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經濟部水利署
國立成功大學 水工試驗所
Tainan Hydraulics Laboratory
National Cheng Kung University, since 1950

PHYSICAL MODELING STUDY ON SCOUR AND SCOUR COUNTERMEASURE FOR SEA-CROSSING BRIDGE PIERS

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- Introduction
- Hydrodynamic and Morphologic Background
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- One Pier Model for Simulation Initial Construction Stage
- Scour around Bridge Pier Groups of Sea-crossing Bridge
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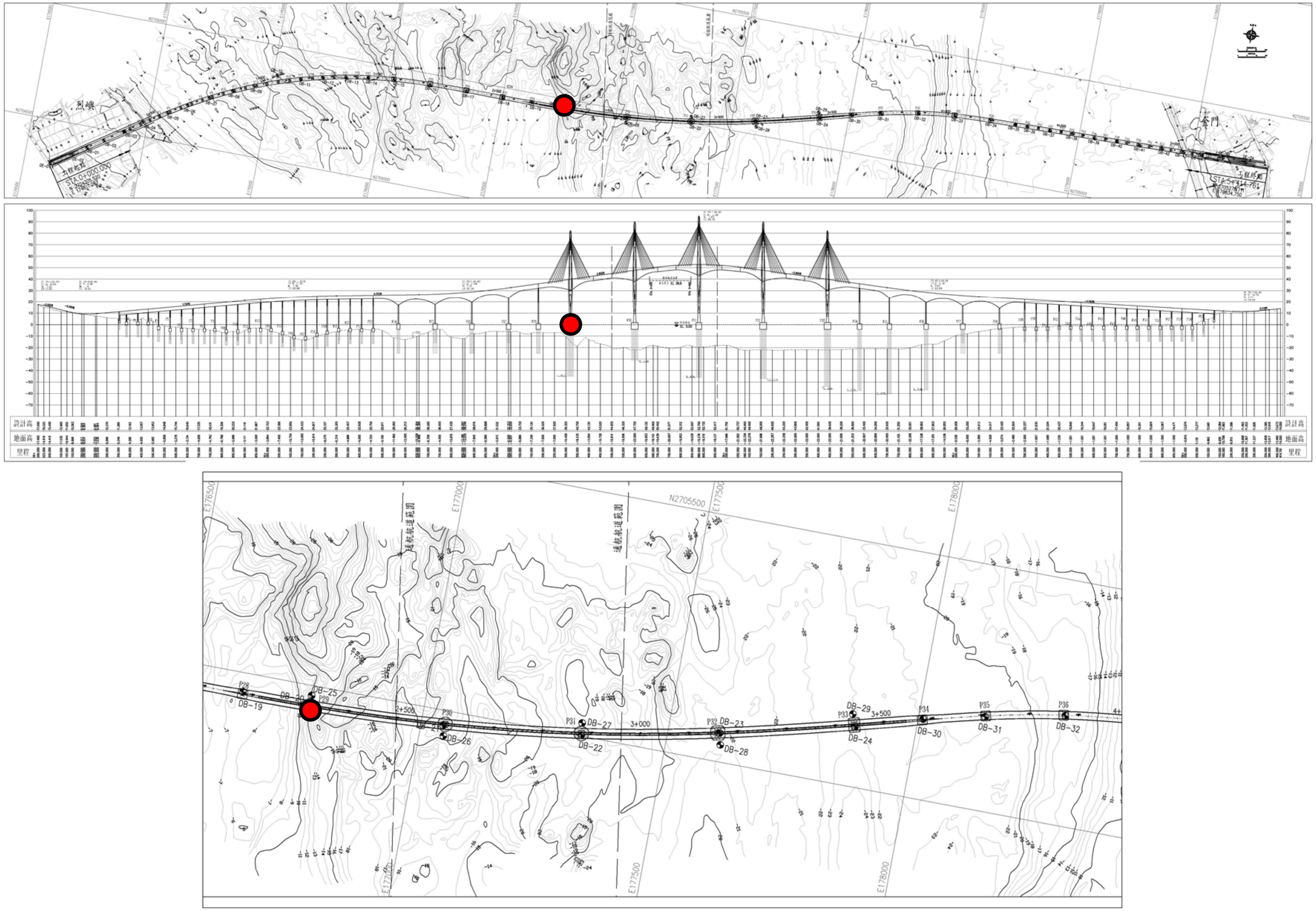
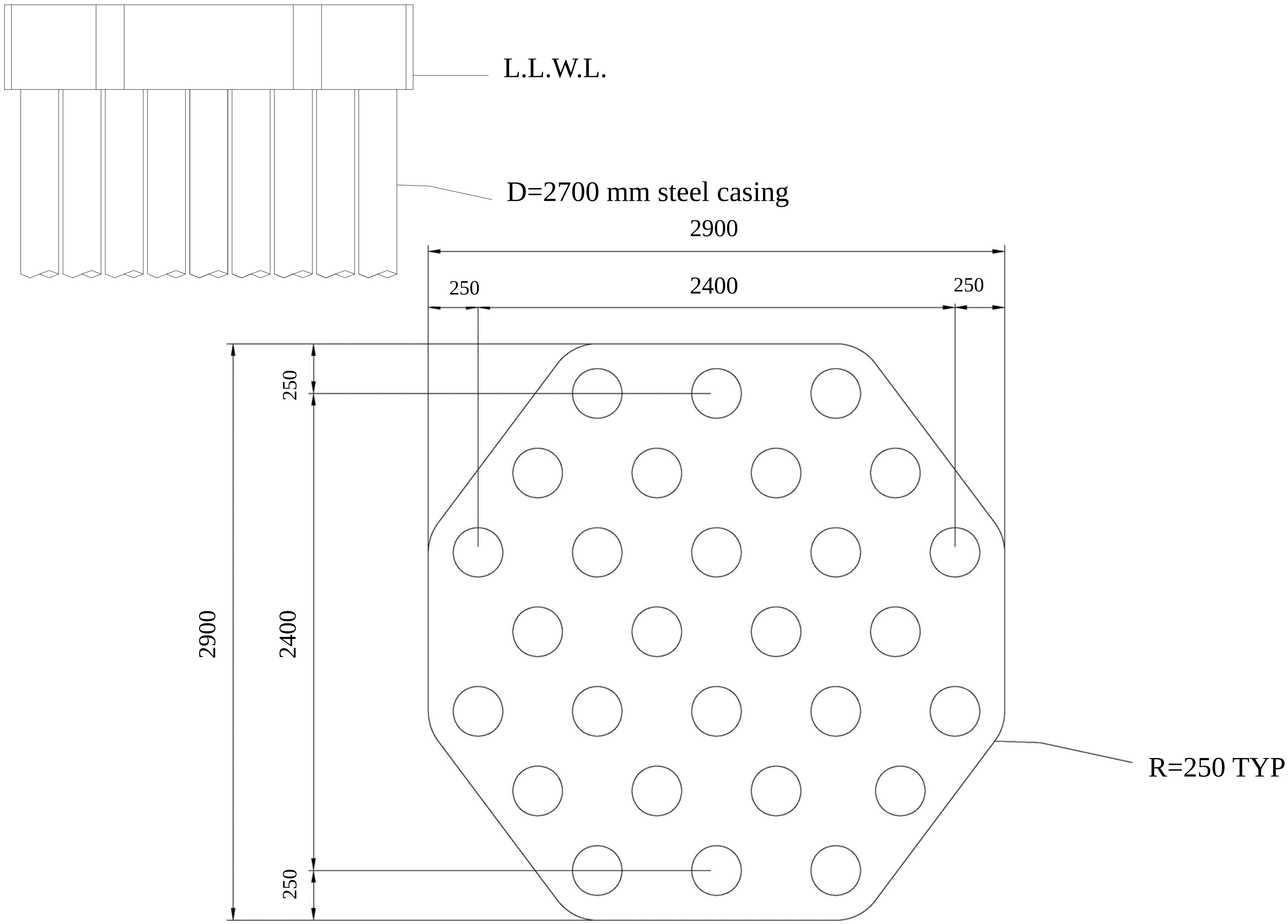
Introduction

Sketch of the Kinmen sea-crossing bridge connecting Greater Kinmen and Lieyu

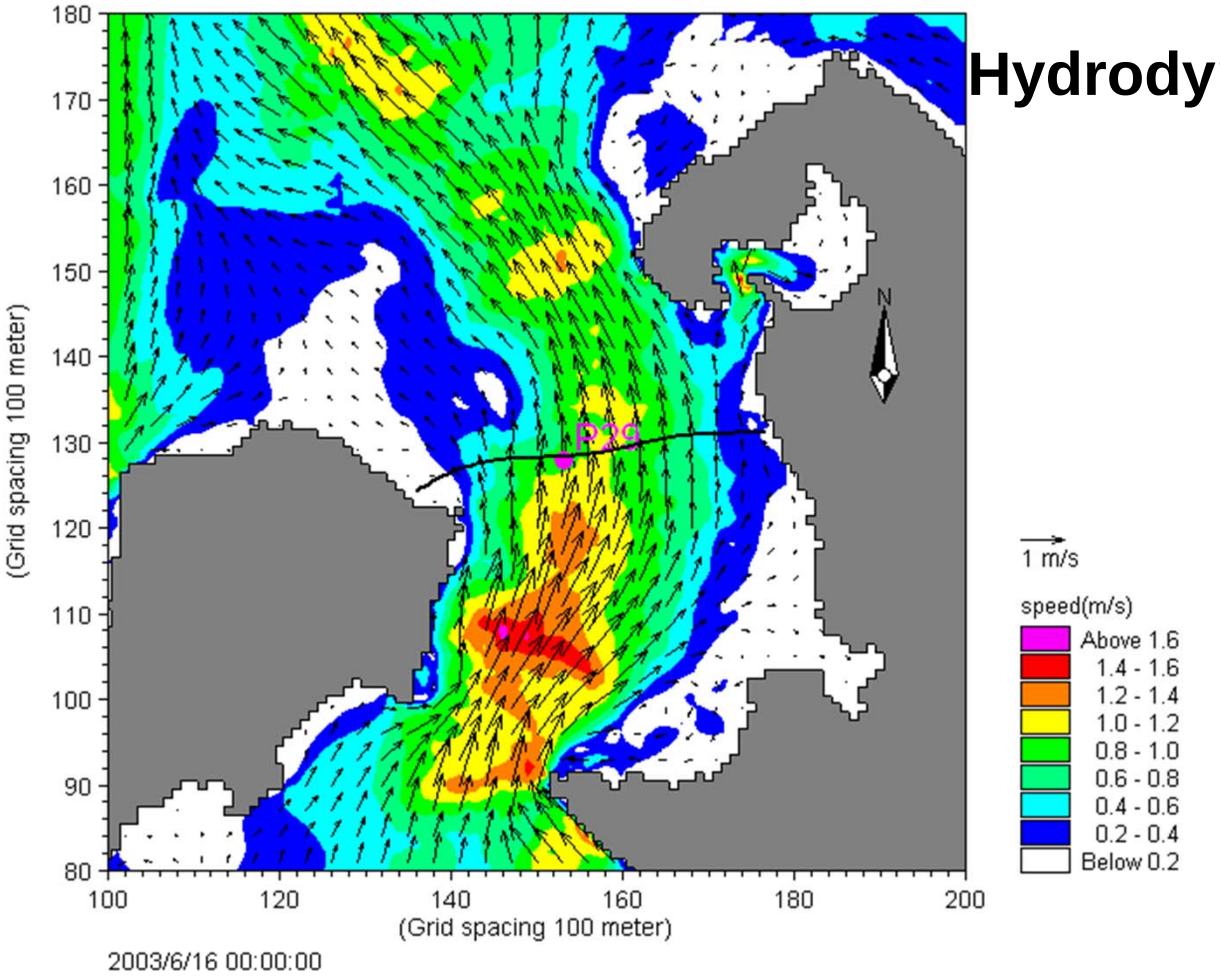


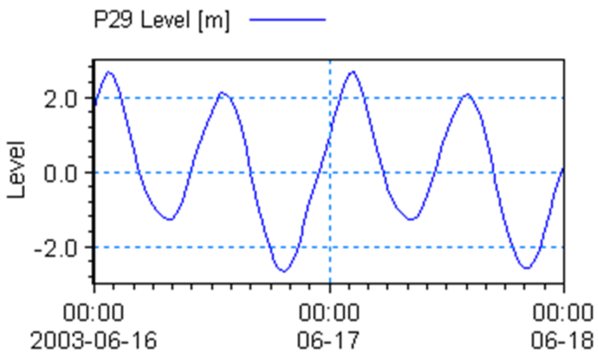
Location of foundation design of the Kinmen bridge foundation

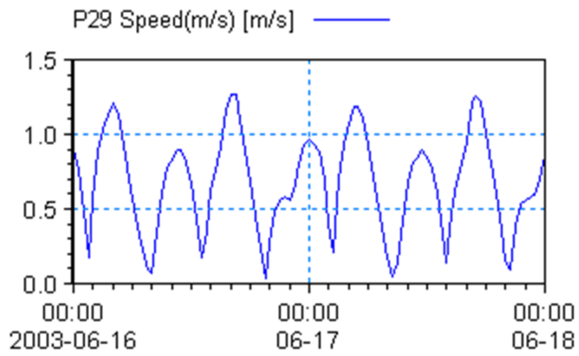


Sketch of foundation design of the Kinmen bridge

Hydrodynamic and Morphologic Background







Flow field simulation for Kinmen water channel (the maximum current speed near No. P29 foundation is around 1.28 m/sec)

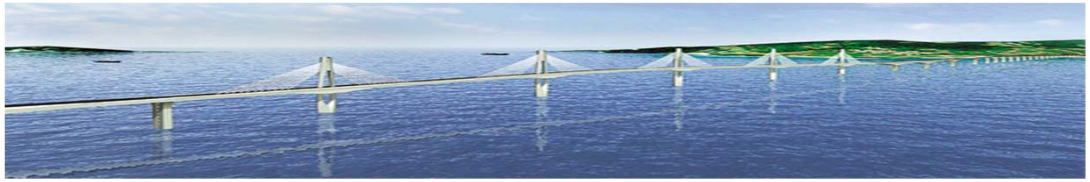
THL

Test conditions of physical model on scour around sea-crossing bridge pier

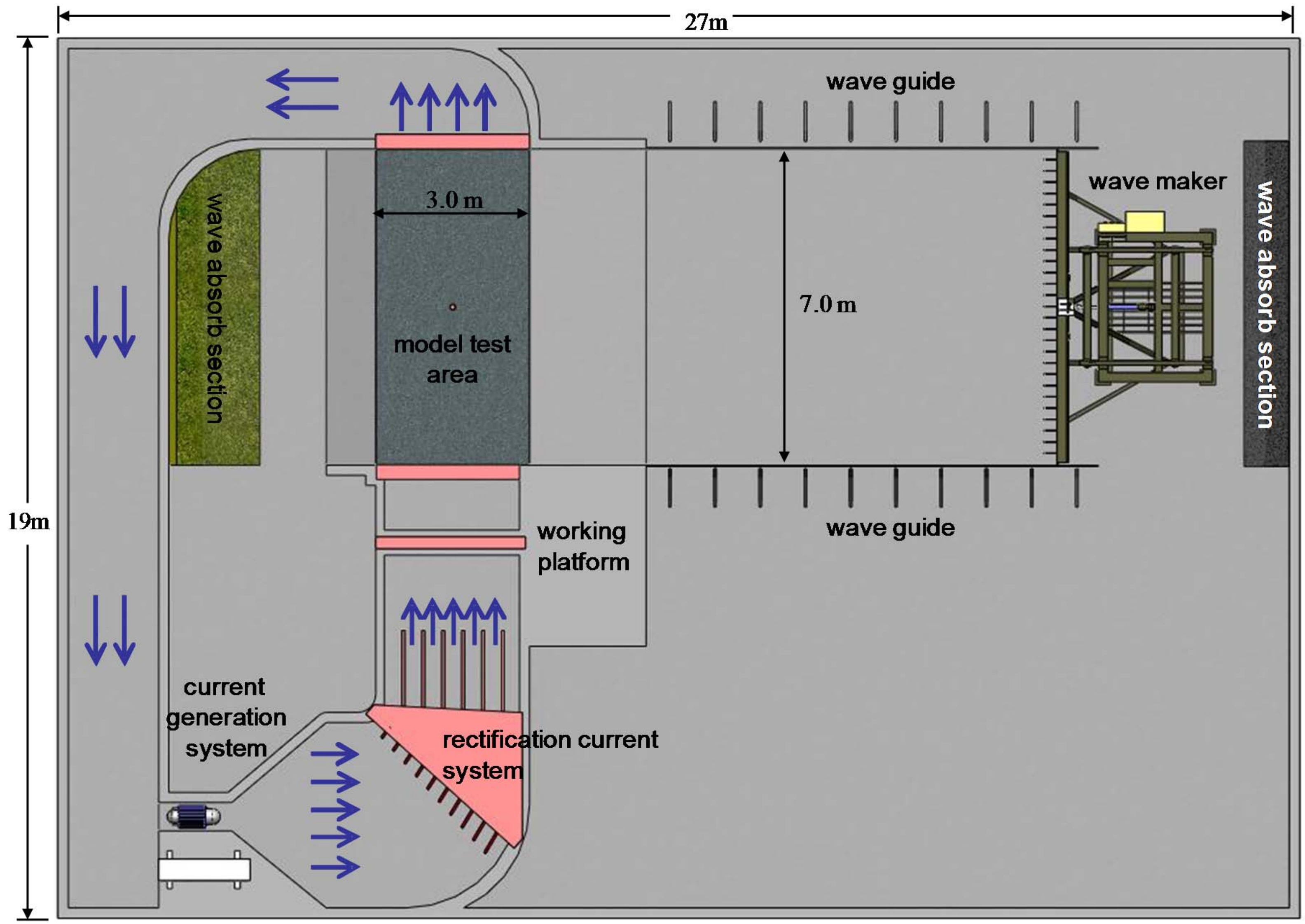
test case	water depth (m)	wave height (m)	wave period (sec)	water level (m)	tidal current (m/s)	note
SMC	15.0	---	---	M.W.L. (+0.00)	1.5	one pier
SHTC		2.0	11.9	H.H.W.L.(+3.16)		
GMC		---	---	M.W.L. (+0.00)		pier groups
GHTC		2.0	11.9	H.H.W.L.(+3.16)		
GMCP		---	---	M.W.L. (+0.00)		pier groups and scour protection
GHTCP		2.0	11.9	H.H.W.L.(+3.16)		

S : one pier
G : pier groups
M : M.W.L
H : H.H.W.L.

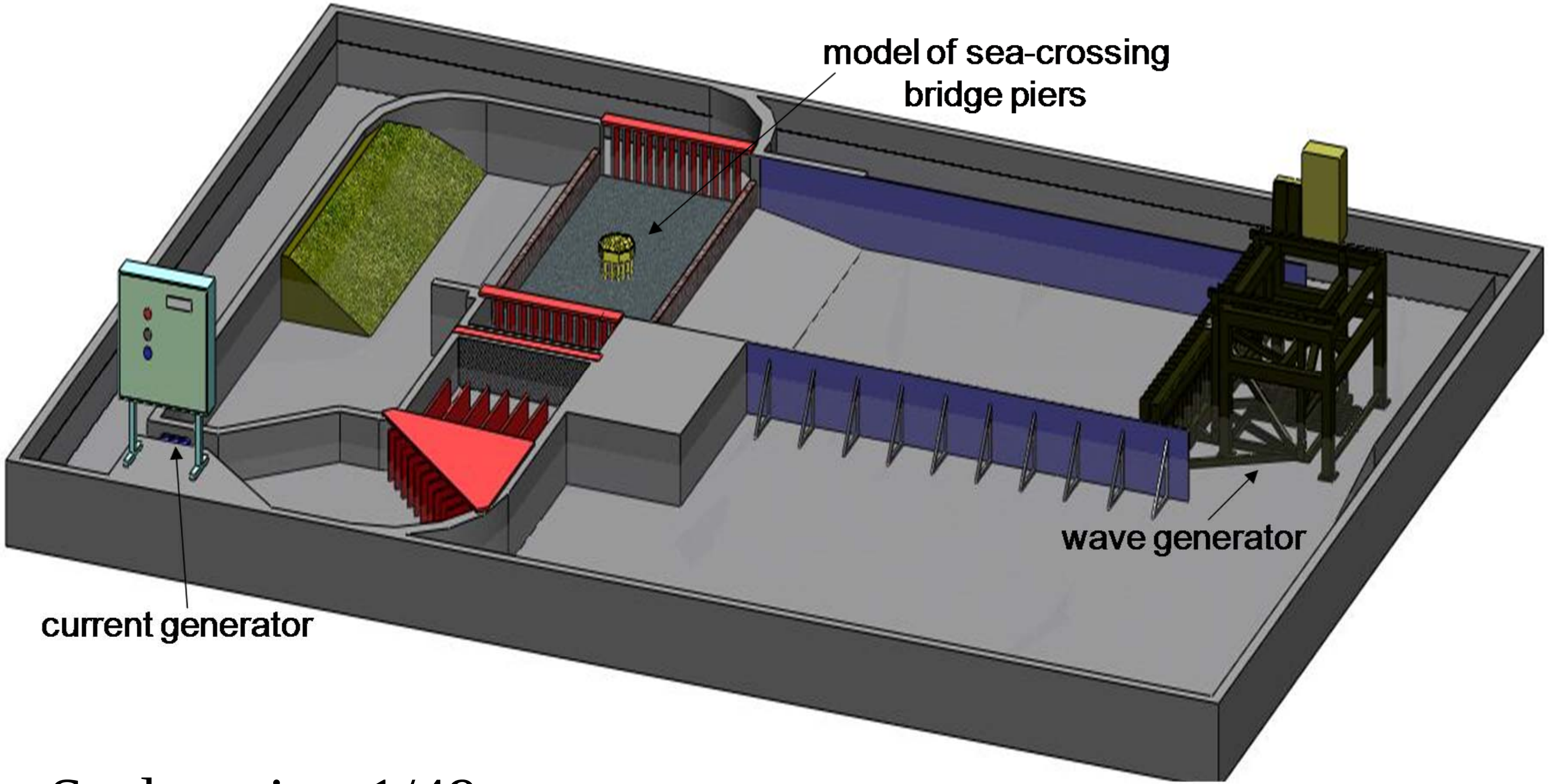
T : typhoon wave
C : current
P : scour protection



Experimental Setup



Sketch of experimental setup for scour around sea-crossing bridge



Scale ratio : 1/49

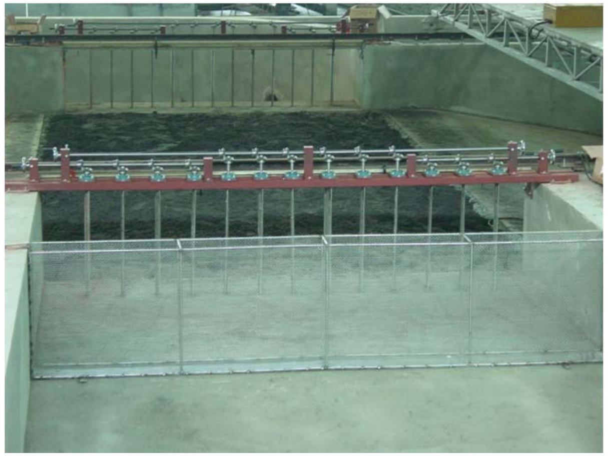
Scale law : Shields parameter

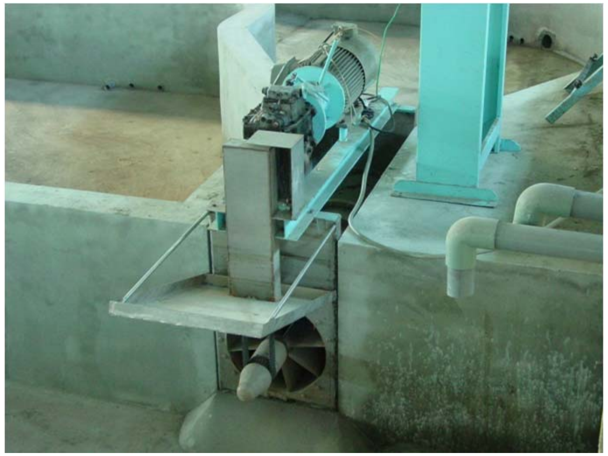
Bed material : coal (specific gravity, r=2.02; median grain size, d50=0.15 mm)

Experimental Facility


current guide


rectifcation current system


current guide


Screw pump


Wave absorb section


bridge group piers model

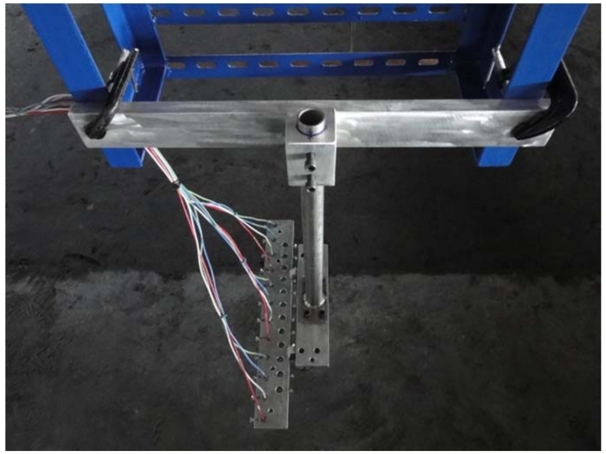
Experimental Sensor

ADV current meter

pressure sensor

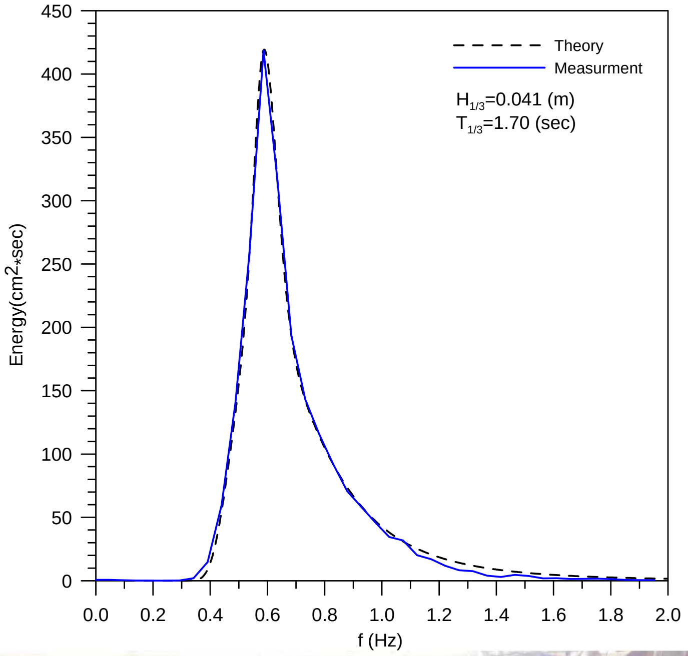
wave gauge

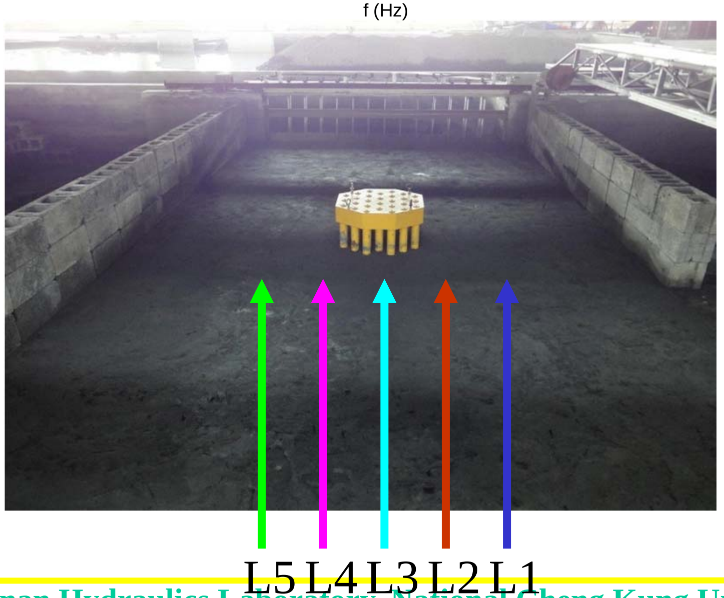
X-Y carriage table system

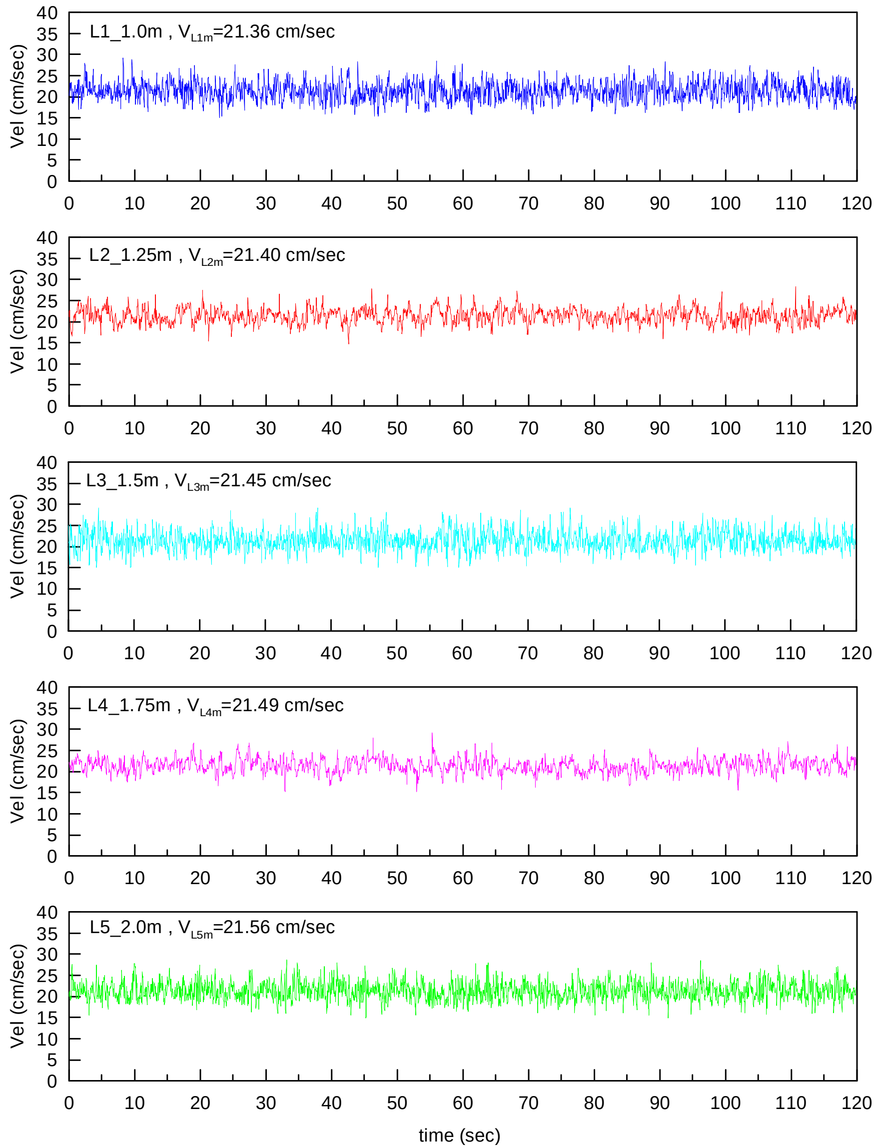


ultrasonic bottom profiler (SeaTek)

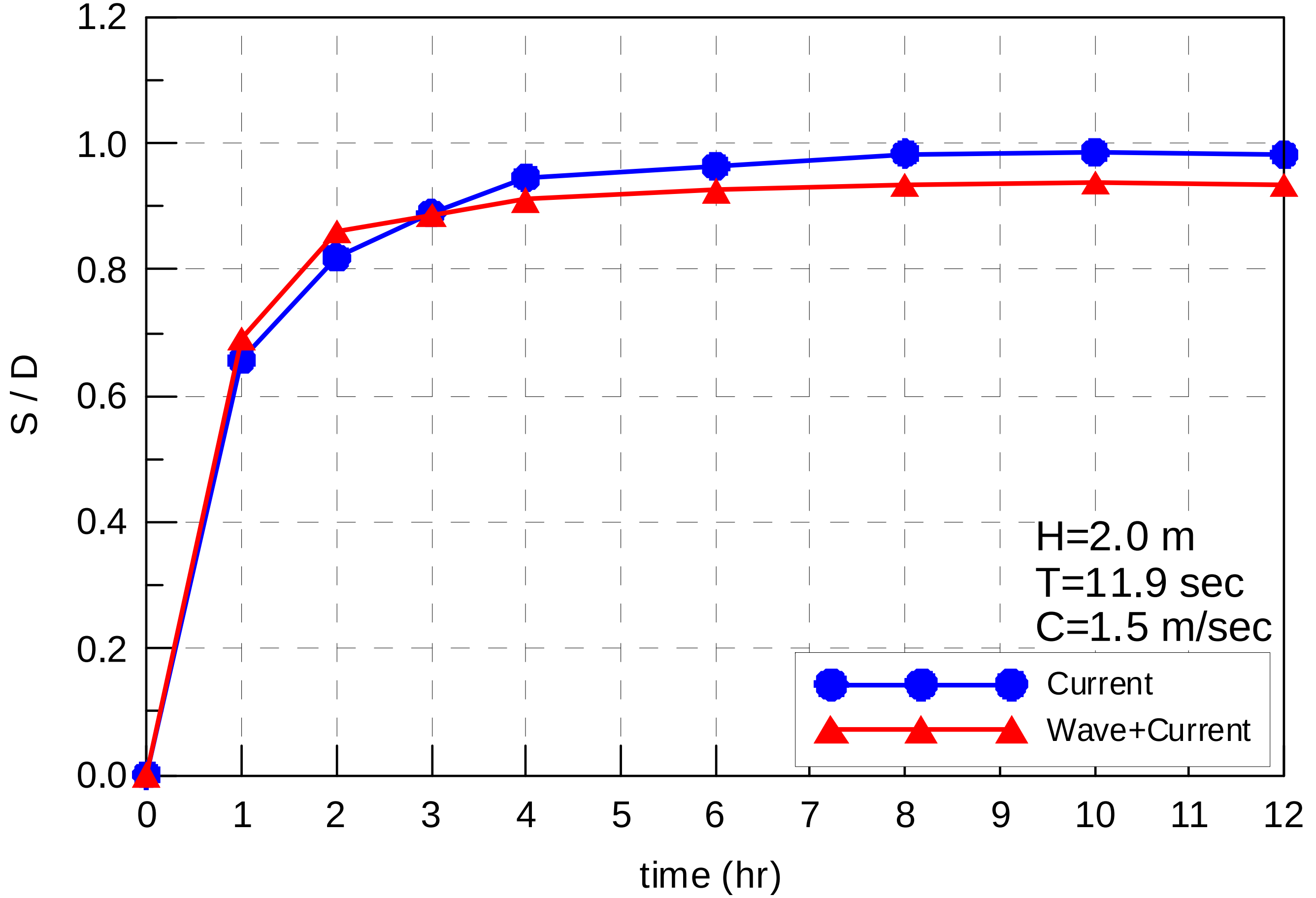
The calibration of the experimental target wave and current test condition





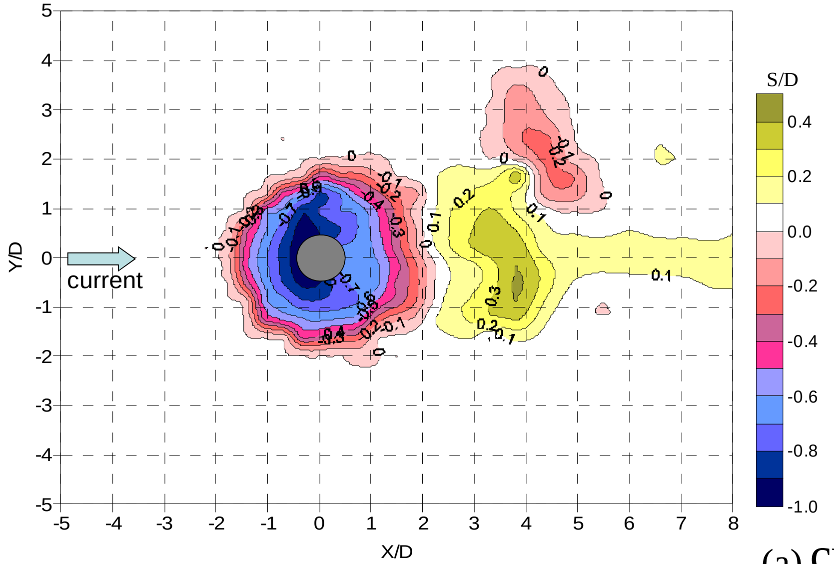


One Pier Model for Simulation Initial Construction Stage

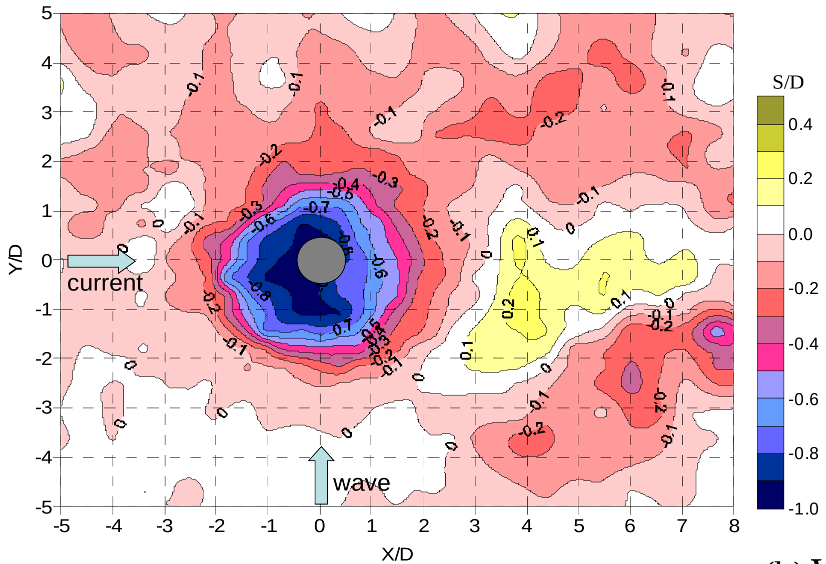


The evolution of maximum scour depth around one pier for the current-alone case and combined-wave-and-current case

The potential impact erosion area and scour around one pier



(a) current-alone case

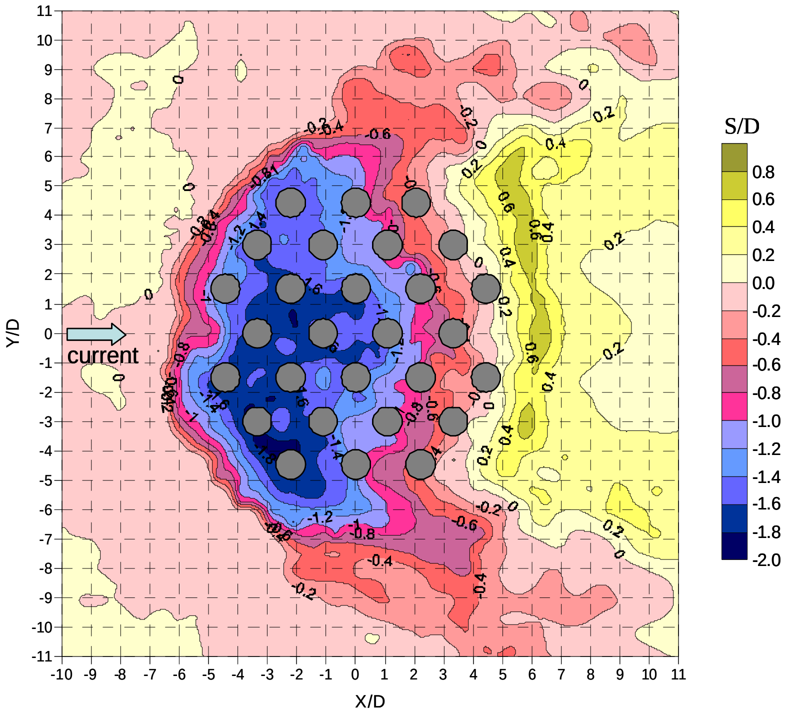


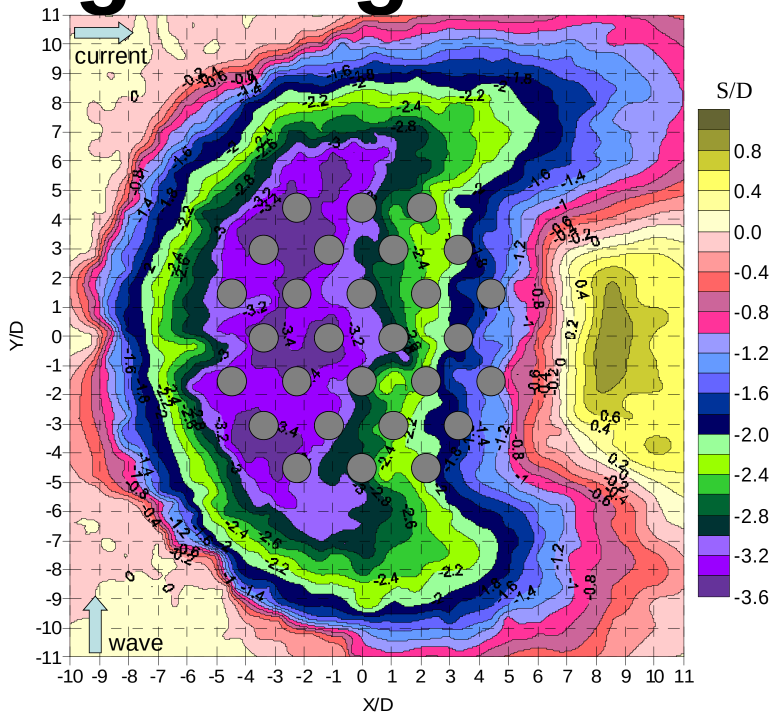
(b) wave and current combined case

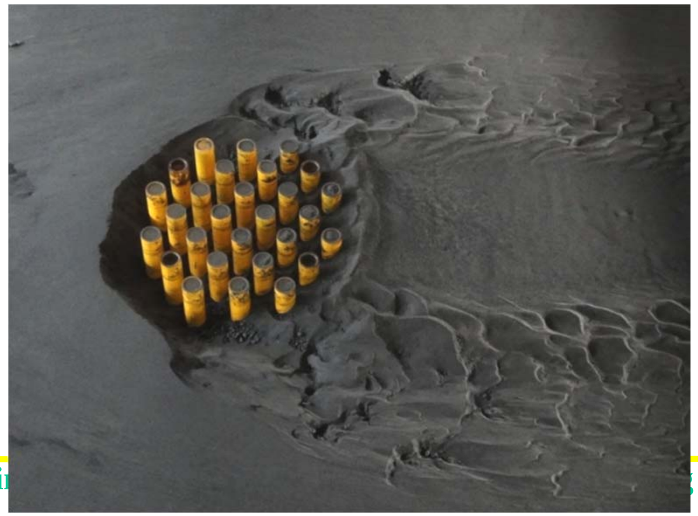
The potential scour area obtained from the one pier experiments

test case	scour direction	impact area of the different scour depth (D)			
		>0.2D	>0.4D	>0.6D	>0.8D
SMC	current-front	1.7	1.5	1.2	0.8
	current-back	1.9	1.6	1.2	0.4
	wave-front	1.8	1.6	1.6	0.9
	wave-back	1.8	1.7	1.5	1.3
SHTC	current-front	2.4	2.0	1.8	1.4
	current-back	2.4	1.8	1.2	0.6
	wave-front	2.3	1.9	1.6	1.3
	wave-back	3.2	1.6	1.3	0.9

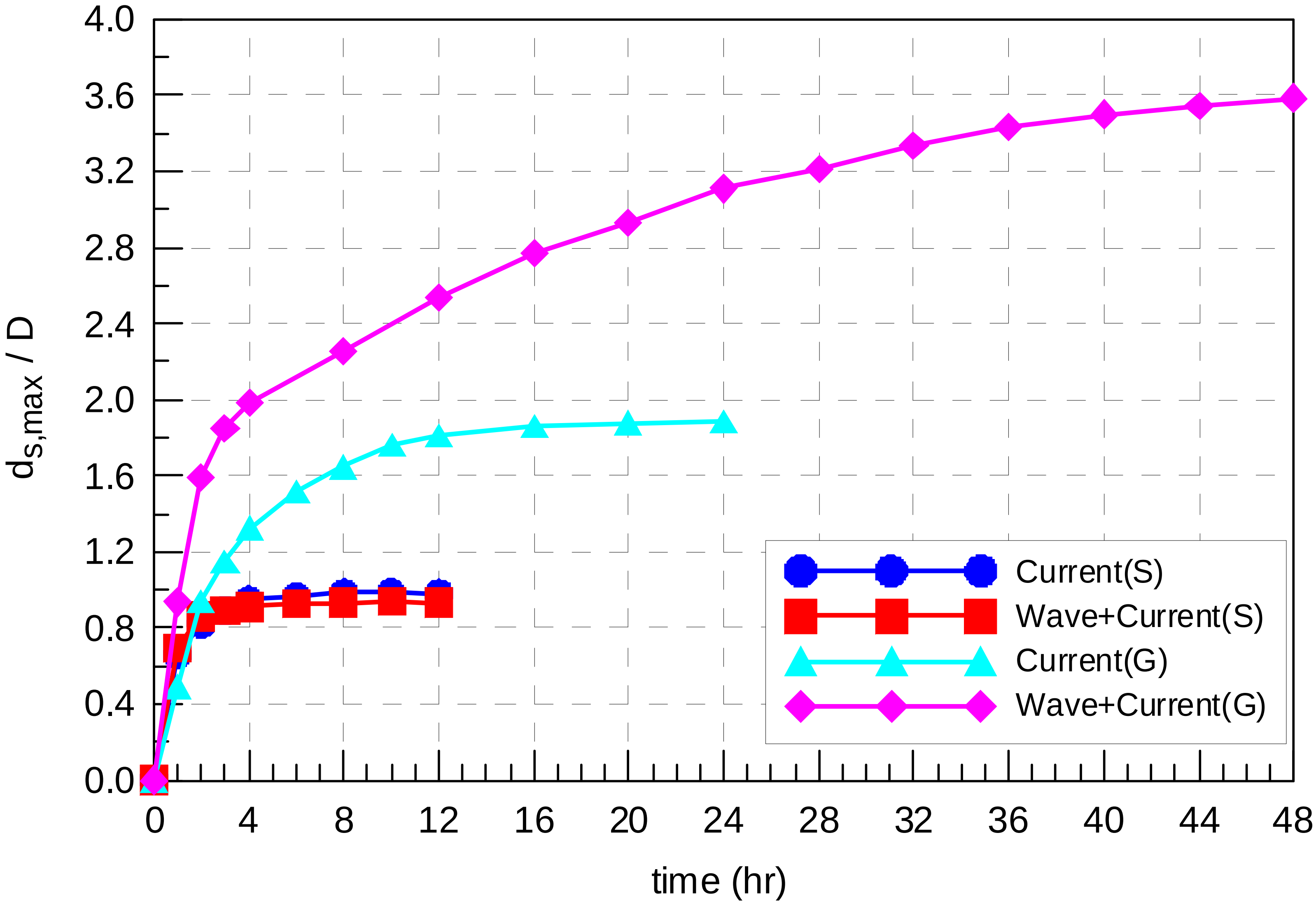
Scour around Bridge Pier Groups of Sea-crossing Bridge



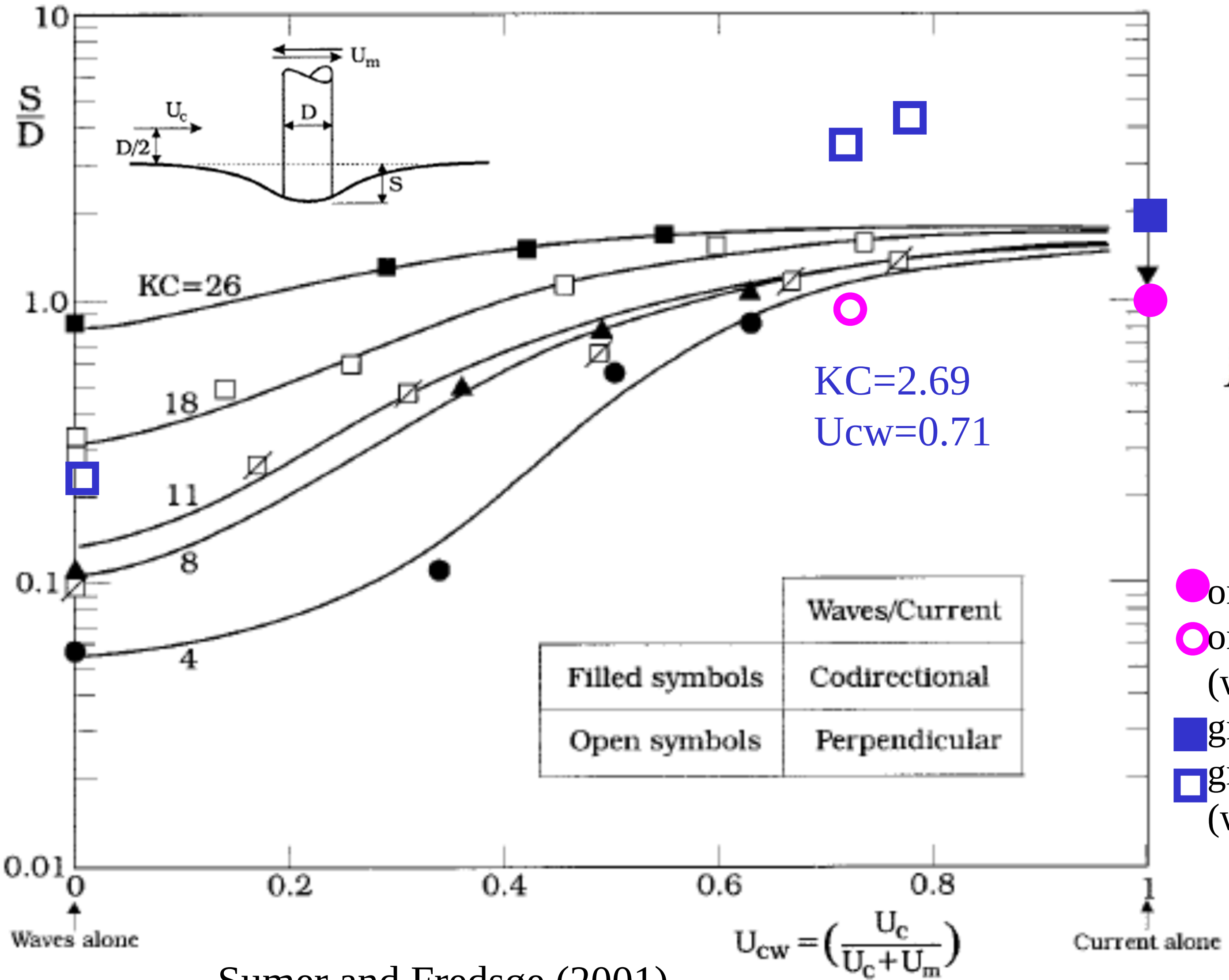




Experimental results comparison between single pier and group piers



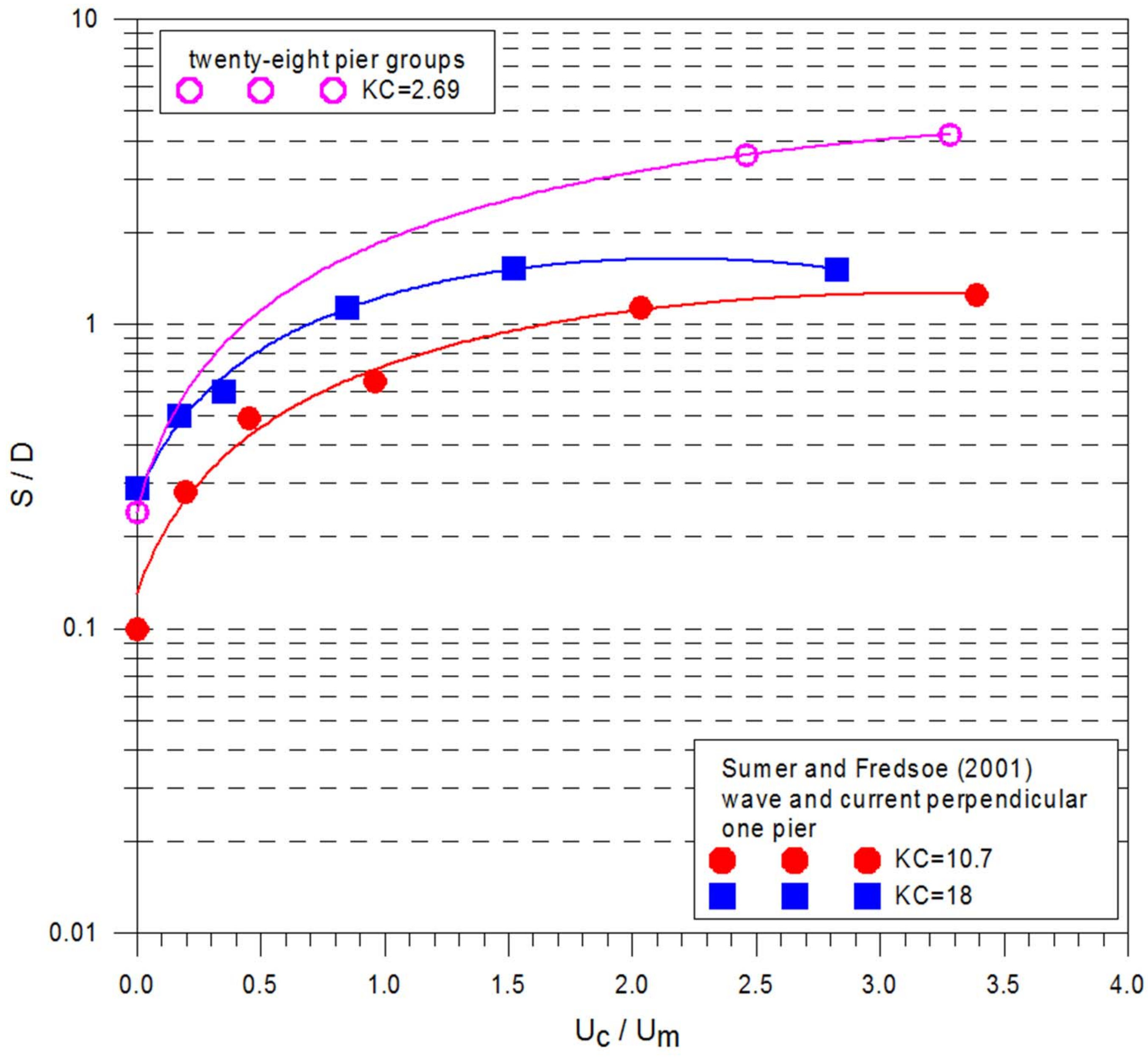
Equilibrium Scour Depth, Perpendicular Waves and Current



Sumer and Fredsøe (2001)

$$KC = \frac{U_w T_w}{D}$$

- ● one pier (current)
- ○ one pier (wave/current)
- ■ group piers (current)
- □ group piers (wave/current)



(Sumer and Fredsøe , 2001)

The maximum scour depth estimated by Hyperbolic Model

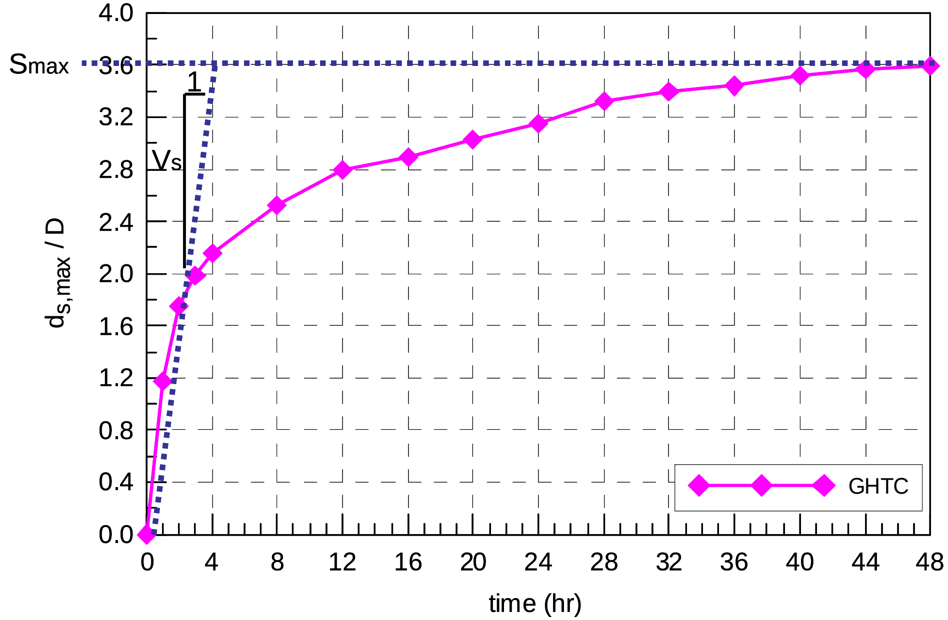
$$t / (d_{s,max}/D) = a + b \times t$$

$$S_{max} = 1/b$$

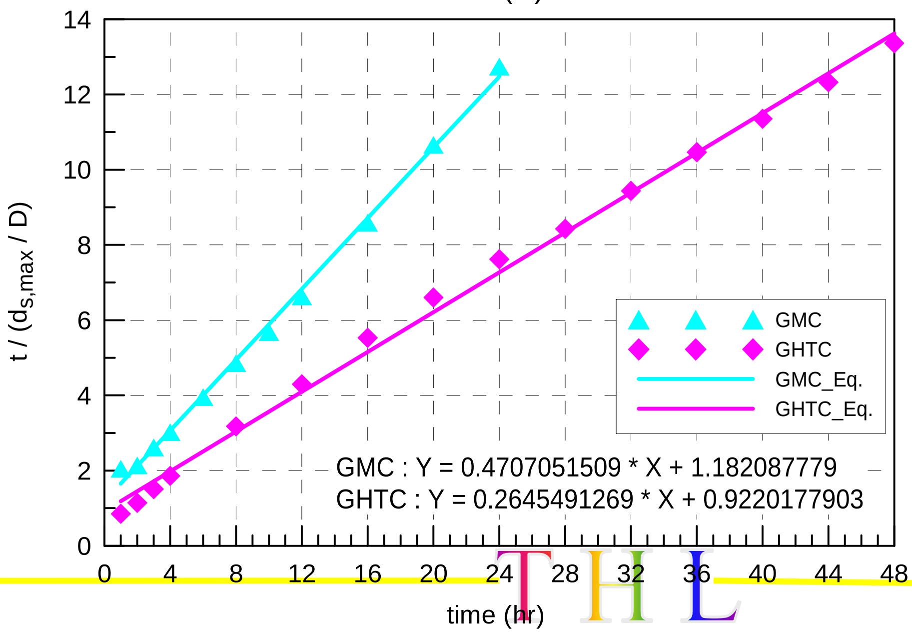
$$V_s = 1/a$$

Asymptote of $d_{s,max}/D$: S_{max}

Initial scour rate : V_s



Test run	Physical Model test		Hyperbolic Model		
	$d_{s,max}$ (m)	$d_{s,max}$ /D	$d_{s,max}$ (m)	S_{max}	V_s
GMC	5.09	**1.88**	5.74	**2.12**	0.85
GHTC	9.70	**3.59**	10.21	**3.78**	1.08

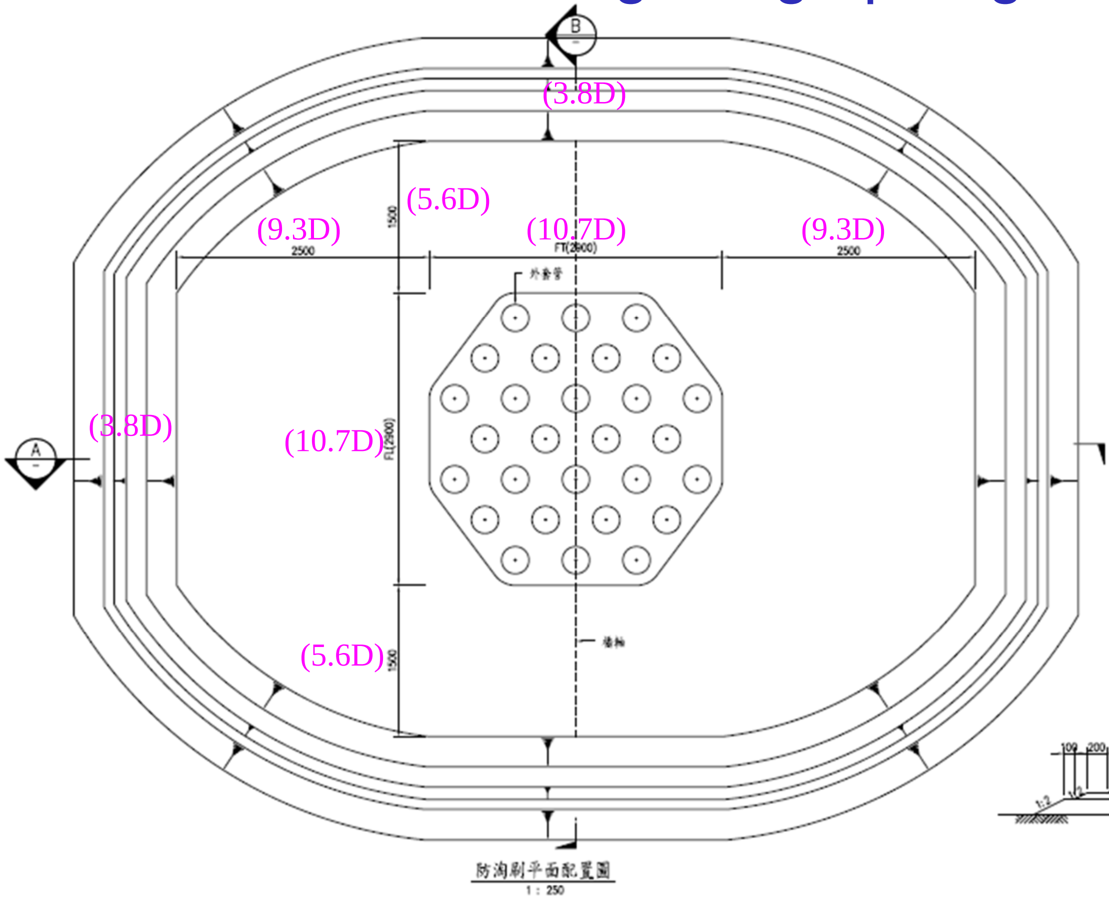


The potential scour area obtained from the pier groups experiments

test case	scour direction	impact area of the different scour depth (D)					
		>0.4D	>0.8D	>1.2D	>1.6D	>2.0D	>3.0D
GMC (current)	current-front	1.5	1.2	0.7	0.1	---	---
	current-back	-0.4	-2.3	-3.5	-4.2	---	---
	wave-front	5.0	2.0	1.5	0.6	---	---
	wave-back	4.8	1.5	1.3	-1.2	---	---
GHTC (wave and current)	current-front	4.8	4.4	3.9	3.5	2.6	1.0
	current-back	8.0	7.0	4.9	3.0	1.0	-3.4
	wave-front	7.6	6.2	5.4	4.8	4.1	2.0
	wave-back	7.2	6.2	5.2	4.5	3.9	2.0

Scour Protection for Bridge Pier Groups of Sea-crossing Bridge

Sketch of the proposed scour protection around the sea-crossing bridge pier groups foundation

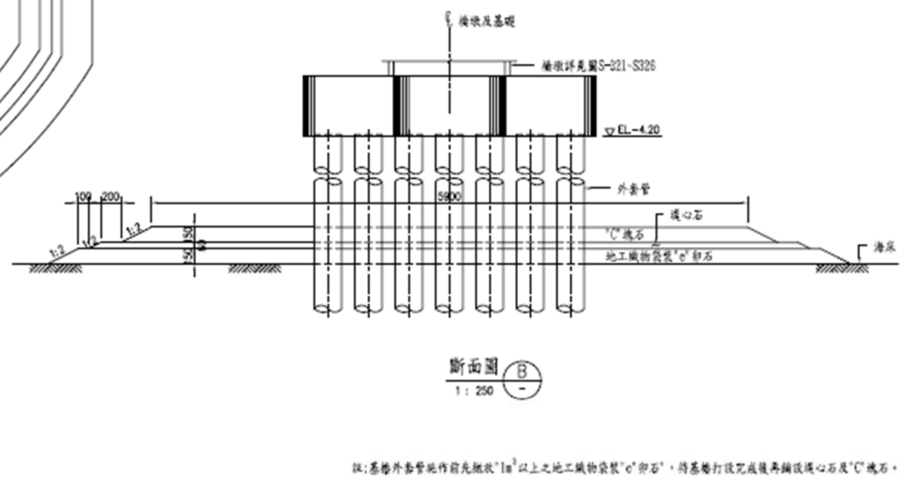


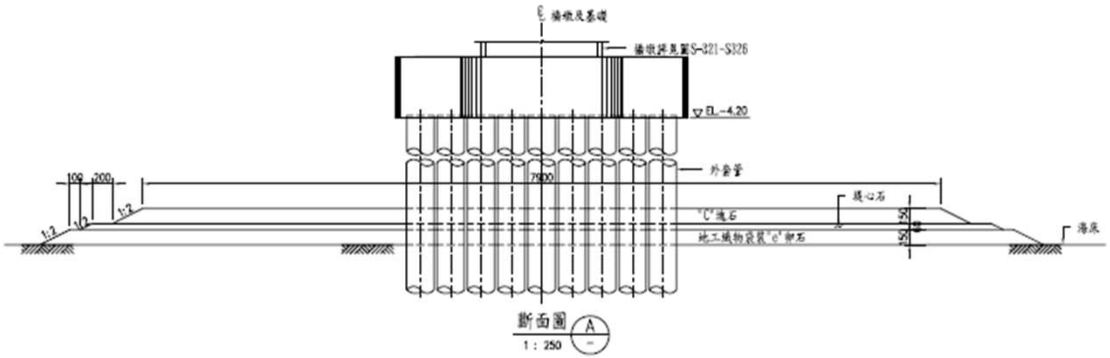
The proposed scour protection consists of three layers：

1.Block stone：300～500 kg(1.5m)

2.Corn stone：grain size 10～30cm(0.6m)

3.Filter stone ： grain size 4～10cm(1.5m)





Experimental setup of scour protection around the bridge foundation

placement of bottom bed

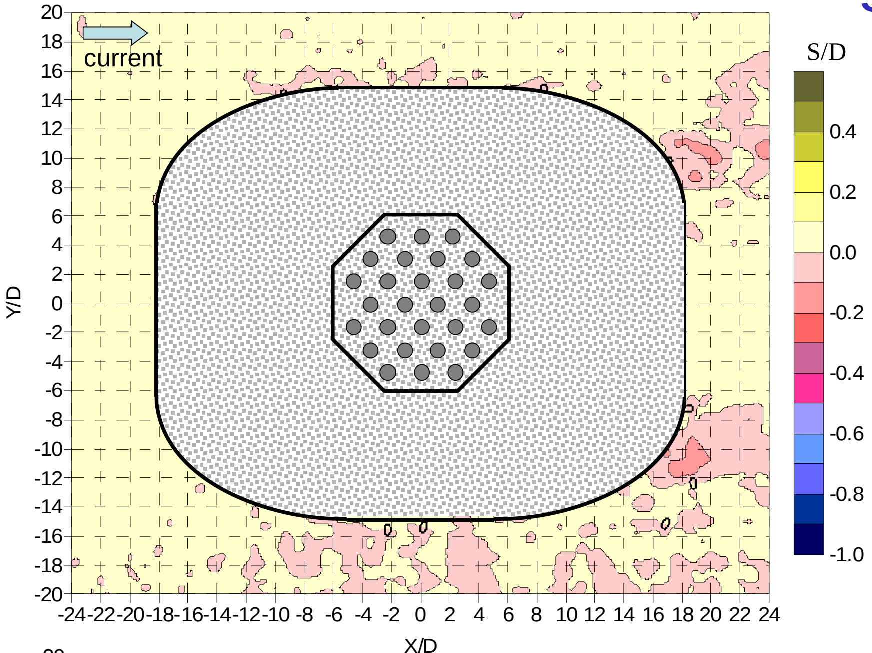
placement of filter stones

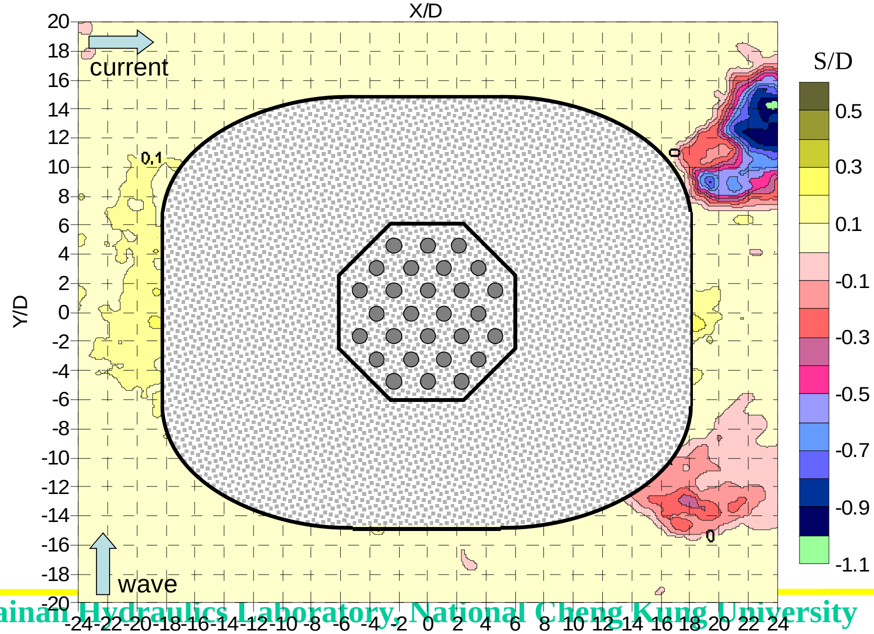
placement of corn stones

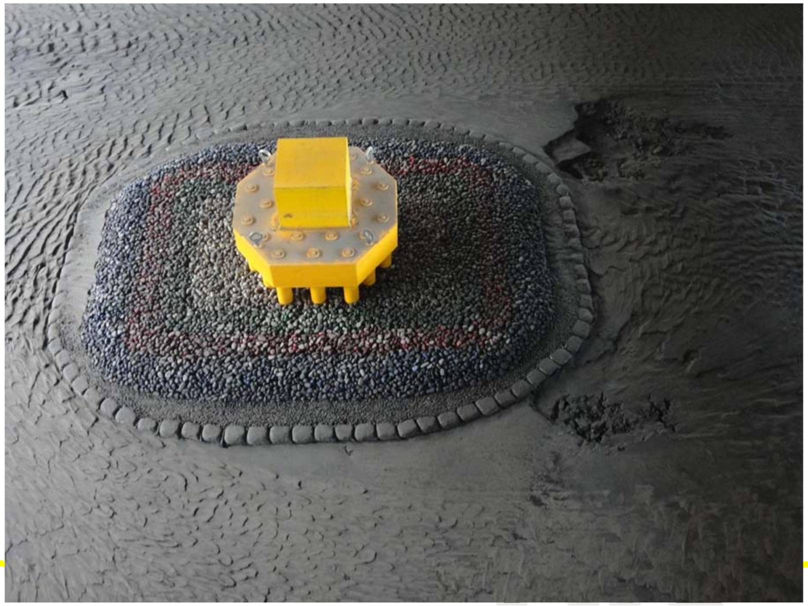
placement of block stones

model of scour protection

The bed configuration of scour hole around the scour protection for the sea-crossing bridge pier groups







$d_{s,max}$ results comparison between those obtained from with and without scour protection

test run	$d_{s,max}$ (m)				$d_{s,max}$ /D			
	12 hr	24 hr	36 hr	48 hr	12 hr	24 hr	36 hr	48 hr
GMC	4.89	5.09	---	---	1.81	1.88	---	---
GTHC	7.55	8.50	9.29	9.70	2.79	3.15	3.44	3.59
GMCP	0.31	0.43	---	---	0.12	0.16	---	---
GTHCP	0.87	1.63	2.21	2.77	0.32	0.61	0.82	1.03

Conclusion

- The average scour depth for bridge pier groups more increases than that around one pier. That is due to the vortices created around the piers will interact with each other, and the flow accelerated owing to contraction created by the adjacent pier. Thus, a higher sediment transport induced by the gap of bridge piers hence contributes substantially to the scour depth.
- The shape of the scour hole around the sea-crossing bridge piers may be approximated by an inverted cone having a circular base, the area of deposition downstream the pier groups increases with time.

Conclusion

- In order to circumvent the scour problem, scour must be presented by means of an appropriate scour protection. Three different layers of scour protection including block stone, core stone and filter stone are proposed in this study. Finally, a three-layer scour protection is tested and investigated to be effective in preventing scour around this twenty-eight pier groups of sea-crossing bridge foundation.

Thanks for your attention !

Acknowledgement

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