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Mooring forces and vessel behaviour in locks -- experience in China

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PIANC
Setting the course

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1 INTRODUCTION

Technical codes for the design of locks used by inland vessels in China:

- *Code for Master Design of Shiplocks*
- *Code for Design of Hydraulic Structure of shiplocks*
- *Design Code for Filling and Emptying System of Shiplocks*
- *Code for Design of Lock Gates and Valves of shiplocks*
- *Code for Design of Headstock Gears of shiplocks*
- *Code for Electrical Design of shiplocks*

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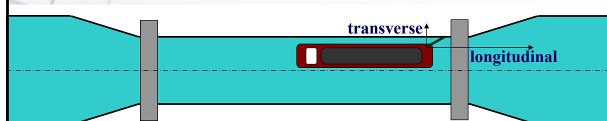
2 SAFE MOORING

Table 1: Acceptable mooring forces of vessels

Vessel Tonnage (t)	3000	2000	1000	500	300	100	50
Horizontal longitudinal components of allowable mooring forces (kN)	46	40	32	25	18	8	5
Horizontal transverse components of allowable mooring forces (kN)	23	20	16	13	9	4	3



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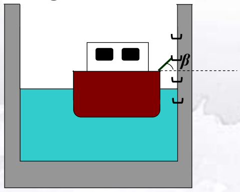
2 SAFE MOORING

The vessel tonnage means the deadweight of the motor barge. For a push train it means the deadweight of one barge of the train. Allowable mooring force on a push train shall be determined by the minimum barge tonnage in the train. When the fixed bollard or hook is used the mooring force shall be multiplied by cosβ, where β refers to the maximum angle of the hawser and water level.



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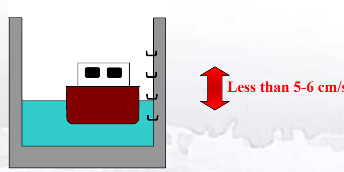
2 SAFE MOORING

For locks with only fixed mooring equipment, the maximum water surface lifting speed in lock chamber during filling and emptying shall not exceed 5-6 cm/s. When floating bollards are used, there is no similar limitation.



2 SAFE MOORING

To simplify the problem the vessel forces are used to compare the acceptable mooring forces of vessels and to evaluate the design of filling and emptying system of the lock.

The vessel forces are usually got by analytical method for loop culvert system and physical model for more complicated system.

physical model test

2 SAFE MOORING

For the short culvert system the vessel forces could be calculated by the following formula. In the process of filling:

$$P_1 = P_B = \frac{k_r \omega D W \sqrt{2gH}}{t_v(\omega_c - \chi)}$$

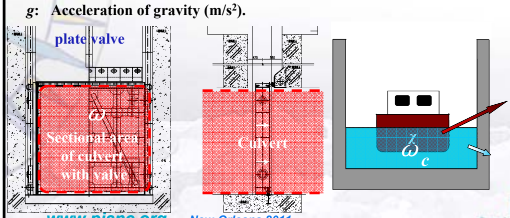
In the process of emptying:

$$P_1 = P_i + P_V$$

P_1: Hydrodynamic force on vessel (kN);
P_B: Wave force in the initial stage of filling (kN);
P_i: Force produced by water-surface gradient during the emptying process (kN);
P_V: Force produced by longitudinal velocity in lock chamber;

2 SAFE MOORING

ω : Sectional area of culvert with valve (m²);
k_r: Coefficient concerning valve configuration (could be 0.725 for a plate valve);
D: Wave force coefficient;
W: ships displacement (t);
H: Design lift height (m);
t_v: Valve opening time (s);
ω_c: Sectional area of lock chamber at the initial water level (m²);
χ: Area of wetted cross section of vessels (m²);
g: Acceleration of gravity (m/s²).

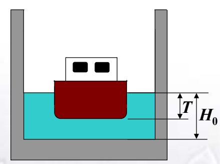


3 HYDRAULIC CRITERION FOR APPROACH CHANNELS

The water depth in approach channel should be decided as follows:

$$\frac{H_0}{T} \geq 1.50$$

H_0: the water depth in approach channel at the lowest navigation level (m);
T: full loaded draft of design vessel (m).

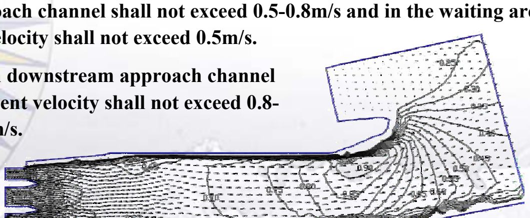


3 HYDRAULIC CRITERION FOR APPROACH CHANNELS

Then the current velocity should be limited to guarantee vessels safe manoeuvring in approach channel.

In upper pool the maximum longitudinal current velocity in approach channel shall not exceed 0.5-0.8m/s and in the waiting area the velocity shall not exceed 0.5m/s.

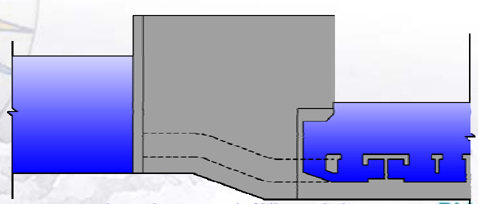
In downstream approach channel current velocity shall not exceed 0.8-1.0m/s.



current velocity simulation in downstream approach channel

4 REDUCING THE FORCE ON VESSEL

The forces acting on the vessel are determined by the water level differences around the vessel, the flow velocity and friction on the vessel. The forces acting on the vessel depend mainly on the design of the hydraulic system of the lock. Fine design could evidently reduce the forces.



short culvert system in Shihutang lock

4 REDUCING THE FORCE ON VESSEL

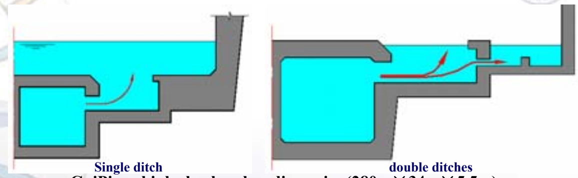
In the longitudinal filling system, the transverse force on vessels is limited. A new type of short culvert system is used in Shihutang lock in China. The forces acting on vessel during filling and emptying are mainly longitudinal and some results got from laboratory model test are shown in Table 2.

Table 2: Forces on vessel of Shihutang lock (chamber dimension 180×23×3.5m)

Lift(m)	F/Etime(min)	Max. longitudinal force	Max. Transverse force
11.14	11.2 (F)	30.8	15.2
	8.4 (E)	31.4	5.6
10.54	10.76 (F)	31.4	8.7
	7.53(E)	24.1	3.8
9.77	9.63 (F)	29.4	9.4
	6.72(E)	23.5	3.0

Note: Acceptable longitudinal force is 32 kN and transverse force is 16kN.

4 REDUCING THE FORCE ON VESSEL

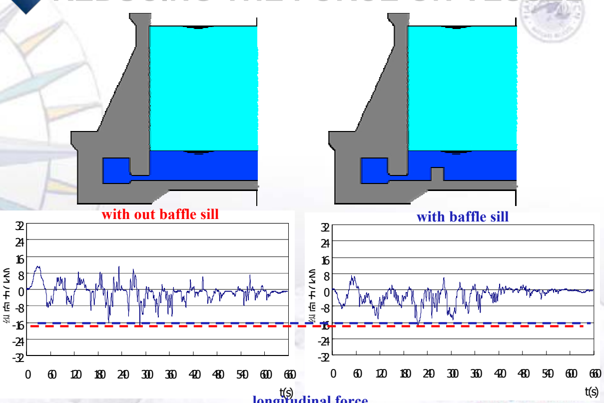


GuiPing shiplock, chamber dimension(280m×34m×5.5m)

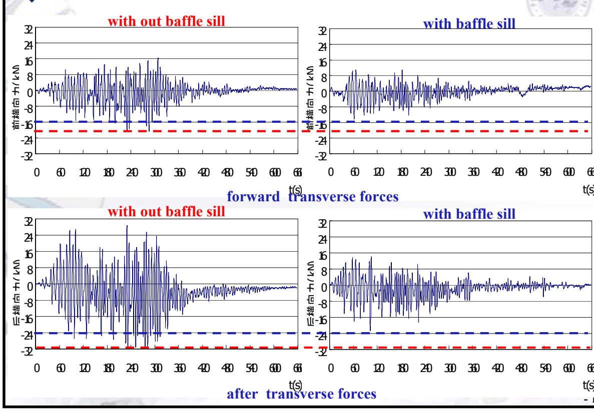
	Filling time	Max. transverse hawser force
Single ditch	9min	56 kN
Double ditches	9min	11.2 kN

Note: Acceptable transverse force is 20 kN

4 REDUCING THE FORCE ON VESSEL

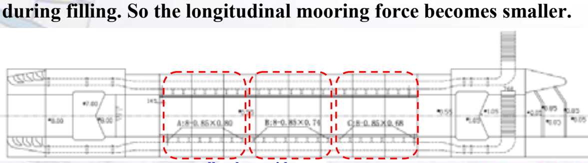


4 REDUCING THE FORCE ON VESSEL



4 REDUCING THE FORCE ON VESSEL

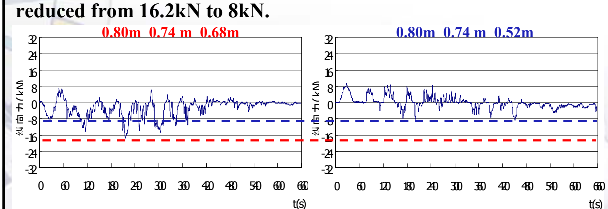
But in the wall culvert side port system, the longitudinal force could be reduced by a fined design to the port size. Along the flow direction the port size could be divided into three groups. The height of all ports can be the same and the width can be narrower along the water flow direction during filling and emptying. This makes the water into the chamber more uniform in the longitudinal direction and reduces the slope of the water surface during filling. So the longitudinal mooring force becomes smaller.



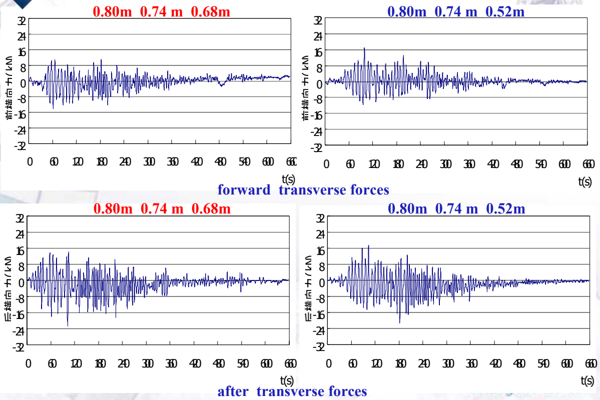
wall culvert side port system

4 REDUCING THE FORCE ON VESSEL

For example, there are 24 ports on one side wall. All have the same height of 0.85m. They were divided into three groups which has the width of 0.80, 0.74 and 0.68m separately. In the test the width of the third group of ports was reduced from 0.68m to 0.52m. The maximum longitudinal force acting on vessel was reduced from 16.2kN to 8kN.



REDUCING THE FORCE ON VESSEL



Thank you for your attention

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