PHOTOGRAMMETRIC MEASURING OF THE DEFORMATION OF THE WATER SURFACE IN THE LOCK IN THE PROCESS OF FILLING AND EMPTYNG.

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1.Introduction

Inland water transport with regard to its economical priority and its influence on the environment recently recorded a considerable development.The contemporary development in the structure of inland waterways is characterized by building high shipping steps and large locks.A lock is from the view-point of the density of traffic a critical element on a waterway,in fact it is a limiting factor of the density of traffic.

In order to obtain the minimum lockage time of a vessel /barge/ in the lock chamber the design of the filling and emptying system required must enable the lockage of a vessel as fast as possible.Since the filling and emptying time of a large lock with a high lift is considered to be the largest part of the total lockage time,it is necessary to find its optimum value with regard to the physical safety of vessels.

To describe the filling and emptying of the lock in terms of hydraulics,it can be said,that it is a very complicated phenomenon and theoretically is not as yet completely explored,especially in the case of large locks,which are filled/emptied/through a complex hydraulic system.The phenomenon of unsteady flow with unceasingly changing hydraulic parameters takes place in the lock chamber.The water surface slope resulting from the above mentioned phenomenon in the lock chamber makes a complicated spatially curved surface,where the resultant of the water surface slopes in the longitudinal and transverse direction causes the motion of a vessel in the lock chamber,and thus hawser forces occur during the filling of the lock chamber.

Direckt measuring of hawser forces is very difficult.That is the reason why there exists a tendency to measure the course of deformation of the water surface during the lock filling/emptying/process sufficiently precisely,amd on the basis of these measurements to determine the course and magnitude of the hawser forces.

The measuring of the water surface deformation in the filling of the lock was made on a model study of the Gabčíkovo lock on the Danube River.The scale ratio of the model was 1:33,33, whereby the actual dimensions of the lock were:the lenght was 275 m,width 34 m and lift 23,6 m.

The water surface slope in the lock varies in the process of filling/emptying/according to the filling velocity and the water surface level raised up to 700 mm/in the model study/ in a short time interval/2-3 minutes/.The measuring method required to determine the water surface slope under the above mentioned conditions must enable in this short time interval to carry out about 20-30 measurements of the height of the vessel terminal points accurate to $m_z = \pm 0,5$ mm.

Out of various measuring methods in our case we used the photogrammetric method with time basis,which recorded the magnitudes by means of recurring exposures of the lock chamber on one photographic plate.The photographs were made by the universal measuring camera UMK 10/1318 Zeiss Jena and were reproduced on photographic plates of the type WP-1,the sensitivity of the plates is 22 DIN ORWO.

2. The Distribution and Signalling of the Control and Observed Points.

The control points/A,B,C,D,E/were located on the plane of the rear wall of the lock chamber/fig.1/,whereby points A and B were in the same level and at the same time the line connecting these two points was the X-axsis of the lock.

The observed points/1,2,3,4/were located on the axsis of the middle vessels of the barge/fig.1/.The line connecting these points was parallel to the X-axsis and the distance between these two lines was ΔY.

The control and observed points were signalled by miniature bulbs made by TESLA/2,6 V and 0,2 A/.

The spatial co-ordinates of the control points and standpoint S were determined by using the forward intersection method /$m_{xy} = \pm 0{,}3$ mm/in the local co-ordinate system and then transformed to the co-ordinate system the lock chamber/X,Y,Z/.

3. Despatch of Photographs.

The photographs were made at the standpoint S/a bracket on the wall of the hydraulic engineering laboratory/fig.1//.The levelled axis of the shot was aimed at the control point E by the orientation device of the measuring camera.

The lock was photographed by means of recurring exposures, the interval being 5 sec.,on one photographic plate in a darkened laboratory,whereby the changes of water surface slope were

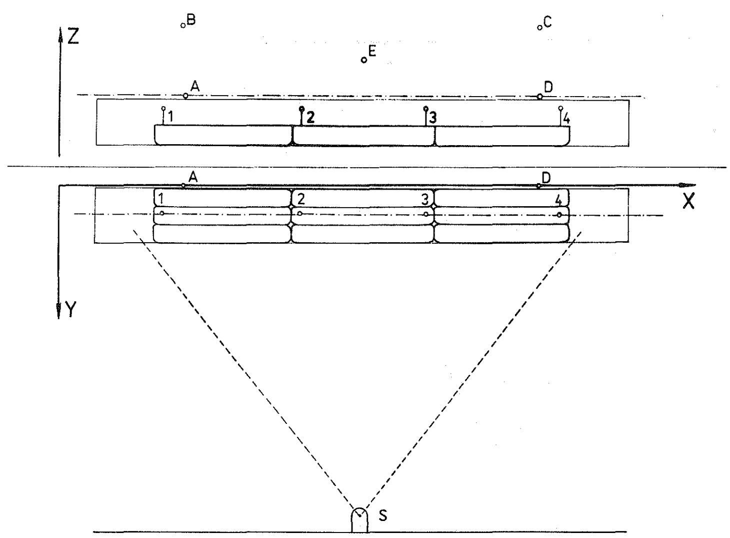

Figure 1

intercepted as a function of the lock filling time.The control points were photographed before the filling valve of the lock was opened.The camera was shut by an electrical device.

The lock chamber was photographed at three different valve opening periods/80,120,100 sec./,whereby the photographs were made for valve opening period 3-5 times.

4. Measuring of the Photographs.

The photographic co-ordinates of the **frame** marks,the control and observed points were measured by a monocomparator KO-

MESS 30/30 Zeiss Jena accurate $\pm$ 2 μm.The comparator co-ordinates (x_φ'),$(z_\varphi')$of the above mentioned points were transformed by the means of an affine transformation to the co-ordinate system of the frame marks x_φ',z_φ' in the photographic plate Π_φ.

5.Computation of the Water Surface Slopes

The water surface slope for the individual lock filling operations was computed on the computer WANG 2200.The computer program in BASIC was based upon these computational stages:

I.stage:

The photographic co-ordinates of the control and observed points x_φ' ,z_φ' ,in the photographic plane Π_φ /the axis of the shot was aimed at point E - fig.2/,were converted into the pho-

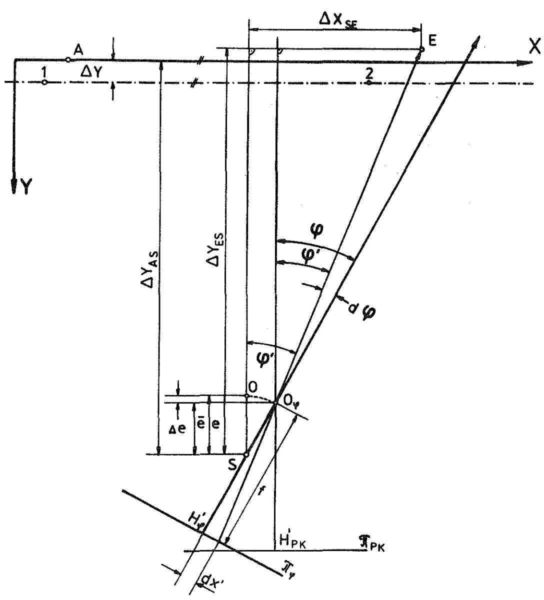

Figure 2

tographic plane Π_{PK} /x',z'/,which is parallel to the X,Z plane of the lock chamber,according to these equations[1]:

$$x' = x_\varphi' - \mathrm{tg}\varphi \, \frac{f^2 - x_\varphi'^2}{f - x_\varphi' \mathrm{tg}\varphi} \qquad z' = z_\varphi' \, \frac{1}{\cos\varphi - x_\varphi'/f.\sin\varphi}$$

where

f is the constant of the measuring camera,

φ - corrected angle of displacement of the shot axis $\varphi = \varphi' - d\varphi$,

$d\varphi$- correction of the angle of displacement/aiming error/.

II.stage:

The photographic co-ordinates of the observed points x', z' in the ohotographic plane $\widehat{\pi}_{PK}$, were transformed into the lock co-ordinate system, using these equations:

$$X_i = X_o + a_1/x_i'.m_s/ + b_1/z_i'.m_s/$$
$$Z_i = Z_o + a_2/z_i'.m_s/ + b_2/x_i'.m_s/$$

where

a_1, b_1, a_2, b_2 - transformation factors of the affine transformation,

X_o, Z_o - translation of the affine transformation,

m_s - scale number of the observed points, which is equal for all observed points and is calculated from the following equation/fig.2/:

$$m_s = \frac{\Delta Y_{AS} - /\bar{e} + \Delta Y/}{f}$$

The deviations of the barge in the direction of the lock chamber Y-axis are minimum, because the barge moves along fixed guiding poles and therefore the difference ΔY/fig.2/ is equal for all observed points.

Photographic co-ordinates of the control points were converted into the lock co-ordinate system, using the following relations:

$$X_i = x_i'.m_{si} \ , \quad Z_i = z_i'.m_{si}$$

The scale numbers for the individual control points were computed by the equation:

$$m_{si} = \frac{\Delta Y_{i,S} - \bar{e}}{f} \qquad , \ i = A, \ldots\ldots, E$$

where

Y_S - co-ordinate of the measuring camera standpoint,

Y_i - co-ordinate of the i-control point,

e - eccentricity of the projection center,

$\bar{e} = e - \Delta e.$

$\Delta e = e - e\cos\varphi$.

III.stage:

The water surface slope was calculated from the co-ordinates of observed points X,Z in the lock co-ordinate system by these equastions:

$$\alpha_{i,j} = \frac{\Delta Z_{i,j}}{\Delta X_{i,j}} \cdot 1000 \qquad (‰)$$

where

$$\Delta X_{i,j} = X_{i,j} - X_{i,j-1} \ , \ \Delta Z_{i,j} = Z_{i,j} - Z_{i,j-1}$$

$$i = 1,2,3,4 \qquad , \qquad j = 1,\dots\dots\dots,n$$

6. Obtained Result

The given values are results of three measurements/photographs B7,B8,B9/of the water surface slope,between the observed points 4 - 1 /fig.1/,whereby the valve opening period was 100 sec.

The course of the water surface slope as a function of the lock filling time was projected by the plotter of the computer WANG 2200/fig.3/.The time intervals of the exposures,the water surface levels,heighst of overtravel between the observed points 4 - 1 and water surface slopes are given in table 1/in table are E-time interval of exposures/sec./,H-water surface level/mm/, DH-height of overtravel between the observed points /mm/ and S-water surface slope in the lock /‰//.

The reasearch results confirmed the fact,that the photogrammetric method is the most convenient method out of all tested methods and completely satisfies the required accuracy of measuring the water surface slope and the time course of the filling/emptying/of the lock chamber.The accomplished accuracy in determining the heights of the terminal points of the barage is $m_z = \pm 0,30$ mm.

7. Conclusion.

The magnitude of the hawswr forces in the lock chamber can be determined on the basis of sufficiently accurate measuringes of the course of the water surface deformation,as well as the assumption of the course of the hawser forces during the filling /emptying/of the lock.

The actual possibility of using the described method in practice will enable us to work out the optimum manipulation of

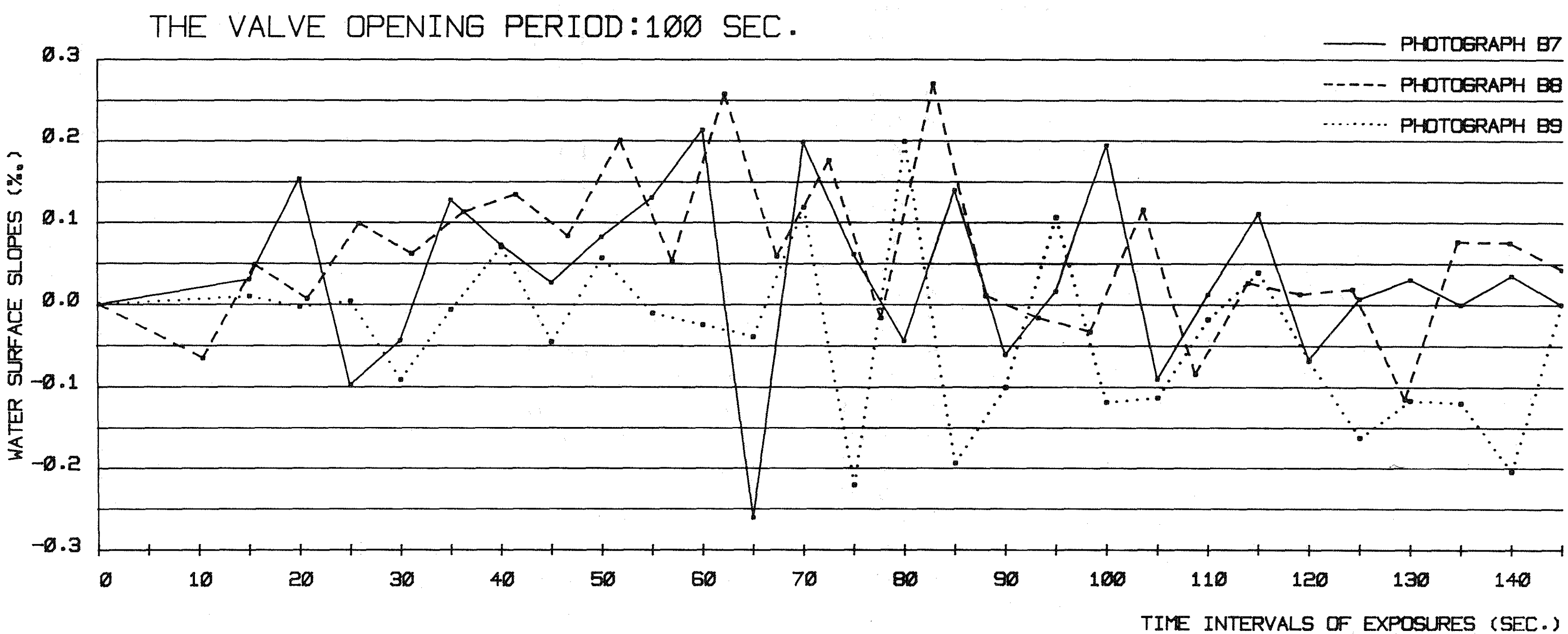
THE VALVE OPENING PERIOD:100 SEC.
PHOTOGRAPH B7
PHOTOGRAPH B8
PHOTOGRAPH B9
WATER SURFACE SLOPES (‰)
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
TIME INTERVALS OF EXPOSURES (SEC.)

Figure 3

Table 1

E	PHOTOGRAPH B7 H	PHOTOGRAPH B7 DH	PHOTOGRAPH B7 S	PHOTOGRAPH B8 H	PHOTOGRAPH B8 DH	PHOTOGRAPH B8 S	PHOTOGRAPH B9 H	PHOTOGRAPH B9 DH	PHOTOGRAPH B9 S
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	6.77	-0.38	-0.06	0.00	0.00	0.00
15	12.11	0.18	0.03	13.32	0.27	0.04	12.28	0.05	0.00
20	21.94	0.89	0.15	23.36	0.03	0.00	22.60	-0.01	-0.00
25	37.16	-0.56	-0.09	37.70	0.57	0.09	36.72	0.02	0.00
30	55.47	-0.25	-0.04	55.81	0.35	0.06	54.02	-0.53	-0.09
35	74.99	0.74	0.12	76.83	0.65	0.11	74.70	-0.03	-0.00
40	100.62	0.42	0.07	102.81	0.77	0.13	103.74	0.40	0.06
45	129.98	0.15	0.02	132.61	0.48	0.08	128.95	-0.26	-0.04
50	163.15	0.47	0.08	165.73	1.16	0.20	163.72	0.32	0.05
55	202.53	0.76	0.13	203.33	0.30	0.05	200.99	-0.06	-0.01
60	244.29	1.24	0.21	244.99	1.49	0.25	243.08	-0.14	-0.02
65	288.44	-1.51	-0.26	290.40	0.33	0.05	286.40	-0.22	-0.03
70	333.65	1.15	0.19	335.46	1.02	0.17	333.72	0.68	0.11
75	382.55	0.35	0.06	383.51	-0.09	-0.01	382.11	-1.28	-0.22
80	429.02	-0.25	-0.04	430.46	1.56	0.26	427.92	1.15	0.19
85	474.52	0.81	0.13	477.42	0.06	0.01	475.24	-1.12	-0.19
90	518.55	-0.35	-0.06	521.94	-0.09	-0.01	520.26	-0.58	-0.10
95	560.50	0.09	0.01	562.13	-0.19	-0.03	565.76	0.61	0.10
100	597.69	1.12	0.19	599.54	0.66	0.11	601.41	-0.69	-0.11
105	631.49	-0.52	-0.09	633.02	-0.49	-0.08	625.64	-0.65	-0.11
110	661.77	0.07	0.01	663.88	0.14	0.02	662.80	-0.10	-0.01
115	687.32	0.64	0.11	691.39	0.07	0.01	685.95	0.22	0.03
120	712.08	-0.38	-0.06	713.90	0.10	0.01	712.16	-0.39	-0.06
125	730.84	0.04	0.00	734.06	-0.67	-0.11	732.49	-0.94	-0.16
130	747.93	0.17	0.03	750.13	0.44	0.07	749.57	-0.68	-0.11
135	761.06	0.00	0.00	762.67	0.43	0.07	761.64	-0.69	-0.12
140	770.87	0.20	0.03	772.10	0.24	0.04	771.89	-1.19	-0.20
145	777.69	0.00	0.00	778.92	-0.00	-0.00	777.82	0.00	0.00

opening and closing the filling valves,and at the same time to accompish the shortest possible lock filling time and the required safety of the vessels.

8. Literature.

[1] Szangelies,K.: Analytische Photogtammetrie - Kompendium, Bad III,VEB Carl Zeiss Jena,1958,p.:769.

[2] Kalibrierungsnachweis für Universalmesskammer UMK 10/1318.