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On the limitation of erosion of the canal and river banks by inland waterways vessels

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ABSTRACT

This paper describes model tests and fullscale measurements to recommend improved design of canal vessels to reduce the energy transfer between canal craft and the bottom and banks of canals and rivers, particularly the narrow canals of Britain.

The nature of the environmental problem and the application to other craft in other waterways is discussed.

INTRODUCTION

Appreciable damage is done to river and canal banks by the passage of boats. This has been a cause of concern to those authorities responsible for many years. Significant articles on this have appeared: [1] describing early stages of the OSTEC / BWB study, [2] dealing with a displacement ducted vessel and [3] reporting on a BMT / Norfolk Broads investigation.

The inland waterways of Britain consist of a mixture of rivers, navigations and canals. The canals were constructed piecemeal over a prolonged period without a national plan. They have not been developed to the standards of western Europe and are largely a scenic leisure resource but with some commercial activity often confined to rivers and navigations. The main pleasure craft either traditional narrow boat designs or GRP cruisers along with barges of varying sizes providing the commercial traffic. In order to limit the damage to the canals and the concomitant maintenance, speed limits are applied but owing to the uneven sizes of the canal sections even the 4 mph (1.8 ms^{-1}) speed limit may be too high on occasions [1] and there is incentive to generate full-form designs which will limit the damage to the banks of the typical trapezoidal British canal and their plant and animal life. A compromise is necessary since some disturbance is necessary to avoid the unlimited growth of vegetation but too much will destroy fragile water plants and uproot others leading to erosion.

The destructive effect on the waterway banks comes largely from the diverging wave system generated by the passage of the craft. This is largely a

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function of bow and stern geometries. The second effect of propeller wash can be reduced by using a shrouded propeller but while this was examined and tested, the prevalence of debris in the canals make it an unattractive refinement since they are likely to be jammed too frequently. In restricted channels, the accelerated flows also change trim and squat with the effect of reducing underkeel clearance.

The behaviour of the vessel is controlled by its shape, the Froude number, the block coefficient and the beam to draught ratio. However the length, breadth and draught are limited by lock size, bridges and water depth. Other factors limiting change are the need to retain the appearance of the traditional narrow boat and provide the same accommodation without significantly increasing building costs.

The study was carried out in three phases followed by an application. Phase I was a theoretical study which concluded with a recommendation for an improved craft design for minimum energy transfer from the craft to the canal bottom and banks. Phase II implemented this recommendation at model scale by carrying out a series of experimental tank model tests in the Hydrodynamics Laboratory of the Department of Naval Architecture and Ocean Engineering at the University of Glasgow. Phase III involved the construction of a 20.0 metre narrow boat (by BWB) to the optimised design developed from phases I and II and on completion, it was comparatively tested against a number of traditional narrow boats in order to quantify the expected improvements and allow verification of the model test results obtained in Phase II.

THEORETICAL STUDY

The theoretical study is overviewed in [1] and described fully in [4]. The outcome was that the design restrictions led to the identification of the cylindrical bow (CB) [5] as a prime contender for the bow shape (as shown in fig 1) and also an improved swim of the stern.

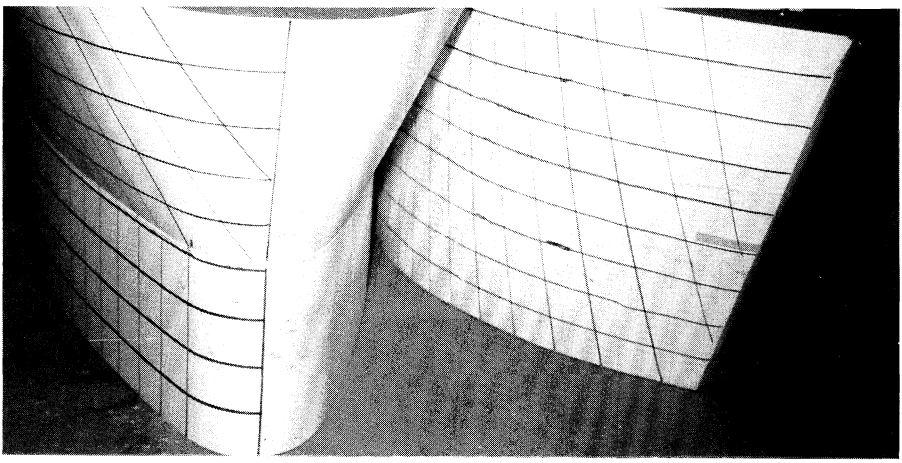

Figure 1: The cylindrical bow of the low wash design

MODEL TESTS

For the model tests on two one quarter scale self propelled models: a narrow boat (in several configurations) and a pleasure cruiser were tested in representative canals of trapezoidal section. The narrow boat was tested with the traditional configuration, with just the bow modified and in the fully modified configuration (with and without a shrouded propeller). The water was lowered and two canal sections were constructed in the 77 metre towing tank to represent a "wide" and a "narrow" section of canal. The narrow section was used at its scale shallow water depth (NS) and a deeper depth (ND) equal to the depth of the wider channel (WD). Although the models were self propelled, they were towed for the resistance tests and tow-assisted at the higher speeds.(up to 3.4 ms^{-1}) since this is appreciably above permitted (design) levels. Measurements were made of the vessel speed resistance, sinkage and trim, propeller characteristics, wave pattern, backflow and pressure field.

The results shown in table 1 indicated that, in spite of a handful of suspect readings (omitted), resistance was little changed whereas wave height, pressure, flow, sinkage and trim showed some appreciable improvements (even though there was some variability). The preponderance of bold entries indicates the extent of the improvement.

FULL SCALE TRIALS

Fullscale trials were carried out on a number of vessels and in particular on the newly constructed narrow boat built to the design deduced from the model experiments. (This is now the BWB Admiral's Barge.)

Verification

There are however a number of problems associated with such a verification which are the consequence of two facts.

(a) The model was not exactly geometrically similar to the new improved hull form as built.

(b) The Bulls Bridge section is not geometrically similar to any of the model test sections used in Phase II.

The difficulties associated with these two facts were studied and full scale performance predictions attempted prior to the full scale Phase III tests.

Test Site

After consideration, the Bulls Bridge section of the Grand Union Canal was selected for the conduct of these experiments. A test length of 250 metres was marked off on the canal bank with a clear run in excess of 250 metres at either end of the measured section.

Test Section

A British Waterways tug / workboat was moored at the start of the test length and used as the test station . All test equipment: amplifiers, recorders and cameras were housed in the cabin of this craft for the duration of the test programme. Power for the portable recorder was provided by a 12 volt DC heavy duty battery. Power for the amplifiers and pressure transducer and display was provided by a petrol driven 240 volt 50 Hz portable generator.

Speed (fullscale)	3 mph							5 mph						
Canal	TBS	MBTS	%	MBS	%	MBS(S)	%	TBS	MBTS	%	MBS	%	MBS(S)	%
	Wave Height(m)													
7.5m by 0.9m (NS)	0.29	0.31	7	0.27	**-7**	0.37	28	0.74	0.73	**-1**	0.71	**-4**	0.76	3
8.4m by 1.2m (ND)	0.15	0.11	**-27**	0.22	47	0.18	20	0.69	0.85	23	0.82	19	0.77	12
12.1m by 1.2m(WD)	0.14	0.08	**-43**	0.08	**-43**	0.06	**-57**	0.55	0.43	**-22**	0.48	**-13**	0.45	**-18**
	Pressure(kPa)													
7.5m by 0.9m (NS)	6.14	4.49	**-27**	3.11	**-49**	3.52	**-43**	6.90	6.83	**-1**	6.76	**-2**	6.56	**-5**
8.4m by 1.2m (ND)		1.17		1.66		1.24		6.62	6.28	**-5**	6.56	**-1**	6.35	**-4**
12.1m by 1.2m(WD)	0.76	0.48	**-36**	0.62	**-18**	0.55	**-27**	5.18	5.38	4	6.69	29	6.14	19
	Flow(m/s)													
7.5m by 0.9m (NS)				0.78		0.51		1.04	0.02	**-98**	0.3	**-71**	0.2	**-81**
8.4m by 1.2m (ND)				0.42		0.48		0.46	0.16	**-65**	0.22	**-52**	0.26	**-43**
12.1m by 1.2m(WD)		0.24		0.3		0.25		1.22	0.92	**-25**	1.18	**-3**	0.88	**-28**
	Sinkage(%L)													
7.5m by 0.9m (NS)	-0.52	-0.49	**-6**	-0.51	**-2**			0.24	0.18	**-25**	0	**-100**		
8.4m by 1.2m (ND)	-0.41	-0.35	**-15**	-0.41	0			-0.43	-0.42	**-2**	-0.47	9		
12.1m by 1.2m(WD)	-0.29	-0.28	**-3**	-0.26	**-10**			-0.8	-0.7	**-13**	-0.71	**-11**		
	Trim(%L)													
7.5m by 0.9m (NS)	0.68	0.54	**-21**	0.79	16			2.29	1.99	**-13**	2.15	**-6**		
8.4m by 1.2m (ND)	0.1			0.09	**-10**			2.82	3.02	7	2.91	3		
12.1m by 1.2m(WD)	-0.15	-0.11	**-27**	-0.07	**-53**			2.38	2.32	**-3**	2.52	6		
	Resistance(kg, model scale)													
7.5m by 0.9m (NS)	3.86	3.85	0	3.85	0			14.38	14.31	0	15.34	7		
8.4m by 1.2m (ND)	1.92	1.71	**-11**	1.71	**-11**			11.83	12.24	3	12.24	3		
12.1m by 1.2m(WD)	1.01	0.96	**-5**	0.89	**-12**			9.73	9.86	1	9.86	1		

Table 1: Fullscale prediction from model tests for Traditional (TBS), Modified Bow (MBTS), Modified Bow and Stern (MBMS) and MBMS with shrouded propeller (MBMS(S))

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Craft

The test craft were the 20.0 m length cylindrical bow improved hull narrow boat (CB) and two representative BWB narrow boats, one 16.8 m long and the other 21.8 m long. In addition, the wave and pressure response readings of three private narrow boats with lengths 9.75 m, 15.8 m and 21.3 m were recorded as they traversed the test site.

Test Measurements

Speed Measured by stopwatch from the bank and checked by stopwatch on board the craft under test.

Pressure Disturbance A pressure sensitive transducer was positioned on the bed of the canal at the mid-width of the start of the test run. The transducer was wired underwater to the test station. Signals from the transducer were fed through the amplifiers to a digital display and multi-pen chart recorder.

Wave Disturbance A variable resistance wave sensing probe was positioned some 10 metres from the test station, 0.8 metres out from the canal bank. The wave sensing probe was wired overland back to the test station where the signals were fed through amplifiers to the multi-pen chart recorder.

Back Flow Back flow was measured using a miniature electronic current meter positioned alongside the wave sensing probe. The current meter was wired back to the test station where the signal was displayed on a digital read out. A function of this instrument was that it could store the maximum flow in any direction for each test run. It is these maximum flow figures which are recorded for analysis.

Test Programme

Instrument Checking The pressure transducer and the wave sensing probe were calibrated at Denny's experiment tank in Dumbarton prior to the tests and then recalibrated on site at the beginning of each day's testing. The miniature current meter, used for measuring the back-flow, incorporated a built-in calibration which was checked at the Denny's tank and found to be accurate. However on the trials it was noted that the meter ceased to function and on inspection it was found that the small bearing had been fouled by material in suspension in the canal water. Although this bearing was subsequently cleaned, from then to the end of the trials, only a few readings were considered sufficiently reliable to be included.

Runs Two dozen runs were made using the principal vessels: the CB hull with no propeller shroud made 10 runs over a speed range from 3.2 mph to 5.3 mph*, L made 4 runs over a speed range from 3.4 mph to 4.2 mph, the CB hull with propeller shroud made 3 runs between 4.1 and 5 mph, the CB hull was towed by C for 3 runs between 2.8 and 4.6 mph and C made 4 runs over a range of speed from 3.4 to 5 mph. Interspersed with these planned tests were a number of private boats whose disturbances were recorded.

Procedure At the start of each day's tests and during the tests, the temperature of the air and water were recorded and the data used in the subsequent analysis. The ambient current movement in the canal was negligible. Helmsmen were instructed to keep to a pre-arranged track over the test length with minimum rudder movement and no throttle adjustment. No run was to commence until the disturbance caused by the previous run had settled.

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* To convert mph to ms^{-1} multiply by 0.447

Results, Analysis and Discussion

The few results for the back flow measurement showed that C had a back flow between 2 and 3 times that of the OSTEC designed CB hull in the corresponding condition.

It can be seen from figs 2 and 3 that throughout the speed range the CB hull creates considerably less bow wave than C both with the initial wave trough and the subsequent wave crest. This is the case for both the absolute measurements and the results presented non-dimensionally with respect to length. In all cases the CB hull with the shroud fitted is the most efficient with regard to the minimum wave disturbance.

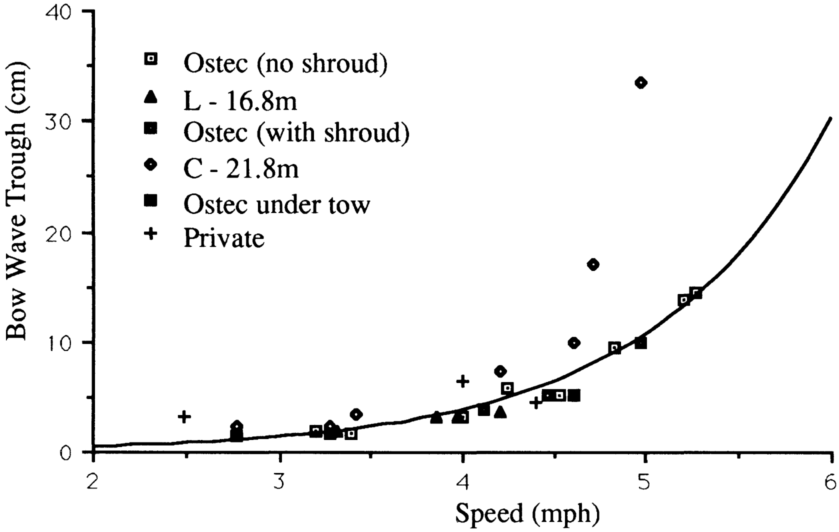

Figure 2: Bow trough depression for various craft

Except for the speed range 4 to 4.7 mph the CB hull gives a lower stern wave. This is especially important at the speeds above 4.7 mph when the stern wave from C increase rapidly when the OSTEC hull's stern wave is reducing its rate of increase. In all cases the CB hull with the propeller shroud fitted is superior to the no shroud condition.

The results of the pressure changes on the canal bottom are given in fig 4. It can be shown that throughout the speed range the CB hull shows a dramatic decrease in pressure disturbance on the canal bottom. Again the CB hull with the propeller shroud fitted gives the minimum pressure disturbance throughout the speed range. Sinkage and trim results are given in fig 5 and although not directly comparable with the earlier model results, they show a similar trend. It is worth noting that the 'with shroud' results indicate a greater sinkage at the bow than the CB hull with 'no shroud'.

A comparison of the power requirements between the full-scale measured results and the power predicted from the model tests showed that the full-scale vessel experienced less drag than that predicted by the model tests.

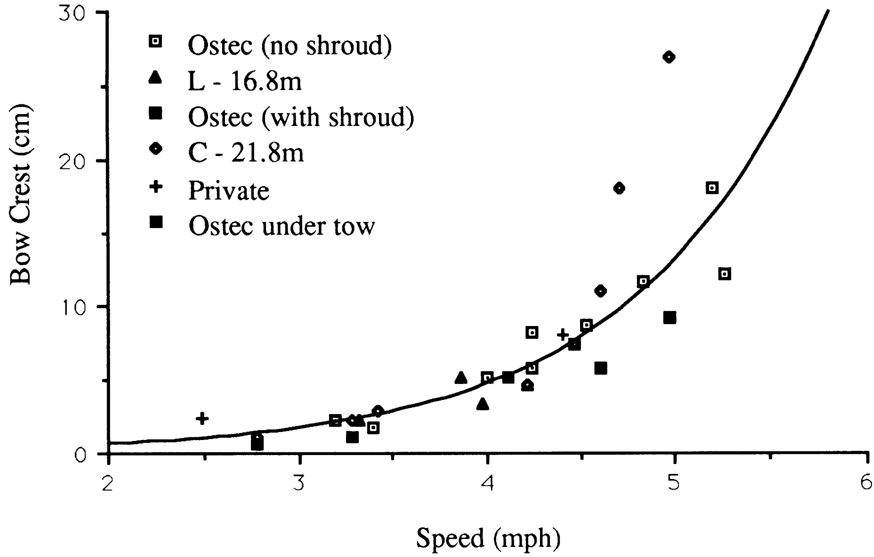

Figure 3: Bow crest elevation for various craft

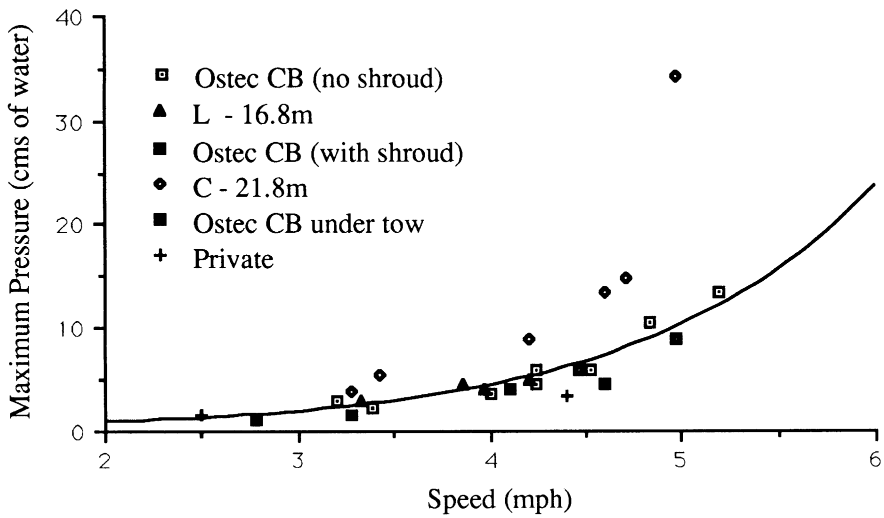

Figure 4: Maximum pressure variation caused by various craft

APPLICATION TO ENVIRONMENTAL PROBLEMS

Using non-dimensional curves relating the wave crests and troughs and the pressure peaks to the Froude numbers and blockage, it is possible, using the fullscale data, to predict the behaviour of barges of a range of sizes in specified channels, as described by their hydrographic data. This, with interpolation, allows a "safe" environmental speeds to be identified in relation to criteria relating to operation of existing craft.

This process has been used successfully on river and canal sections although more work is needed on identifying the criteria.

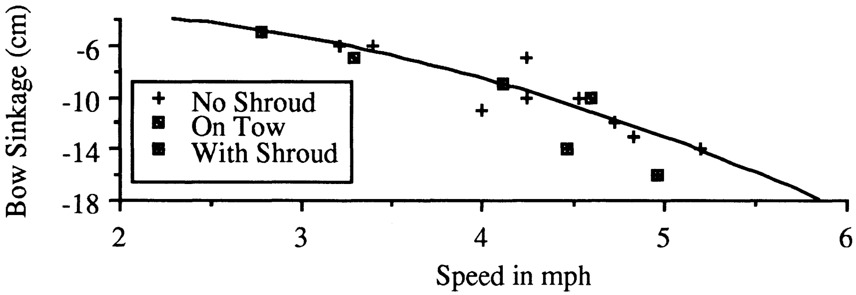

Figure 5: Bow sinkage for the Cylindrical Bow (CB) Hull Design

CONCLUSIONS

In all the fullscale trials, the OSTEC designed CB hull with the shroud fitted is the most efficient with regard to the minimum wave disturbance although the 'no shroud' design is also much superior to the other vessels tested. The CB hull shows a dramatic decrease in pressure disturbance on the canal bottom.

Although sinkage and trim results are not directly comparable with the earlier model results, thetrend is similar. The lesser sinkage of the CB hull with 'no shroud' is an advantage in this case. The full-scale measurements indicate less drag is experienced than that predicted by the model tests.

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