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Field Measurement of Fishing Boats Generated Waves

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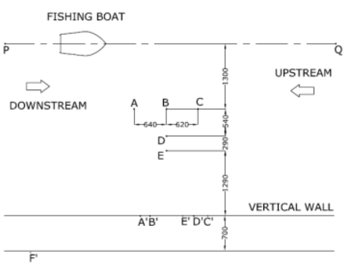
Graphical abstract



Arrangement of field measurement.

Abstract

Ship generated waves can cause banks erosion as well as disturbance on stationary boats. Studies have shown that the boat generated waves are dependent on and affected by environmental factors and vessel parameters. The main environmental factors are tidal and current direction, and for vessel parameters are speeds and hullforms. This paper describes a full-scale experimental work to measure wave heights and wave angle direction on boat generated waves. The measurement method used in this paper is based on the analysis of digital video recordings and image processing techniques.

Keywords: Boat generated wave; wave height; wave angle

1.0 INTRODUCTION

Ship generated waves (SGW) is increasingly becoming an important field of study. SGW can give an impact in terms of environmental effects such as coastal / bank erosion, destruction of fragile water plant and disturbance of silt, disturbance to parked boat and anchored vessels, and stability of smaller boat.[1] Thus, SGW is sometimes included as a design criterion similar to main dimensions, speed, deadweight capacity, number of passenger and manoeuvrability of the ship.

There are three main disturbances that can cause bank erosions namely current, wind-generated waves and SGW.[2,3] The disturbances also give different effect of erosions pattern on the river banks. River current and wind-generated waves will cause erosions mainly at the corners of the river bank while SGW can cause erosions along the whole length of the river banks particularly when the river is narrow.

The study about SGW in a river is important, because the river have several characteristics as shallow water and narrow channels. Stumbo found that the energy of ship wake wash in shallow water is higher than deep water, exposing it to more wave energy. [4]

Fishing boats normally ply the river mouth where fishing ports are located. Their wake wash can cause disturbance on parked boat and loading-unloading activities as well as cause the parked boats collide or rub with each other.

Currently, there are not many studies on fishing boats SGW. Table 1 shows that majority the studies on SGW are focused on high speed craft, passenger vessel (ferries) and catamaran.

In SGW study, there are two important parts to be considered. The first part is consideration of the environmental factors; such as water depth, current velocity, tidal conditions and initial waves. Macfarlane describes these factors as shown in Table 2.[7] The other part is related to vessel parameters namely speed, hullform, draft and boat direction

Table 1 Comparison of research work in ship generated waves studies

No	Author , year	Type of ship
1	Stumbo, 1999.[5]	High speed catamaran
2	Stumbo, 1999.[6]	Catamaran
3	Macfarlane, 1999.[7]	Catamaran
4	Whittaker, 2000.[1]	Catamaran, monohull fast ferries
5	Stumbo, 2000.[4]	Fast ferries (catamaran)
6	Fox Associate, 2002.[8]	MV Condor Express (ferry)
7	Belibassakis, 2003.[9]	Fast ferry (small ferry 38 m)
8	Osborne, 2007.[10]	High speed passenger ferry (catamaran)
9	Velegrakis, 2007.[11]	Conventional and high speed ferries
10	Kumar, 2007.[12]	Ferry
11	Pauzi, 2008.[13]	Harbour patrol boat (monohull)
12	Dam, 2008.[14]	Water buses
13	Soomere, 2009,2011.[15,16]	Fast ferry (high speed craft)
14	M. Fadhli, 2011.[17]	Fishing boat
15	Kandasamy, 2011.[18]	HSC ferry (catamaran)
16	Yaakob, 2012.[19]	Asymmetric catamaran, leisure boat
17	Macfarlane, 2012.[20]	Monohull, catamaran

Table 2 Environmental factors, vessel parameters and other factors[7]

Vessel parameters	Environmental factors	Other factors
Speed	Water depth	Distance from sailing line
Trim	Current velocity & direction	Wake interactions
Hull form	Tidal characteristics	Location of measurement site
Direction	Wind generated wave	
Draft	Coastal morphology	
Loading	Sub-surface flows	
Propulsor		

2.0 LOCATION

The field measurement area is in Mersing River at Johor, Malaysia (Figure 1). This river is directly connected with South East China Sea. Therefore, the relevant environment effects are tidal rise and fall, sea current and wind generated wave. The traffic in this river is high mostly fishing boats accessing the Mersing fishing port. Other users are patrol boats, fast ferries and sampans.

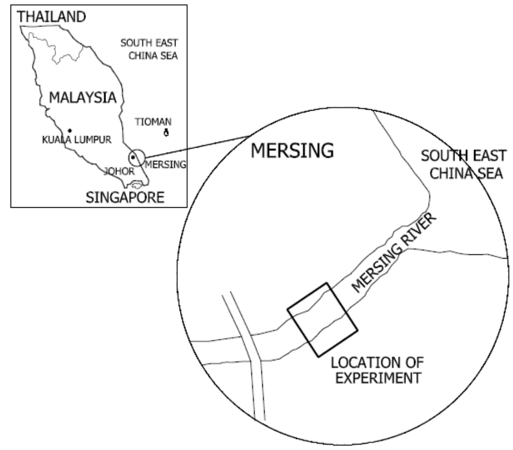


Figure 1 Map of Field Measurement Location

3.0 FIELD MEASUREMENT METHOD

The full scale experiment is the best way to know the actual results/effects of hydrodynamic interactions. One of the challenges of field full scale measurements is how to measure wave heights. Table 3 shows three methods used by various researchers to measure SGW.

Table 3 Comparison study of methods to measure wave height

No	Category	Methods: Submerged pressure [6]	Methods: Wave buoys - wave gauge – wave probe [5, 13]	Methods: Visual observation using digital video camera [11]
1	Location	point	point	point
2	Method	contact	contact	contact
3	How to get data	directly	directly	image processing
4	Application	sea	sea and laboratories	coastal
5	Output data	wave height	wave height	wave height

4.0 IMAGE CAPTURE AND PROCESSING

In this study digital video cameras were used to record the wave heights video footages and the images were processed to obtain wave heights and directions. In this field measurement five scaled poles were used as targets, while five digital video cameras were used to record the movement of waves on every pole, the recorded video footage was then processed by imaging method to find wave heights time series.

The set-up of the field measurement is shown on Figure 2. The targets of the digital video cameras were scaled poles and those were placed in the river at point A, B, C, D and E. The video cameras were placed on the top of the vertical wall along the river bank at point A', B', C', D' and E'. Another video camera was placed on a high position (point F') to record the overall scene of the experiment such as poles, boat movement and wave propagation. The boats were run with constant speed between point P and Q. Distance between poles and vertical wall is 13 meters.

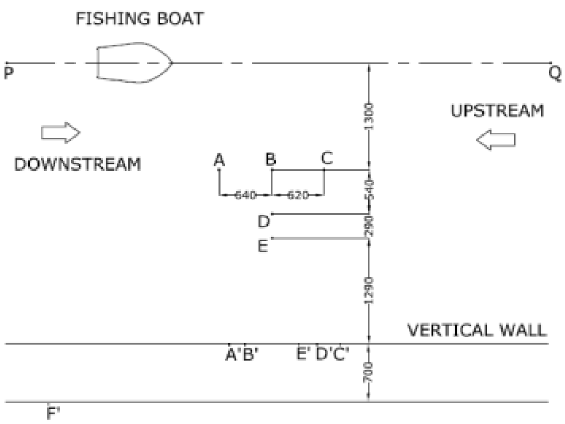
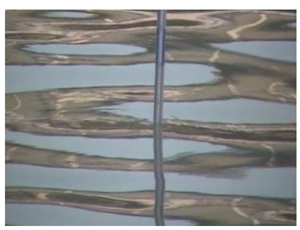


Figure 2 Arrangement of field measurement

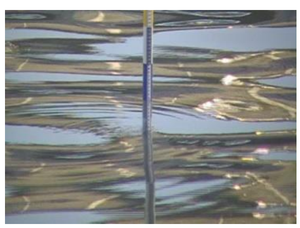
The video cameras recorded movement wave heights for certain time duration and the resulting video footage were extracted to frame by frame images, at 5 frames per second. Figure 3 shows one example the simultaneous image capture from the six cameras.

(a)



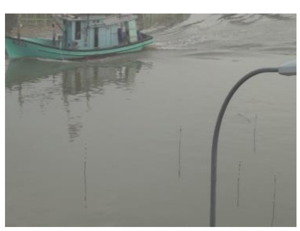
(b)

(c)



(d)

(e)

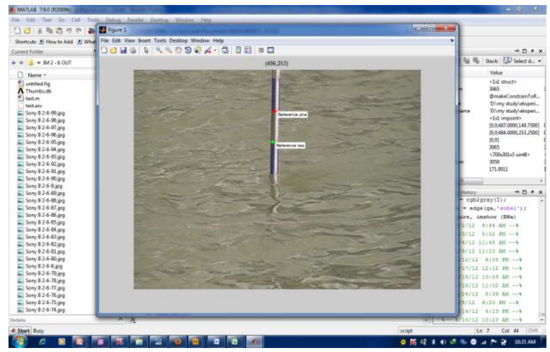


(f)

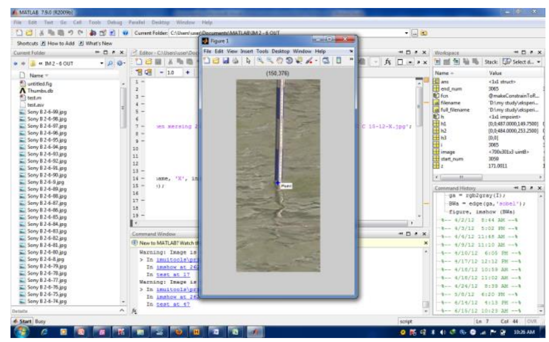
Figure 3 Example of image every video cameras, (a).video at pole A, (b). video at pole B, (c). video at pole C, (d). video at pole D, (e). video at pole E, (f). video from high place (point F')

4.1 Derivation of wave heights

In this work, the several processes must be implemented to obtain the wave heights data. First, the reference points in first image must be determined. The objective of this process is to get a scale factor between actual size in meter and image size in pixel. Figure 4(a) shows the two points of reference. The next step of the programme displays a sequence of images and the point corresponding to the peak of the wave is selected. This step is shown in Figure 4(b). By putting that point, the wave height can be found. By repeating the process for the whole sequence, a compilation of wave heights for every image, associated with a discrete time step will be obtained, thus creating a time series.



(a)



(b)

Figure 4 Matlab image processing, (a) determine the reference for scale factor, (b) determine wave height on the pole

4.2 Derivation of Divergent Wave Angle

Work on visual observation using digital video camera method did not derive the wave propagation angle direction. In this study, an attempt is made to derive this angle which is needed to determine the direction of wave propagation.

A typical Kelvin pattern (Figure 5) shows two waves types – transverse and divergent waves. The envelope of Kelvin pattern wave stands at a fixed angle 19.5 degrees.[21] The fixed angle 19.5º is the angle between cups locus line (intersection between transverse and divergent waves) and sailing line. Majority of researchers deal with divergent waves because these waves have higher energy than transverse waves. The propagation of the divergent waves is thus more damaging to the environment. Therefore it is important to estimate the angle (Xº) of the divergent waves.

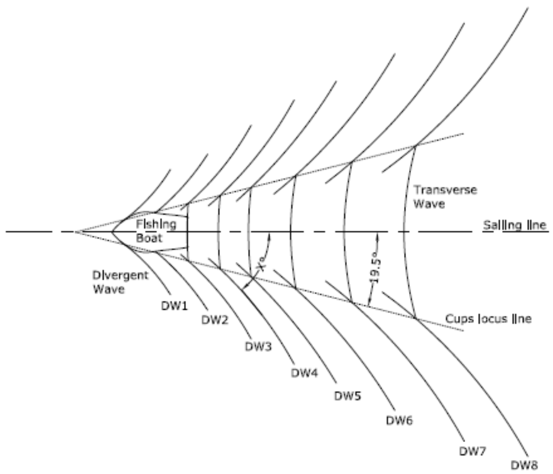


Figure 5 Kelvin pattern of fishing boat

The method to get angle of the divergent waves is shown in Figure 6. The poles position will be the reference line for wave angle. By considering the actual distance between poles as shown in Figure 2, the angle between poles position can be the first references. In Figure 6(a), the reference angle aº (angle between poles C, A and D / between Line A and Line B) is 41°. Besides that, in Figure 6(b), the reference angle bº (angle between poles C, A and D) is 18º. The second reference is Line C which is parallel to the sailing line and Line A. Line D will be put on each divergent wave and intersect with line C to get the wave angle in image (dº).

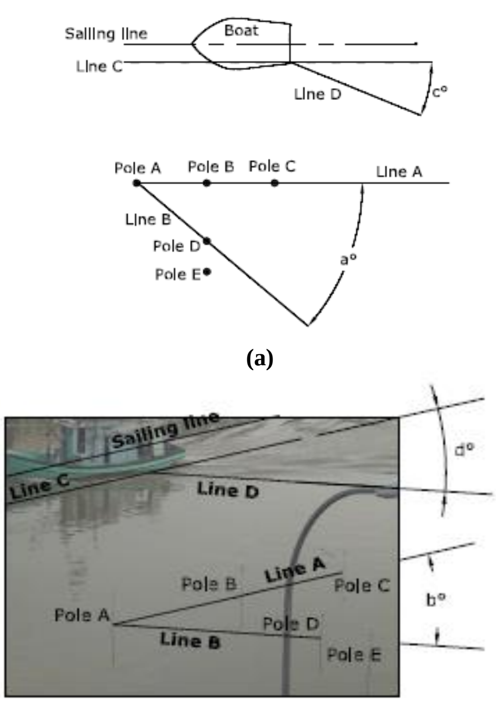


Figure 6 (a) Arrangement of field measurement in actual condition, (b). field measurement in image

The relations between the angles for actual condition and image can be found by using Equation 1 while Equation 2 can be used to obtain the actual wave angle:

$$\frac{a^\circ}{b^\circ} = \frac{c^\circ}{d^\circ} = \alpha \tag{1}$$

$$c^\circ = \alpha \times d^\circ = \frac{a^\circ}{b^\circ} \times d^\circ \tag{2}$$

5.0 FISHING BOAT PARTICULARS

Malaysian fishing boats are classified into three categories (A, B and C) based on gross tonnage (GT) and the distance of area for operation. Although the sizes are different, the Mersing boats use similar hullforms, with category B boats being most common. Thus, a 'B' type fishing boat with dimensions shown in Table 4 was used in this experiment.

Table 4 Particular dimensions

No	Description	Value
1	Length overall (LOA)	14.05 m
2	Length waterline (LWL)	10.25 m
3	Breath (B)	4.35 m
4	Draft (T)	1 m (AP), 0.5 m (FP)
5	Block coefficient (Cb)	0.3
6	Water depth – sailing line (D)	4 m

Water depth (D) at the sailing line was 4 meters as shown in Table 4. The water depths at the pole are indicated at the respective captions of Figure 7, 8, 9 and 10.

6.0 RESULTS & DISCUSSION

All videos were extracted and analyzed using image processing programme using Matlab. The duration for the videos areabove 30 seconds or 150 frames of images. The images were the main input for the image processing programme.

6.1 Wave Heights

Examples of results of wave heights time series are shown in Figure 7, 8, 9 and 10. The resume of quantitative measurement of wave height between Figure 7, 8, 9 and 10 is shown in Table 5.

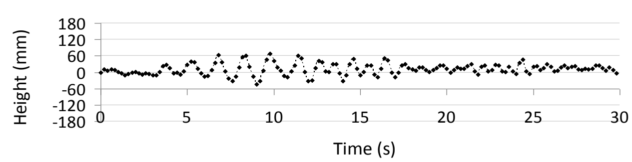


Figure 7 Wave height fishing boat with Vs = 6 knot (boat moving in at water depth 2.09 m with upstream current) at pole A

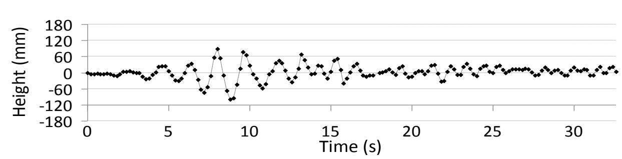


Figure 8 Wave height fishing boat with Vs = 6 knot (boat moving out at water depth 2.09 m with upstream current) at pole A

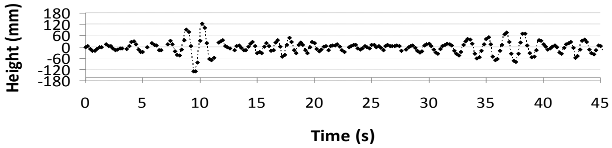


Figure 9 Wave height fishing boat with Vs = 9 knot (boat moving in at water depth 2.13 m with upstream current) at pole A

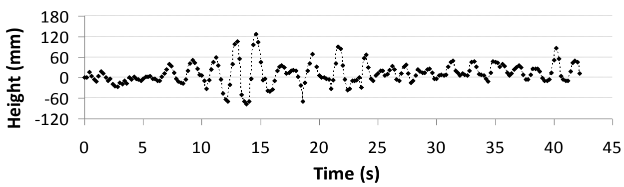


Figure 10 Wave height fishing boat with Vs = 9 knot (boat moving out at water depth 2.13 m with upstream current) at pole A

Figures 7 and 8 have similar conditions in terms of boat speed, water depth and stream current direction. However, Figure 7 is associated with the boat moving in, along with the rising tidal stream while in Figure 8, the boat is moving out against the tidal flow. The resulting increase in relative velocity modified the SGW by giving higher wave heights in Figure 8. Similar results can be seen in Figure 9 and 10.

During the experiment, the river surface was relatively calm. This can be seen in Figure 7, 8, 9 and 10, where the wave records for the initial condition are shown. The first around 3 seconds in the records indicate the background waves, for ship generated waves is occurred in between around 3 until 30 seconds. The descriptive analysis of the background waves and ship generated waves areshown in Table 5. The background waves were excluded from the subsequent analysis.

The effect of reflected waves also can be seen in Figure 9 and 10 which show an increase in wave's heights after 30 seconds. Our subsequent analysis does not include the wave records next 30 seconds which contain the reflected waves.

Macfarlane divides divergent waves into 3 categories, as wave A, B, and C.[20] Wave A is the leading diverging wave that have long period. Wave B is the most significant wave following the leading wave, the period is shorter but the wave height is greater than the leading wave. Wave C has short period divergent wave which always follows waves A and B. Figure 11 shows the position of waves A, B and C on time series of Figure 7.

The results shown in Figure 11 are obtained at pole A. The location of pole A which respect to the boat is shown in Figure 2 and 6.

Table 5 The quantitative measurements of wave heights of the cases (Figure 7, 8, 9 and 10)

		Vs = 6 knot		Vs = 9 knot	
No	**Description**	**Fig. 7**	**Fig. 8**	**Fig. 9**	**Fig. 10**
	Background waves (around 0-3 sec)				
1	Mean (mm)	-0.72	-2.92	-5.99	-3.92
2	Variance (mm^2)	49.03	24.67	113.93	32.75
3	Std. Dev. (mm)	7.00	4.97	10.67	5.72
4	Maximum [mm]	11.51	6.24	12.84	4.65
5	Minimum [mm]	-11.51	-12.47	-21.02	-16.27
	Ship Generated Waves (around 3-30sec)				
1	Mean (mm)	12.98	2.06	-1.35	9.13
2	Variance (mm^2)	440.36	880.89	1092.56	1262.27
3	Std. Dev.(mm)	20.98	29.68	33.05	35.52
4	Maximum [mm]	68.03	89.39	124.94	126.67
5	Minimum [mm]	-45	-98.75	-129.62	-77.86

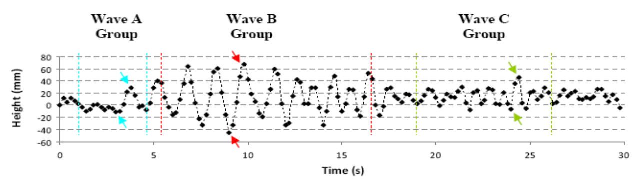


Figure 11 The wave height with dividing into three categories waves (Wave A, B and C)

The detail characteristics of wave A, B and C are shown in Table 6. From this data, the period and wave energy can be defined by using Equations 3:

$$E = \frac{\rho.g.H.(T_H - T_L)}{\pi} \tag{3}$$

Table 6 Analysis of a single wave elevation time series

Wave A Group		**Wave B Group**		**Wave C Group**	
From :	1.8 s	From :	5.6 s	From :	19 s
To :	4.6 s	To :	18 s	To :	26 s
Max :	28.3 mm	Max :	68 mm	Max :	46.1mm
Tmax :	3.8 s	Tmax :	9.8 s	Tmax :	24.4 s
Min :	-10.5 mm	Min :	-45 mm	Min :	-6.3 mm
Tmin :	4.6 s	Tmin :	9 m	Tmin :	24 s
Height:	38.77 mm	Height:	113 mm	Height:	52.4 mm
Period	1.4 s	Period	1.8 s	Period	0.8 s
Energy:	5.78 J/m	Energy:	81.23 J/m	Energy:	3.45J/m

6.2 Wave Angles

The values of divergent wave angles in actual condition (c°), calculated using Equation 1 and 2 for one particular test condition are given in Table 7. The number labels of the divergent waves are based on Figure 5.

Table 7 Wave angle of divergent wave (DW)

Divergent wave	d°	a°	b°	c°
DW 1	18	41	18	39.86
DW 2	15	41	18	34.74
DW 3	13	41	18	29.23
DW 4	13	41	18	28.47
DW 5	13	41	18	29.04
DW 6	12	41	18	28.19
DW 7	13	41	18	28.47
DW 8	13	41	18	28.47

As can be seen from Figure 5, the progression of a single wave such as DW1 will, after some time, develop into DW8. The divergent angles reduces as time goes, and it is expected that the incident angle on banks further from the sailing line will be less, nearing zero i.e. parallel to the banks.

■7.0 CONCLUSIONS

The study shows that visual observation using digital video cameras can be used to obtain wave heights and divergent wave angles.

For next development, this method must be validated properly with other research work such as CFD simulation or laboratories experiment.

Nomenclatures

a - Angle of poles in actual condition [°]
b - Angle of poles in image condition [°]
c - Divergent wave angle in actual condition [°]
d - Divergent wave angle in image condition [°]
B - Breath [m]
D – Water depth [m]
E - Energy [J/m]
H - Wave height [m]
Loa - Length of overall [m]
Lwl- Length of waterline [m]
T - Draught [m]/ Period [s]
T_H - Period at highest wave [s]
T_L - Period at lowest wave [s]
α - Ratio between the angles

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