial and gravitational forces are acting, buoyancy forces belonging to the latter, and if the surface friction coefficients are as high as in real size, the co-called Froude's number to be held constant is sufficient. The speeds then are to be produced due to this number and forces and energies absorbed will be scaled correspondingly.

But one cannot be sure, in my opinion, that the surface friction coefficients are the same in real size, and that there will not be of influence further relevant types of forces, e.g., cohesive and destructive forces in the sand structure of the protection isles. This perhaps could lead to completely different results in full scale.

Therefore I want to point to Mr. Minorsky's proposal, he made close to the end of his paper in written form, to conduct at least one full-scale test with a ship grounding, in a case which due to model tests is non-destructive to the ship. However, the possibility of some damages happening to the bottom of the ship should not be completely excluded.

Another proposal would be to repeat some of the model tests performed in some considerable different geometrical scale (not as close as scale 1:79 and 1:94 to each other), and to compare the results in view reliable extrapolation to full scale.

A third possibility could be to repeat the mechanics of a suitable grounding which happened unintentionally, in a hydraulic model. Of course, some problems are to be expected receiving reliable datas, e.g., on the speed, and to obtain a case and sandy grounds which can be simulated within the possibilities of the model test set-up.

It would be most interesting to observe whether scale effects can actually be exclused.

<u>Answer</u> by: Mr. O. Brink-Kjær.

We should like to thank Dr. Woisin for his interesting discussion comments.

We agree that the surface friction coefficients of scale model and prototype shall be carefully evaluated. However, it should be realized that the mathematical model does allow the influence of different surface friction coefficients to be investigated. Therefore the proper interpretation of hydraulic scale model tests can also be performed in cases where Froude scaling is not adequate.

In the study reported in our paper it was prescribed by other investigators that the surface friction characteristics of the scale model were applicable. In some of our more recent ship grounding studies we have used the mathematical model to provide collision data which showed the sensitivity of varying surface friction coefficients.

In the study reported here we have made no attempt to model collision forces in cohesive materials, neither by scale model tests nor by mathematical formulations. (For other studies, a modified description for contact forces has been applied for the mathematical simulation of ship groundings in cohesive materials).

We agree that scale model tests performed at a wide range of scales will be of great interest. However, our approach of accumulating experience from scale model tests in a deterministic mathematical model has proven to be a viable one, as it provides an engineering tool which can be applied within the significant time constraints which characterize many engineering projects. To date the mathematical model has been applied in Danish, Norwegian and American studies.

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Paper Title : Small-Scale Models of Bridge Pier Protection
Presented by: Mr. M.P. Luong, Laboratoire de Mecanique des Solides, Ecole Polytechnique, France.

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Discussion by: Mr. N.-O. Larsson, Swedish State Railways, Sweden

In the Danish-Swedish investigations for a fixed connection crossing the sound between Denmark and Sweden we have proposed artifical islands as protection for the ventilation towers for a road tunnel. In this case it is essential to notice that a colliding ship will press an amount of sand in front of it, thus causing increased earth pressure to the ventilation tower. In order to give the tower a satisfactory protection it is necessary to give the island an appropriate diameter. In my opinion, most of the islands we have seen in the contributions to this colloquium are too small, even for protection of bridge piers. An interesting problem is to find out the optimum slope of the island. If a long slope can be arranged, it will be possible to reach the favourable effect, shown by Mr. Minorsky, of the lifting of the front part of the ship during the collision.

Answer by: Mr. M.P. Luong

For an artificial island used as protection for the ventilation towers of a road tunnel, it is recommended to design the island with an appropriate diameter large enough to withstand the impact of vessel collisions.

A long slope island may be very costly due to a large volume of fill materials.

Test results from scale models have shown that the ship is practically indeformable compared to the deformability of the sand island. In addition, large vessels present such a large inertia that they cannot rise out of the water.

The main problem is the dissipation of kinetic energy: 2.4×10^9 J for a 80,000-ton ship moving at 15 knots. Small scale tests in the laboratory showed that the dissipated energy during impact is about 10^{10} J for 30 m of displacement toward an island having a slope 3/5. With a long slope island, the most favourable effect of the lifting of the centre of gravity is approximately: 8.10^8 N x 2 m = 1.6×10^9 J less than the dissipated energy due to passive pressure. This dissipated energy can be doubled if reinforced earth is used as shown in Fig. 11 p. 309 of the preliminary report.

Paper Title : Pier Protection by Man-Made Islands for Orwell Bridge, U.K.
Presented by: Mr. J.A. Perkins, Hydraulics Research Station Ltd. U.K.

Introduction by: Mr. J.A. Perkins.

Islands are a very cheap way of protecting bridge piers. Their other significant advantage is that islands have almost no maintenance cost. This is important when designing a bridge for a load case such as ship collision which may occur only once or twice during the life of the bridge.

The problems with islands which have to be considered at the design stage are:-

(1) the effect on the scour and deposition of the river bed materials

(2) the depth of water has to be reasonable as the size of the islands increases the span of the bridge

(3) it is very hard to prevent serious damage to small boats if they strike an island

(4) how much energy goes into the ship, the type and structure of the ship is unknown, it may not have been designed yet

(5) does the ship penetrate the island or slide up its armoured inclined surface

(6) how easy is it to refloat a ship which has stuck on an island

(7) what degree of protection should be provided during the very vulnerable construction period - it seems sensible to build the islands before starting bridge superstructure

and finally how do you choose the size of islands to prevent the design vessels from reaching the bridge and how much force is transmitted to the bridge pier when a ship strikes an island.

At the Public Inquiry into the construction of Orwell Bridge it was necessary to convince the port owners, the ship owners and the river pilots that a protective system of islands would be successful.

Model tests were commissioned to be carried out by the UK Hydraulics Research Station.

The basis for designing the experimental study and the principal findings from it, are discussed in the paper.

The advantage of recording the experiments on video was that it enabled the movement of the ship during the impact to be analysed in detail. Calculations of the initial and final energies showed that only a small part of the initial kinetic energy of the ship (less than 15 per cent) would be absorbed by the penetration of the ship into the island.

In order to assess the importance of the speed of the ship, tests were carried out in which the ship was forced into the island by a slowly applied horizontal force. The results suggested that for a given horizontal penetration into the island, the work done under static loading was approximately 75 per cent of the energy before impact i.e. 25 per cent of the initial energy is used in overcoming the dynamic resistance associated with the sudden impact.

One of the principal conclusions from the experiments was that the combination of a shallow draft vessel and a high tide level, presented the greatest threat to the bridge piers: the geometry of the islands was modified to take account of this.

Discussion by: Mr. G. Woisin, Private Consultant, F.R.G.

Mr. Fletcher at first mentions Froude's scaling law to be supposed and then states 'the dynamic resistance tends to conflict with the requirements for the other forces considered previously'. By which different type of force is the dynamic resistance governed if the beach material is non-cohesive as supposed for the static component of the resistance, and with inertial forces taken into account by Froude's law already?

Answer by: Mr. J.A. Perkins.

Mr. Woisin asked for some amplification of our discussion of the scaling of the dynamic resistance of the island material when the ship penetrates the island, some of the impact energy will be dissipated in the form of a shock wave, whose speed of transmission will be a function of (amongst other things) the elasticity of the island material. By using the same fluid and the same island material in both model and prototype, it is not possible to reproduce the elastic behaviour in a Froudian model. As well as absorbing some of the impact energy, the speed of the shock wave relative to the speed of the impact also determines the way in which the material moves during the impact. In a very low speed impact the material is able to shear so as to adjust to the penetration of the ship; in a high-speed impact the beach structure does not have time to adjust and presents the appearance of a more solid body to the ship. This aspect is not governed by the Froudian scaling and so constitutes another scale effect.

In conclusion we would like to support Mr. Woisin's plea for further research on this topic. The modelling of ship penetration described in papers at this colloquium is breaking new ground and is recognised to have shortcomings. Any further work is greatly to be welcomed.

Discussion by: Mr. N.-O. Larsson, Swedish State Railways, Sweden
Same discussion as to the paper by Mr. M.P. Luong, France.

Answer by: Mr. J.A. Perkins.

Mr. Larsson has drawn attention to the earth pressures produced during impact. The earth pressure onto the bridge pier partly depends on the ratio of the width of the pier to the width of the island. There is a case for keeping the pier as thin as possible, for Orwell Bridge for example the width of the top of the island was about seven times the width of the pier.

The optimum slope of an island has generally to be evaluated for each bridge site because as the island becomes larger, due to a flatter slope, the span of the bridge between the pier is increased.

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Paper Title : Geotechnical Model Tests for the Design of Protective Islands
Presented by: Dr. H. Denver, Danish Geotechnical Institute, Denmark.

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Discussion by: Mr. G. Woisin, Private Consultant, F.R.G.

Dr. Denver conducted dry soil tests. In the film shown the day before, perhaps therefore the behaviour of the beach material looked unnatural or something artificial, as I felt. My question now is whether and in which way the buoyancy forces to the beach material is taken into account. The soil tests conducted with a rigid ship model rigidly guided, are to my impression, rather far away not only, e.g., from Mr. Minorsky's contribution to the same subject, but also from real groundings.

Answer by: Dr. H. Denver.

The intentions behind the test series with dry model sand or gravel are to develop a mathematical earth pressure theory and not to determine the actual movements of the vessel. The problem is to determine the total earth pressure from the protective island when the ship has reached a certain penetration. Whether this position is reached as a straight line or as a more natural curved line is in my opinion of minor importance.

The buoyancy forces are taken into account when the model is used in connection with real islands or used to predict the traces in hydraulic model tests. (The weight of the submerged part of the soil is reduced in conventional manner).

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Paper Title : Hydrostatically Supported Sand Structures as Ship Collision Barrier
Presented by: Mr. A. Yoshida, Taisei Corporation, Japan.

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Discussion by: Dr.L.C. Zaleski, C.G. Doris, France

The presented protection system seems quite attractive. Could Mr. Yoshida specify, for which range of water depths has he considered its application?

Answer by: Mr. M. Yudasaka.

Theoretically, the water depth at which the sand isle can be constructed is unlimited. In view of workability and economy, however, the appropriate range is considered to be 15 to 30m, or 60m at the maximum, below the sea level.

Discussion by: Mr. Bejon Panthaky, Hindustan Construction Co. Ltd., India

I would like to have the following clarification:

I) External pressure on a rubber island is indicated as to be more than internal sandfill pressure. Since sandfill is placed hydrostatically internal pressure will be that of sand plus water & hence bound to be more.

II) What is the protection if someone cuts the rubber accidentally or deliberately as sabotage?

III) What is the life of rubber bag in sea water conditions?

IV) What is the cost of such protection compared to sand islands or any other conventional type?

Answer by: Mr. M. Yudasaka.

I) The principle of constructing sandisle is based on the ability to dewater the sand during construction thus reducing the internal porewater pressures and providing stability for the sand mass. As indicated in fig. 2, as the sand level inside the membrane rises, the internal water pressure throughout the placed sand is decreased by pumps installed at the bottom so that the internal pressure (water pressure + sandfill pressure) can be controlled to be lower at any point than the external water pressure.

II) Laboratory tests carried out during the development of the sandisle showed that if this occurs a local concave sand face will develop in the torn area but that thereafter, the inward seepage pressures of the water will hold the sand in place and permanent pumping systems will be more than adequate to maintain the stability of the sandisle structure. As the seepage continues, fine particles suspended in the water or bentonite introduced into the tear from outside the membrane will tend to coat the exposed face forming its own seal. However, we suggest that the area be patched as soon as conveniently practical.

III) When rubber is exposed to the air for many years, it generally deteriorates. However, in sea water, there is little deterioration and we consider that the life of the sandisle's rubber bags is indefinite.

IV) Compared with traditional sand islands, the sand quantity of the sandisle can be drastically reduced by artificially steepening the sides of the island. According to our cost study, the sandisle is more economical than the traditional sand island, specially in the case that the water depth at the construction site is large.

Paper Title : Floating Pier Protections Anchored by Prestressing Tendons
Presented by: Mr. P.E. Mondorf, Freyssinet International, France

Discussion by: Mr. Bejon Panthaky, Hindustan Construction Co. Ltd., India

The author is requested to explain his system if a ship hits the floats from the other side in which case the cables would be ineffective and the boat will carry the floating buffer and may disturb the whole system.

Answer by: Mr. P.E. Mondorf.

The Fig. no. 1 on my paper shows the lay-out of the system for a particular case i.e. the Zarate Brazo Largo (RA). For that bridge the owner asked for protection of the piers against ships coming downstream within an angle of $\pm$ 12° with the pier axis. Therefore no protection against ships coming from the other direction is shown, it could certainly be arranged, but it was not requested.

In case the buffer is hit by a vessel in a direction opposite to what it is designed for, it will probably be pulled along by the ship till it is completely reversed and then it will start functioning again. The case you have raised certainly has to be taken into account and deserves further analysis.

Dicussion by: Dr. U. Rabien, Germanischer Lloyd, F.R.G.

There can be reasonable peaks of stress in the line, when a counter-weight buried in the ground will be raised.

Answer by: Mr. P.E. Mondorf.

Peak stresses may occur, but the system possesses reasonable margin to cater for them as it will be seen from the following. Firstly, the service load of the tendons has been counted as less than half of their breaking load, secondly, at the moment when the activation of the counterweight starts, the theoretical tendon forces amount to only about a third of their ultimate value, and finally, between the floating element and the counterweight a supplementary loop of a smaller size tendon has been provided, which may help dragging the counterweight out from its more or less buried position.

Discussion by: Professor Ingvar Schousboe, Univ. of Illinois, U.S.A.

When the counterweights are lifted (stages 2, 3 & 4 in Fig. 6, page 369) there must be a considerable tendency for the buoys in the Fencing Line to be dragged under, the downward component of the force in the tendons being the cause.

The question is prompted by thoughts about bulb-nose bows travelling with the bulb partially out of the water or, perhaps, by bows such as found on icebreakers (to be extreme).

How are the cables engaged by the ship kept on the bow?

The text on page 364 could perhaps be expended by a few sentences.

Answer by: Mr. P.E. Mondorf.

The floating elements have all been designed so that the downward components of the tendon forces will not compromise their floatability. This leads to elements of considerable dimensions, therefore their number has purposely been kept low.

As far as the second question is concerned please refer to the answer given to Dr. U. Rabien on the same subject.

Discussion by: Dr. U. Rabien, Germanischer Lloyd, F.R.G.

There are many ships with inclined bow lines without bulb. Some detailed analysis is required, whether shipping over the protective device moored in front of the pier may occur or not. Most wrong going vessels are in unloaded condition, normally with aft trim, sometimes with bottom line above waterlevel at fore end.

Answer by: Mr. P.E. Mondorf.

In order to analyse the oversailing risk, many different cases have to be considered, depending among other things on the shape of the bow of the ship, its loading and trim, etc.

Roughly speaking, a ship having a bulb nose below the water could be caught by a single strong tendon hanging at about water level, whereas to catch an aft trimmed ship with a bulb nose above the water several tendons hanging at different levels and forming a curtain could be more efficient. Such curtain might be able also to catch some types of ships with inclined bows, but probably not all and not in all loading conditions, so other variants may have to be included.

The tendons themselves will have to be protected against sharp kinks, therefore they need to be fendered with neoprene cylinders or similar which will force the tendon to adopt a smooth curve around the nose of the striking ship.

In order to transform several parallel tendons into a curtain or other types of netting, diagonal nylon bracing or rigid spacers could be envisaged.

Obviously, a fully satisfactory solution to the oversailing problem can be developed only in a teamwork involving naval architects, tendon specialists and maybe other interested parties. However, we are confident that good solutions covering the majority of cases could be found.

Discussion by: Mr. Eric Ingerslev, Canarian Islands, Spain.

Mr. Ingerslev posed a question concerning impact forces.

Answer by: Mr. P.E. Mondorf, Freyssinet Int., France

For the particular case considered in my paper, the impact force for the vessel striking a stiff pier is estimated to about 110 MN ± 50% (see Saul and Svensson).

Applying the floating buffer proposed in my paper, and passed the first instants of the stock, the force exerted by the buffer system anchored by the retainer tendons, does not exceed 15 MN, which means, that the buffer through its withdrawal gives a substantial reduction of the impact forces on the ships, so the system is very favourable to the ship as well as to the piers.

Considering the kinetic energy involved, we found that a maximum of about 1/4 is absorbed through the deformation of the ship, a small part through the extension of the tendons whereas the overwhelming part goes into the lifting of the counterweight - in fact a very favourable way of energy absorption.

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Paper Title : Protection of Offshore Structures against Ship Collision
Presented by: Mr. R. Lacroix, Ecole Polytechnique, France

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Discussion by: Mr. M.F. de Rooij, Shell U.K. Exploration and Production U.K.

A) The paper describes a cable system which is placed around a platform by means of buoys and an anchoring system to absorb impact energy. This system as described would prevent supply boat operations and a large opening (in the protective cable system) would be required in order not to endanger these operations. What is proposed as solution?

B) Fatigue due to cyclic wave loading is an important design consideration for offshore structures. Has this aspect been addressed in the design of this proposed protection system which may require a 20 - 30 years life-span?

Answer by: Mr. R. Lacroix.

A) Indeed an opening must be let in the cable system, in order to permit the naval operations around the platform. As collisions are mainly due to the action of wind and current, it is easy to find the best orientation of this opening, which minimizes the probability of hazard; this way is wellknown in harbour design.

B) Fatigue has been taken into account as usually in offshore structures by reducing the working stresses. It is important to notice that even in heavy storms, the stresses imposed to the various structural elements are very low, because these elements are dimensioned to withstand collisions, which are exceptional actions.

General Comments to Theme D2
Means of Reduction of Consequences of Collisions

Comment by: Dr. David J. Ball, Simon Engineering Laboratories, University of Manchester, U.K.

If we are to protect both ship and bridge pier we must consider the implications of any protection devices beyond the moment of impact. We may have the situation where a ship is deflected off course by the protective device and as a result collides with another ship or another part of the structure or another structure. Even on impacting the device the ship may swing around and be involved in a collision. We are therefore only beginning to establish the problem and find solutions - it will in addition be necessary to fully examine the consequences of the solutions.

Comments by: Mr. J.A. Perkins, Hydraulic Research Station, U.K.

Fixed structures adjacent to bridge piers have been proposed as one method of protection. When considering such methods, the effect that they will have on the flowpattern around the piers of the main bridge must be taken into account. It is quite conceivable that the fixed structure could produce significant scour depths around the main bridge.

Comments by: Dr. William C. Brown, Freeman Fox & Partners, U.K.

With regard to the use of rigid protective islands, comment on the need to provide more flexible devices to protect both vessel and bridge.

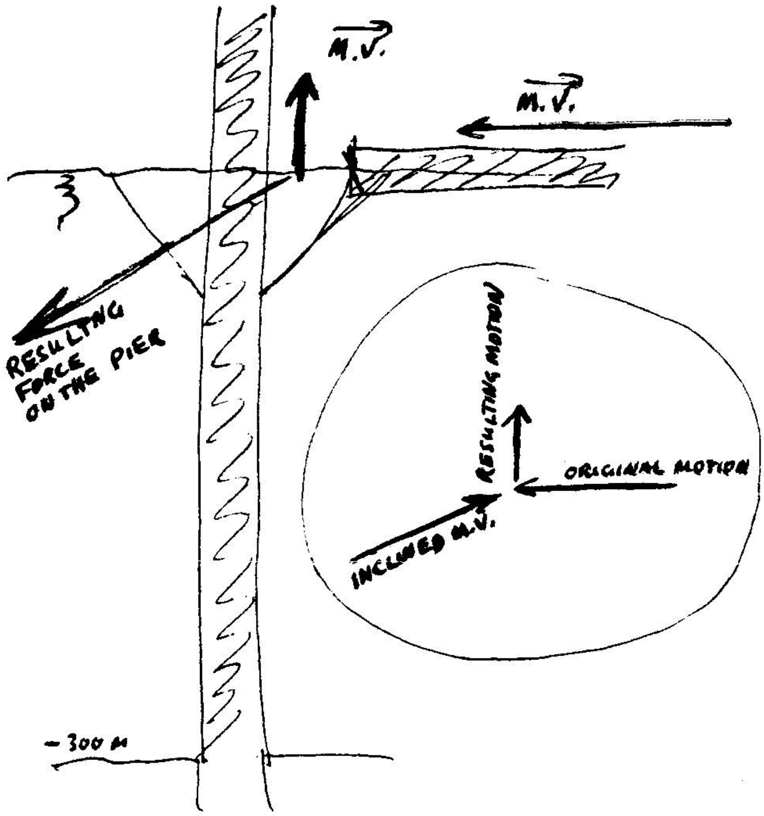
Spillage of oil in accidents involving tankers as a problem perceived by the general public cannot be totally ignored.

Possible solution aimed at protecting both ships and bridge is outlined.

Discussion by: Dr. L.C. Zaleski, C.G. Doris, France

I have been impressed by Dr. Brown's presentation of the umbrella type piers protection concept. I would, nevertheless, be happy to obtain some basic explanations with regard to its mechanism. I have understood, the suggested system is converting a horizontal motion in a vertical one. But, according to the conservation criteria of motion quantity, this involves action of an inclined motion vector, its coordinates being equal to minus the horizontal one and plus the resulting vertical one. Such motion, as I understand, should be generated by the pier reaction. As reaction = action, the latter one applied on the pier, seems to conserve a horizontal coordinate quite unchanged. Thus the overturning moment generated by the ship collision occurring near to the water level seems to remain high, especially in the presented example of a pier in 300 metres sea depth. Am I wrong or am I not?

Illustration to Mr. Zaleski's discussion:



Answer by: Dr. W. Brown.

It is not suggested that the system eliminates forces on the pier, simply that it provides an economic device for maintaining a retarding force for a considerable time and hence reduce it to a level which can be accepted by the pier and the ship without serious damage.