
Keywords: coastal structures, breakwater design, harbour entrance, concrete armour units, hanbars.

1. Introduction

7KH ¿SÄWLNL +DUERXU 'HYHORS
LPSURYH PDULWLPH DFFHVV IRU
VWDELOLVLQJ WKH :DLRHND 5LY
WUDLQLQJ ZDOO EUHDNZDWHUV
ZLOO EH WRFDWHGDVW RI WKH H[
DQG[WHQG RXW WR DSSUR[LPDW
H[LVWLQJ VKZLGHQHLQJ WRD SU
QXPI
FRXS
HQY



RQDO FK
DPLF ZL



)LJXUH([LVWLQJ :DLRHND 5LYHU HQWUDQF
LQFOXGLQJ ULYHU WUDLQLQJ ZRUNV VRX

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¿ SÀWLNL +DUERXU 'HY-H ~~RSJCHW~~ 13LR MHD ~~QDQG~~ TV ILUVW KDUERXU RSHQLQJ LQ RYHU
-RQDWKDQ &ODUNH *UDQW 3HDUFH 7RP 6KD ~~QGG~~/DQFH 3DUWQHU (GGLH %HHWKDP

¿ SÀWLNL +DUERXU 'HY-H ~~RSJCHW~~ 13LR MHD ~~QDQG~~ TV ILUVW KDUERXU RSHQLQJ LQ RYHU
-RQDWKDQ &ODUNH *UDQW 3HDUFH 7RP 6KD ~~QDQG~~ ~~SDW~~ ~~DE~~ ~~FN~~ ~~DR~~ ~~ON~~ HU (GGLH %HHWKDP

3.2

¿SÁWLNL +DUERXU 'HY-HRISPHQW 13LRMHDFODQG TV ILUVW KDUERXU RSHQLQJ LQ RYHU
-RQDWKDQ &ODUNH *UDQW 3HDFUH 7RP 6KDDQSDWDEHNDORRQHU (GGLH %HHWKDP

3.4 *URXQG ,PSURRPHQW

4.1 Armour unit s

7KH FRQFHSW GHVLJQ SUHVHQWHG UHFRPPHQGDWLRQV
IRU '\QDPLF &RPSDFWLRQ '& *URXQG
,PSURYHPHQW DQG JHRWH[WLOH UHLQIRUFHPHQW
GHSWK RI LPSURYHPHQW KDV EHHQ VKRZQ WR EH FULWLFDO
IRU WKH VWUXFWXUH WDWDELOLWORDG FDVHV
DQG LW LV DFNQRZOHGJHG WKDW '& LV RQO\ VXLWDEOH IRU
VRPH VRLO WSHHVBUR 7ULDOUH
ZDV FRPSOHVHGULO\ WR XQGHUVWDQG WKH
VXLWDELOLW\ RI '& IRU WKH VLWH DQG OLNHO\ GHSWKV RI
LPSURYHPHQW DQG GHVLRQVFRQFHSW
GHVLJQ DOVR LQFRUSRUDWHG D KLJK VWUHQJWK EDVDO
JHRWH[WLOH DQG WKH '& 7ULDO DVVLVWHG LQ
XQGHUVWDQGLQJ WKH SRWHQWLDO IRU GDPDJH WR WKH
JHRWH[WLOH ZKHQ VXEHHFW WR '&

7KH SURSRVHG '& PHWKRQ ZDV HIIHFWLYH LQ
GHQVLILQJ WKH ZLSHLQ WRKLO WULDO DUHD ZKLFK
DUH ODUJHO\ UHSUHVHQWDWLYH RI WKH WUDLQLQJ ZDOO ZRUNV
7KH HQHUJ\ OHYHOV DSSOLHG ZHUH GHWHUPLQHG EDVHG
RQ SXEOLVKHG UHODWLRQVKLSV WR DFKLHYH WKH WDUJHW
GHSWK

)LJXUHS '& WULDO ZDV FRQVXVHGVWRV WKH
OLNHO\ GHSWK RI LPSURYHPHQW DQG SRWHQWLDO GDPDJH WR
JHRWH[WLOHV

6LJQLILFDQW GHQVLILFDWLRQ ZDV REVHUYHG LQ WKH VDQGV
LQ WKH WRS WR P 5HGXFHG OHYHOV RI GHQVLILFDWLRQ
ZHUH VKRZQ WR H[WHQG WR D GHSWK RI DURXQG WR
P ZKLFK LDOHTXWYWR P5/ ZKHQ '&
LV FRPSOHWHG5URQ WKH WUDLQLQJ ZDOOV
7KH WDUJHW LPSURYHPHQWZDVGHVLRQ RI
DFKLHYHKG EDVDO JHRWH[WLOH UHLQIRUFHPHQW ZDV
DOVR VKRZQ WR EH VLJQLILFDQWO\ GDPDJHG GXULQJ WKH
'& WULDO HYHQ ZLWK D JUDYHO VDQG 'FXVKLRQ' DERYH WKH
JHRWH[WLOH %DVHG RQ WKHVH REVHUYDWLRQV IURP WKH
'& 7ULDO LW ZDV FRQFOXGHG WKDW WKH JHRWH[WLOH
UHLQIRUFHPHQW ZRXOG EH UHPRYHG IURP WKH GHVLJQ
DQG DOWHUWLRQVRIWHVQHWZSL OLQJ
VHOHFWHG WR V'XSSOPHQW WKH

4. Key design considerations

%DVHG RQ WKH LQYHVWLJDWLRQV FRQGXFWHG DV SDUW RI
WKH GHWDLOHG G[VVDJQXSURFHVRU
FKDQJHV ZHUH PDGH WR WKH GHVLJQ 7KH NH\
FRQVLGHUDWLRQV DUH RXWOLQHG EHORZ

¿SÁWLNL +DUERXU 'HY-HRISPOH 13LRMHDFVDQGTV ILUVW KDUERXU RSHQLQJ LQ RYHU
-RQDWKDQ &ODUNH *UDQW 3HDUFH 7RP 6KDDQSDWDFHNDORRNUHU (GGLH %HHWKDP

OD\HU RI SDWWHUQ SODFHG XQLWV WKH HIIHFWLYH
LPSHUPHDEOH FUHVW KHLJKW ZDV DOVR XQNQRZQ DV
GSHHQGLQJ RQ WKH ZDYH DQJOH WKH JDSV EHWZHHQ WKH
+DQEDU FKLPQH\ V PD\ DOORZ LQFUHDVHG ZDYH
SHQHWUDWLRQ DQG RYHUWRSSLQJ

6HYHUDO RYHUWRSSLQJ WHVWV ZHUH FRPSOHWHG LQ WKH
SK\VLFDQ PRGHORLQWV ZHXGH\ GRQH ZLWK
ZDYHV SHUSHQGLFXODU WR WKH WUDLQLQJ ZDOOV DQG DW DQ
DQJOH RI GHJUHHV WR WKH ZDOOV 9DULRXV +DQEDU
VL]HV ZHUH WHVWHG XVLQJ D UDQJH RI ZDYH FOLPDWHV
7KH UHVXOWV VKRZHG WKDW DV H[SHFWHG RYHUWRSSLQJ
UDWHV LQFUHDVHG DV ZDYH FOLPDWHV LQFUHDVHG DQG
FUHVW IUHHERDUGV UHGXFHG GHFUHDVHG DV WKH
+DQEDU VL]H DQG OD\HU WKLFNQHV LQFUHDVHG
DEVUELQJ PRUH ZDYH HQHUJ\ DQG GHFUHDVHG ZLWK
W#B€P R B B O DWX W# @ZDW B€ P @p#E WLLVKS H € LQ YuDT• € p#
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SÄWLNL +DUERXU 'HY-H R S P C W 1 3 H R M H F O V D Q G 1 V ILUVW KDUERXU RSHQLQJ LQ RYHU \
-RQDWKDQ &ODUNH *UDQW 3HDUFH 7RP 6KDDQ &ODUNH 3DUERXU (GGLH %HHWKDP

DJDLQVW ZDYH GRZQ UXVK VXFNL QVQV QR IR XW HW W U B X Q K Q J Z D O O V Z K
DUPRXU I R R F N W K H W R H D U H D F O R X O G M W W H R V W L Q H Z L W K G D P D J H Z H O
E U H D N Z D W H U V , W L V L P S R U W D Q Q V H Y H P V L D L H F R R F A K G H J H C W K H U H V \
S H U V S H F W L Y H W K D W W K H L Q Q H U S D Q W H B Y D W K I H Y B S D R S U R V D N H S V O G D G R
L Q S O D F H D V D E V K H M U H S L V O M R R V G S W K H I L H G U R F N V L J H I U R P D U D Q J H
R I W K H F R Q F U H G V H O D K S P I R X U H U W R R Q S L W L R Q V
L V W R E H W R G V X W L Q B R Q O \ D U P R X U V W R Q H V R W K D W
L Q D U L Y H U V F R X U V L W X D W L R Q W K H S U R M A D Y H G V O R S H K D V P R U H
H Y H Q D Q G F R Q W L Q X R X V S U R W H F W L R V O D D O H G V G H V L J Q D F I O W K H R S Ä W L N L +
D U L Y H U V F R X U S H U V S H F W L Y H U H O L H G R Q W K H F R O O H F W L R Q R I V L
D G G L W L R Q D O G D W D Q X P H U R X V Q X P H
P R G H O V D Q G F R Q V W U X F W L R Q W U L D O
Z D V R I W H Q L W H U D W L Y H Z L W K U H V X O
V W U H D P V I H H G L Q J E D F N L Q W R D V
H O H P H Q W V D Q G U H V X O W L Q J L Q V L J Q L
G H V L J Q D Q G D J U H D W H U F R Q I L G
F R Q V W U X F W D E L O L W \ D Q G X O W L P D W H
V W U X F W X U H V

6. \$FNQRZOHGJHPHQWV

7KH DXWKRUV DFNQRZOHGJH SÄWLNL
7KH %D\ RI 3OHQW\ 5HJLRQDO &RXQF
=HDODQG OLQLVWU\ RI %XVLQHV

)LJXUH([DP SOH RI 3K\VLFDQ PRGHO WHVW V K P F Z Q J W K H I X O G L Q J D Q G K L V
S H U I R U P D Q F H R I D I D O O L Q J U R F N D S U R Q X V L Q J W K U H H O D \ H U V R I
D U P R X U D Q G F N Q X Q G H U O D \ H U > @
F R Q W U D F W R U V + (% & R Q V W U X F W L R Q
G H V L J Q W R O L I H

\$SURQV DUH GHV LJQHG WR EH FRQVWUXFWHG WKUHH OD\HUV
WKLFN ZLWK WKH H[SHFWDWLRQ WKH R e f e r e n c e s O O L Q L W L D O O \ I D O O W R
D Q D S S U R [L P X P V O R S H L Q U H V S B Q V H W K D P (& W X B O L Q J 1 X P H U L F D O
V F X U D Q G X O W L P D W H O \ I R U P D 3 K \ V L F D Q V O R S H X O G H Q G O O L Q J I R U S Ä W L N L
H [W U H P H V F R X U H Y H Q W O J Z X B Q W H V L J S W Y U B O D V L D Q & R D V W V 3 R U W V
D Q G F R Q W L Q X R X V S U R W H F W L R Q R I D V O H D V W R Q H O D \ H U W K L F N
& K U L V W E K X U F K 1 H Z - H D O D Q G

)DOOLQJ DSURQ ZLGWKV ZHUH V.L]HG SEVVMG PHQW WKH WKH XVH RI &RQF
PD[LXP SUHGLFWHG ULYHU VFRXU SURXUKEQLWKRQFKD:QVYMDNZLWH&R
GHILQHKE XPHULFDO PRGHOOLOQJ DQG HP SHULFDO SURFHHGLQJV \$O
FDOFXODWLRQV RI SUHGLFWHG VERXU (&QDG IQRVYQDWLRQV LQ DQ DQXDO
EHG OHYHOV RQ WKH VHDZDUG V b G X D Q G K H D S Y R H W H H W D O (Q J L Q H H U
WUDLQLQJ ZDOOV 5 H V H D U F K & H Q W U H : D W H U Z D \ V ([S H U L P
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7KH URFN WRH DZSUPLQHGURRKOJ D UDQJH
RIHPSLUURDQDQDQ ZLWK WKH DGRSWHG
PHWKGR YDU\LQJ GHSHQGLQJ RQ ZDWHU GHSWK \$W
KLJKHU ZDWHU OHYHOV ODUJHU ZDYHV FDQ UHDFK WKH
VWUXFWXUH EXW WKH WRH LV VXEPHUIHG DQG ZDYH IRUFHV
DUH UHGXFHG /RZHU ZDWHU OHYHOV DOORZ IRU ZDYH
DFWLRQ WR DFW PRUH GLUHFWO\ RQ WKH WRH KRZHYHU GXH
WR GHSWKZDYPHWLQ VPDOOHU \$ UDQJH RI ZDWHU
OHYHOV ZDYH KHLJKWV DQG PHWKRGV ZHUH DVVHVVHG
DQG WKH FULWLFDO ZDWHU OHYHO DQG DVVRFLDWHG
PHWKRGRORJ\ XVHG LQ VL]LQJ WKH URFN

5RFN VL]LQJ ZDV YDOLG DW HG ZLWK SK\VLFDQ PRGHO
WHVWLQJ DW D UDQJH RQ FZDXVHG OHYHOV WKLV L
DGGUHVVLQJ FRQFHUQV WKDW HPSLULFDO FDOFXODWLRQV
PD\ XQGHUHVWLPDWH WRH DUPRXU VL]LQJ DW WKH KHDGV