I-59 DESIGN OF MARINE STRUCTURES PROVIDED WITH RUBBER FENDERS CONSIDERING SHIP LOAD IMPACT

BY

SADAO KOMATSU *

ABDEL HAMID SALMAN **

(Members of JSCE)

Introduction

In the annual conference of JSCE held in Osaka in November 1970, the authors presented, (Abstract I -174), a hypothetical method for designing berthing structures provided with fenders of linear or non-linear spring constants. The method of analysis is based on the dynamic behaviour of the system (ship, fender structure) after collision.

This paper describes the practical application of the method on structures provided with rubber fenders,which are in this class, are being used extensively due to their large energy-absorbing characterstics.

Existing Methods For Design Rubber Fenders System

Engineers involved in designing berthing structure, estimate, first, the part of the ship's kinetic energy that transfered to the fender system(fender and struct.) by using emperical formaulas. Second, the fender is selected to absorb all the estimated energy. Third, the structure is then designed to withstand the horizontal load corresponding to the selecting fender absorbing capacity. The fender absorbing capacity, and consequently the design horizontal load, are evaluated from the

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* Prof. of Civil Engineering, Osaka University

** Doctorate Course Student, Osaka University (Eng. Suez Canal Research Center, Egypt)

behaviour of the fender under statical tests. Thus by this procedure the dynamic action after collision is overlooked.

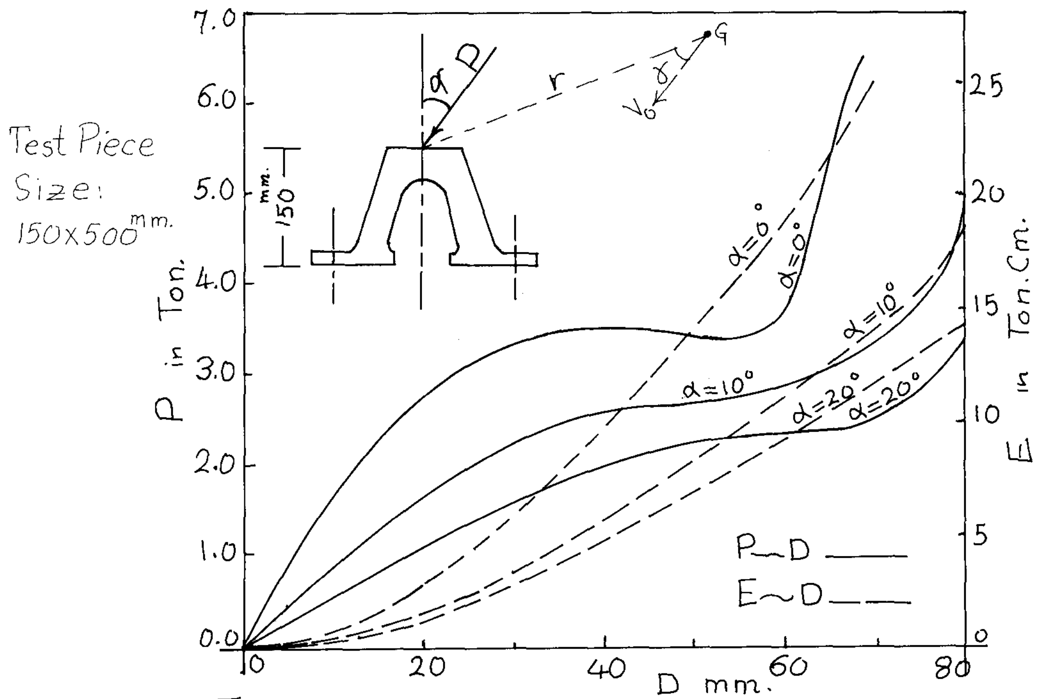
The dynamic motion of the system after collision

Structure deflection	$\ddot{x}_1 = P/M_1 - K_1 x_1 / M_1$
Point of contact on the ship,s hull	$\ddot{x}_2 = - P/M_2 - (r \ddot{\theta} + H \ddot{\phi}) \sin \gamma$
Yawing motion of the ship	$\ddot{\theta} = P r \sin \gamma / I_{2-2}$
Rolling " " " "	$\ddot{\phi} = (P \sin \gamma H - W H_1 \phi) / I_{1-1}$
Fender contraction	$D = x_2 - x_1$

with the following initials conditions of motion;

$x_1 = x_2 = \theta = \phi = 0.0 \qquad \dot{x}_1 = \dot{\theta} = \dot{\phi} = 0.0 \qquad$ and $\dot{x}_2 = V_0$

In solving these eq. the effect of the direction of the ship's impact load should be taken into consideration as the energy absorbing capacity of rubber fenders depens on the load direction as seen by the tests result in fig.(1) carried out by the authors.



Fig(1) Load and Energy vs. Deflection

N.B. The tests are carried on rubber fenders Produced by Sumitomo Rubber Co.

Selection of the Parameters for Solutions of the Motion Equations

On the basis of the experimental and theoretical work carried out by investigators involving in Naval Architecture ,the authors could derive formulas for estimating the virtual mass of the ship in case of berthing, these are;

M_2= virtual mass in sway motion $= M + 1.38\ d^2\ L$

I_{2-2}= virtual moment of inertia in yawing motion $=0.04\ L^2\ M_2$

I_{1-1}= " " " " " rolling " $=0.202\ B^2\ M$

and

H_1= vertical distance between the ship's center gravity and its metacenter

$$= 1.33\ (B-L/C_1)/\ C_2$$

C_1= 12.5 (U- shape) , 13.5 (V-shape) C_2= 5.7

On the basis of investigations of existing berthes in Kobe Harbour, the effective mass of the structure M_1 can be assumed ,for the first design approximation, as

$$M_1 = 0.01\ M_2$$

L, d, B, and M are the ship's length , draft ,beam and the displacement weight respectively. The solution of the eq. is carried in step-by-step using numerical integration methods as Newmark β method.

A P P L I C A T I O N

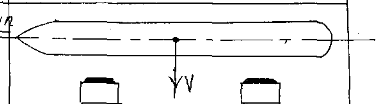
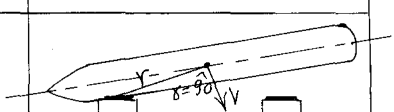
A tanker ship of 40 000 ton displacement weight is approaching to berth with velocity V_o=11.5 cm./sec. Assuming the berthing structure consisting of two dolphins of spring constant K_{II}= 15 ton./cm. each .Two cases of berthing are to be investigated.

L= 200 m. d = 10.30 m. B = 25.80 m.

I) Broadside Berthing

II) Oblique Berthing

r = 80 .0 m. H = 3.00 m. $\gamma = 90^{\circ}$

Case No	Description of the Fender	Energy Absorbed by Fen.	Max. Dynamic Load	Max. Deflec. of Structure	Notations
		Per Dolphin	Per Dolphin	In Load direction	
I	Each dolphin is Provided with one	20.5	168 ton	11.2 cm	
II	Peice of V600H×2500 Produced by Tokyo Rubber Dock Fender Co.	11.70 t.m.	79.62 ton	5.31 cm	

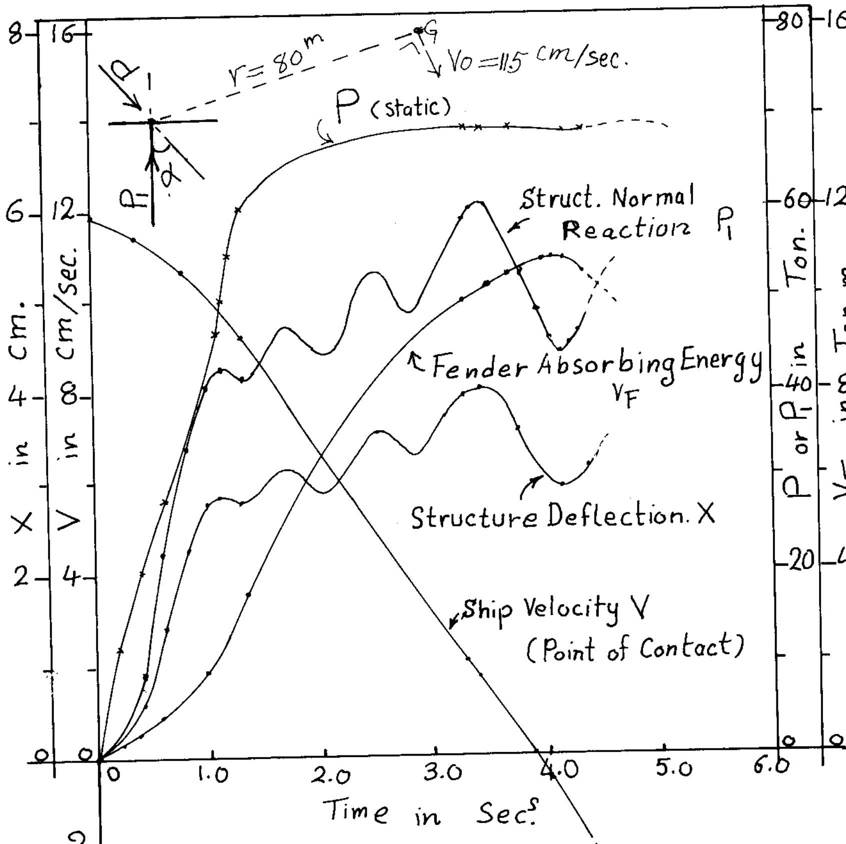


Fig (2) Typical Response of The Berthing System After Collision

[" Case II Oblique Berthing"]

CONCLUSIONS

By the design procedure presented here above ,the part of energy that transfered during berthing to each of the fender and the structure and the max. impact force can be evaluated . Economic design can be achieved by trying different types of structures (different K_1) and in each trial , the structure is provided with different types of fenders (different P～D) untill the allowable deflection of the structure accompanied by the min. max. dynamic force is attained.