3DUDPHWULF)LQLWH (OHPHQW $QDO\VLV RI 0RGXODU ([SDQVLRQ 'HYLFH RI %ULGJH

Fang Wu, Jianwu Pan, and Minghua Zhou

Abstract ² In order to research the cause of disease in modular expansion joints, in this paper, based on the secondary development, a general static analysis program has been compiled to facilitate the analysis of the integral finite element model of modular expansion joints. On this basis, the parameter analysis of modular expansion joints has been carried out using this program, mainly discuss the factor that affect the horizontal displacement of lamella. Moreover, the effect of the failure of sliding spring and control spring has been analyzed. The formula for the horizontal displacement of lamella is presented. The results show that the rigidity of control system and the condition of edge beam have a larger influence on horizontal displacement of lamella, then is friction coefficient of contact element, pre-tightening force and stiffness of sliding spring. Moreover, the failures of sliding spring and control spring are all close to the end of sliding. The research can provide scientific basis for the disease mechanism and the disease control of modular expansion joints.

Index Terms² Control spring, Lamella, modular expansion joints, sliding spring.

I. INTRODUCTION

7KH HODVWLF FRQWURO V\VWHP RI WKH PRGXODU H[SDQVLRQ GHYLFH KDV JRRG SHUIRUPDQFH DQG LV ZLGHO\ XVHG EULGJHV DW KRPH DQG DEURDG ... %ULGJH ... <DQJW]H 5LYHU %ULGJH ... 1RUPDQG\ %ULGJH ... ,QFKHRQ %ULGJH ... XQGHUVWDQGLQJ RI WKH ZRUNLQJ SULQFLSOH DQG IDLOXUH PHFKDQLVP RI WKH PRGXODU H[SDQVLRQ GHYLFH SUREOHPV LQ ... QHHGV WR EH UHSODFHG ... RULJLQDO ... QRW OHVV WKDQ ... \HDUV 7 KDV UHVXOWHG LQ D JUHDW ZDVWH RI UHVRXUFHV DQG HFRQRPLF ORVVHV ... GDQJHU WR WUDIILF VDIHW\ DQG EULGJH OLIH ... VFKRODUV DW KRPH DQG DEURDG KDYH VWXGLHG WKH GLVHDVH PHFKDQLVP RI PRGXODU ... ILQLWH HOHPHQW ... G\QDPLF DQDO\VLV RI WKH PRGXODU H[SDQVLRQ GHYLFH ... ZKHHO LPSDFW RQ ODPHOOD ... showed WKDW ZKHQ WKH VSHHG LV OHVV WKDQ ... NP K WKH KRUL]RQWDO LPSDFW RI WKH ZKHHO ... VPDOO\ ZKHQ WKH YHKLFOH VSHHG UHDFKHV ... NP K ZLOO LWV KRUL]RQWDO ... > @ > @ =XDGD &RHOKR FRQGXFWHG D ...

GLVHDVH RI WKH PRGXODU H[SDQVLRQ GHYLFH ... VKRZHG WKH LPSDFW ORDG RI YHKLFOH ... RQ WKH VWDWLF DQDO\VLV ... UHVXOWV GLVFXVVHG WKH FDXVH RI ... GHYLFH IURP ... IDLOXUH RI WKH ... sliding VSULQJ DQG FRQWURO VSULQJ ... UHSODFHG ... WKHQ WKH HQWLUH H[SDQVLRQ GHYLFH > @ 7KHUHIRUH LW LV QHFHVVDU\ ... LQIOXHQFH horizontal ... WKH IDLOXUH ... %XW DW SUHVHQW WKHUH LV QR ... 7KUHH GLPHQVLRQDO LQWHJUDO DQDO\VLV ... H[SDQVLRQ GHYLFH ... QRW EHHQ IRXQG LQ WKH ... QHFHVVDU\ WR DQDO\]H ... WKH IDLOXUH PHFKDQLVP RI WKH PRGXODU ... VWXG\ ... DQ DOO FDOFXODWLRQ ... VKRZV WKH GLVHDVH RI WKH H[SDQVLRQ ...

Fig. 1. Disease of the expansion device.

II. PROGRAMMING OF GENERAL CALCULATION PROGRAM OF MODULAR EXPANSION DEVICE

A. Establish the Parametric Finite Element Model

The modular expansion device is mainly composed of joist beam, lamella beam, edge beam, rubber seal, joist beam box, stirrup, bearing, VOLGLQJ VSULQJ DQG FRQWURO VSULQJ)LJ 3DUDPHWULF ILQLWH HOHPHQW ...

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HVWDEOLVK ANSYS $3'/)LJ ,QWKH SURFHVV RI PRGHOLQJ WKH VHFRQGDU\ VWUXFWXUH ZDV VLPSOLILHG %($0 (OHPHQW ZDV XVHG WR VLPXODWH ODPHOOD EHDP VOLGLQJ VSULQJ ER[DQG VOLGLQJ VSULQJ &RQWURO VSULQJ ZDV VLPXODWHG E\ &20%,1 (OHPHQW 7KH FRQWDFW IULFWLRQ EHWZHHQ WKH VSULQJV DQG MRLVW EHDP ZDV VLPXODWHG E\ &217$& (OHPHQW $QG PXOWLSOLHU DOJRULWKP ZDV DGRSWHG)LJ ODPHOOD EHDP HGJH EHDP)LJXUH

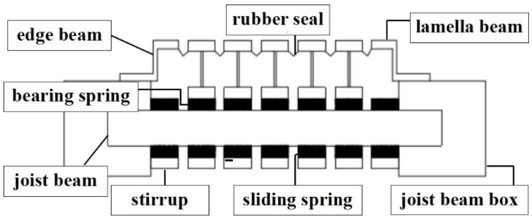

Fig. 2. Components of the modular expansion device

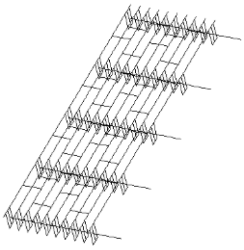
Fig. 3. Finite element model for modular expansion joints

Fig. 4. Section shape of Lamella beam, edge beam, joist beam.

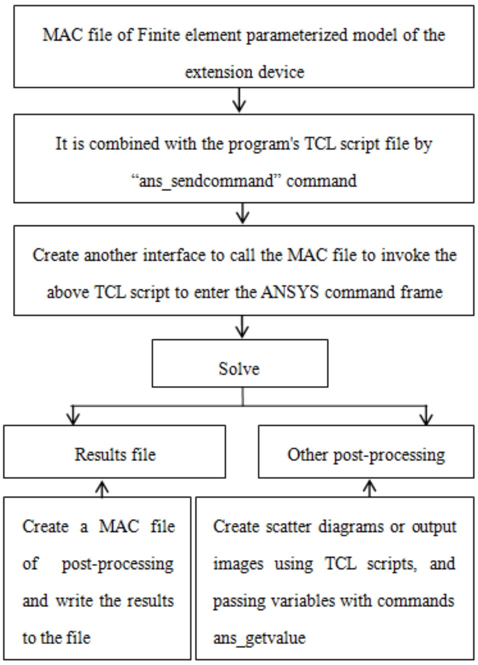

Fig. 5. Program block diagram

2QH HQG RI WKH MRLVW EHDP LV IL[HG DQG DOO GHJUHHV RI IUHHGRP DUH FRQVWUDLQHG WKH RWKHU HQG DOO GHJUHHV RI IUHHGRP DUH FRQVWUDLQHG H[FHSW

B. Establish an interactive interface by TCL/TK

1) Overview of the program interface

8VLQJ WKH LQWHUDFWLRQ EHWZHHQ (OHPHQW 7KH FRQWDFW HVWDEOLVK WKH SURJUDP LQWHUIDFH LQWHUIDFH WKH PRGHO SDUDPHWHUV /DQJXDJH WKH ILQLWH HOHPHQW DQDO\VLV FD 3DUDPHWHU FDQ EH DVVLJQHG E\ /DEHO 7&/ VFULSW ILOH WKH 3ODFH FRPPDQG ORFDWLRQ ZLGWK DQG KHLJKW RI H IRQW ZLWK WKH 6HW DQG)RQW FRPPDQG XVHG LQ WKH LQWHUIDFH $16<6 DUH $QV_VHQGFRPPDQG ZKLFK FD $16<6 LQWR 7&/ $QV_JHWYDOXH ZKL SURFHVVLQJ WR SDVV YDULDEOHV IU SRVWSURFHVVLQJ VHFWLRQ JLYHQ WKH RXWSXW GRHV QRW FXPEHUVRPH WKH 7;7 ILOH 7KH JUDSKLFDO RXWSX GRFXPHQW EXW XVLQJ WKH %/7 FRQW GLDJUDP GLUHFWO\ 7KH SURJUDP EO)LJ

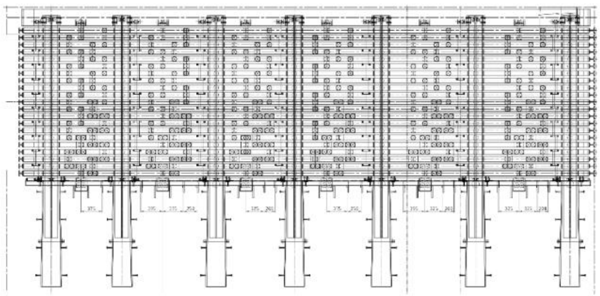
Fig. 6. Plan view of 22 gap joint with mageba elastic control system (Nanjing).

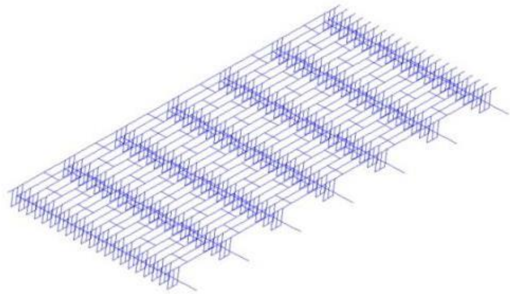
Fig. 7. Finite element model for modular expansion joints of some bridge in Korea

7KURXJK WKH SURJUDP XVHU FDQ FXVWRP VL]H RI WKH PRGHO FRQGLWLRQV DQG ORDGV RI SRVWSURFHVVLQJ UHVXOWV DUH REWDL WKH ; GHIRUPDWLRQ ODPHOOD EHDP DQG MRLVW EHDP &RPSUHVVLRQ GHIRUPDW VOLGLQJ VSULQJV 6KRZ WKH RYHUD 0LVHV 6WUHVV RI EHDP 9RQ 0LVHV 6W /DPHOOD EHDP ZKHQ FRQWDFW HOHPH 7KH IRUFH RQ WKH FRQWURO VSULQJ SRVWSURFHVVLQJ LQIRUPDWLRQ D DQG VWRUHG LQ WH[W ILOHV

2) Example

)RU WKH PRGXODU H[SDQVLRQ MRLQW VHFRQG ORDG FRQGLWLRQ WKH H[SDQVLRQ JDS

/DPHOOD EHDPV 7KH GLVWDQFH RI
and RI WKH /DPHOOD EHPHWHUV 7K
FRQWURO VSULQJ LV H DQG WKH
HOHPHQW LV 7KH VHFWLRQ UDGLXV RI WKH
7KH YHUWLFDO ORDG RI WKH EULGJH LV
KRUL]RQWDO GLVSODFHPHQW ORDG LV
$IWHU FOLFNLQJ WKH FRQWURO GHIRUPDWLRQ RI /DPHOOD
EHDP EXWWRQ WKH SURJUDP ZLOO GUDZ WKH KRUL]RQWDO
GLVSODFHPHQW FXUYH RI WKH FXUUHQW PRGHO DXWRPDWLFDOO\
[-FRRUGLQDWH RI WKH FXUYH LV WKH
DQG WKH RUGLQDWH RI WKH FXUYH LV WKH KRUL]RQWDO
GLVSODFHPHQW RI 0LQXV LQGLFDWHV WKH
GLUHFWLRQ RI WKH KRUL]RQWDO GLVSODFHPHQW LV WKH
PRYLQJ WRZDUGV WKH VOLGLQJ HQG
GLVSODFHPHQW RI /DPHOOD EHDP
/DPHOOD EHDP LQYROYHG LQ WKH ZRUN
$IWHU FOLFNLQJ WKH 9RQ 0LVHV 6WUHVV EHDP
EXWWRQ WKH SURJUDP ZLOO GLVSOD\ WKH VKDSH RI WKH
HQWLUH PRGHO DQG WKH 9RQ 0LVHV 6WUHVV RI WKH
PRGHO DXWRPDWLFDOO\ 7KH 9RQ 0LVHV /DPHOOD
EHDP LVH 3D PXFK OHVV WKDQ LWV \LHOG VWU

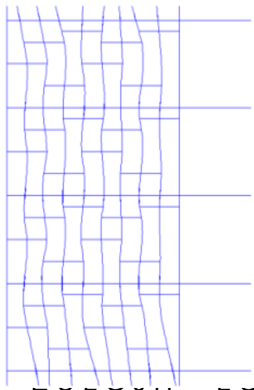

Fig. 9. Too large stiffness of control spring

III. THE PARAMETERS THAT MAY CAUSE THE DISEASE OF THE MODULAR EXPANSION DEVICE WERE ANALYZED BY FINITE ELEMENT METHOD

7KH IROORZLQJ DQDO\VLV GRHV QRW X GXODU
H[SDQVLRQ GHYLFH PRGHO RI WKH .RUHDQ LQVWHDG D
VLPSOH ILQLWH HOHPHQW PRGHO LV HVWDEOLVKHG IRU DQDO\VLV
7KHUH DUH MRLVW EHDPV DQG /DPHOOD EHDPV 7KH GLVWDQFH
RI WKH MRLVW EHDPV RI WKH /DPHOOD EHDPV LV
PHWHUV 7KH VWLIIQHVV RI WKH
IULFWLRQ FRHIILFLHQW RI FRQWDFW HOHPHQW LV
UDGLXV RI WKH VOLGLQJ VSULQJV DUH
WKH EULGJH LV WKH KRUL]RQWDO
KRUL]RQWDO GLVSODFHPHQW ORDG LV
HQG WR IL[HG HQG

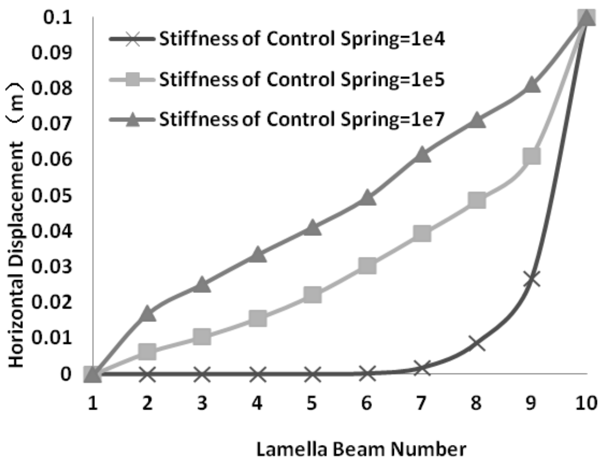

Fig. 8. Horizontal displacement curve of lamella under different stiffness of control spring

A. Stiffness of the Control Spring

:KHQ WKH VKULQNDJH RI WKH H[SDQVLRQ GHYLFH LV
WKH GLVSODFHPHQW RI WKH ODPHOOD EHDPV JUDGXDOO\ LQFUHDVHV
XQHYHQO\ IURP WKH IL[HG HQG WR WKH VOLGLQJ HQG :KHQ WKH
VWLIIQHVV RI WKH FRQWURO VSULQJ LV H DQG WKH
GHIRUPDWLRQ RI FRQWURO VSULQJ
FRQWURO VSULQJ QHDU WKH VOLGLQJ
GDPDJH $V VKRZQ LQ)LJ WKH VWLIIQHVV
FRQWURO VSULQJ LV VPDOO DQG WKH
HDVLO\ REVHUYHG $QG ZLWK
VSULQJ VWLIIQHVV WKH JUHDWHU
RI WKH ODPHOOD EHDPV +RZHYHU ZKHQ WKH
FRQWURO VSULQJ LV SDUWLFXODU
GLVSODFHPHQW DQG WKH KRUL]RQWDO
DUH VLJQLILFDQWO\ LQFUHDVHG DV
7KH HIIHFW RI WKH GHVLJQ RI GLIIHUHQ
H[SDQVLRQ GHYLFH 7KH VWLIIQHVV RI
FRQWURO VSULQJ LV H DQG WKH
VSULQJ LV WKH KRUL]RQWDO VWLIIQHVV RI
HDFK FDQ EH VHOHFWHG E\ FRQVLG
WKH FRQWURO VSULQJ DQG WKH GH

B. Uneven Arrangement of the Control Springs

$V PHQWLRQHG DERYH ZKHQ WKH
XQHYHQ arranged WKH GLVSODFHPHQW RI WK
XQHYHQ VKRZV WKH FKDQJH RI
GLVSODFHPHQW RI WKH ODPHOOD
VSULQJV DUH XQHYHQ DUUDQJHG
DUH DUUDQJHG XQHYHQO\ 7KH QXP
IURP IL[HG HQG WR VOLGLQJ HQG L
VWLIIQHVV RI WKDW GHFUHDVH JU
ODPHOOD EHDPV DUH ZRUNLQJ

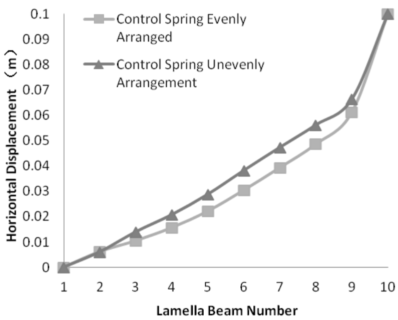

Fig. 10. Horizontal displacement curve of lamella under Uneven arrangement of control spring

C. Friction Coefficient of Contact Element (MU)

$V VKRZQ LQ)LJ WKH IULFWLRQ FRHIILFLHQW RI FRQWDFW HOHPHQW YDULHV ZLWK WKH KRUL]RQWDO GLVSODFHPHQW RI /DPHOOD EHDP WKH decrease WKH IULFWLRQ FRHIILFLHQW RI FRQWDFW HOHPHQW 08 /DPHOOD EHDP GLVSODFHPHQW RI ZLOO LQFUHDVH 7KH VPDOOHU coefficient WKH VPDOOHU WKH IULFWLRQ DQG OHVV VWDWLF IULFWLRQ GLVSODFHPHQW RI /DPHOOD 7KHUHIRUH WKH KRUL]RQWDO GLVSODFHPHQW LV VHQVLWLYH WR WKH FKDQJH RI IULFWLRQ FRHIILFLHQW 0

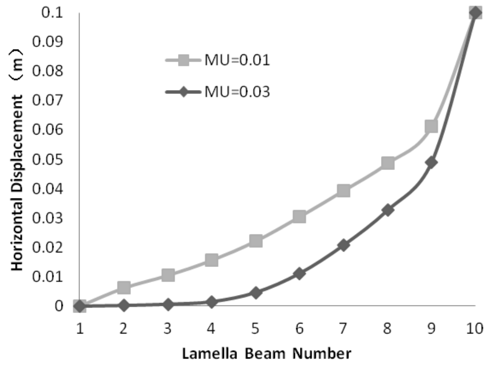

Fig. 11. Horizontal displacement curve of lamella under different MU

D. Pre-tightening Force

)LJ VKRZV WKH FKDQJH RI KRUL]RQWDO GLVSODFHPHQW RI /DPHOOD EHDPV ZLWK GLIIHUHQW SUH-WLJKWHQLQJ IRUFH :KHQ WKH SUH-WLJKWHQLQJ IRUFH EHFRPHV ODUJHU the UHDFWLRQ UHVLVWDQFH RI /DPHOOD LQFUHDVHV DQG WKH KRUL]RQWDO GLVSODFHPHQW GHFUHDVHV 7KHUHIRUH WKH SUH-WLJKWHQLQJ IRUFH KDV VRPH LQIOXHQFH RQ WKH KRUL]RQWDO GLVSODFHPHQW RI /DPHOOD

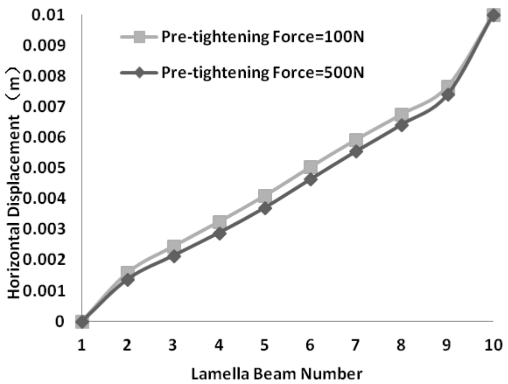

Fig. 12. Horizontal displacement curve of lamella under different pre-tightening force

E. Stiffness of Sliding Springs

)LJ VKRZV WKH FKDQJH RI KRUL]RQWDO GLVSODFHPHQW RI /DPHOOD EHDP ZLWK GLIIHUHQW VWLIIQHVV RI VOLGLQJ VSULQJV 7KH KRUL]RQWDO GLVSODFHPHQW RI /DPHOOD EHDP LV YHU\ ODUJH ZKHQ WKH VWLIIQHVV RI VSULQJ LV VPDOO ,Q WKH FDVH RI DSSO\LQJ SUH-WLJKWHQLQJ IRUFH WKH VPDOOHU WKH VWLIIQHVV RI VOLGLQJ VSULQJV Increased WKH VWLIIQHVV RI WKH VSULQJ ZLOO LQFUHDVH WKH IULFWLRQ VWLIIQHVV WKH KRUL]RQWDO GLVSODFHPHQW GHFUHDVHV DQG WKH KRUL]RQWDO GLVSODFHPHQW LQFUHDVHV $V D UHVXOW WKH VWLIIQHVV VSULQJ LV YHU\ LPSRUWDQW WR WKH KRUL]RQWDO GLVSODFHPHQW RI 'XULQJ FRQVWUXFWLRQ WKH SUH-WLJKWHQLQJ IRUFH LV DSSOLHG

E\ WLJKWHQLQJ WKH VWLIIQHVV RI VSULQJ LV VXFK D OLQHDU VSULQJ 7KHUHIRUH WKH VWLIIQHVV RI VSULQJ EHDULQJ KDV OLWWOH LQIOXHQFH RQ WKH KRUL]RQWDO GLVSODFHPHQW RI /DPHOOD +RZHYHU WKH LQWHUDFWLRQ RI WKH VSULQJ DQG WKH VWLIIQHVV RI WKH VOLGLQJ VSULQJ VKRXOG EH HQVXUHG WR SUHYHQW WKH LPSDFW RI disengagement WKH ORDG FDQ QRW EH WUDQVIHUUHG WR WKH YHKLFOH

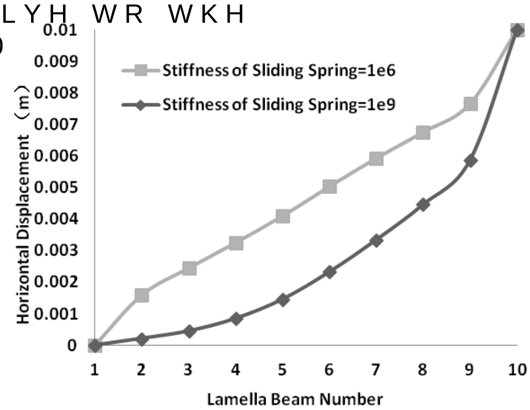

Fig. 13. Horizontal displacement curve in different stiffness of sliding spring

F. Analysis of the Most Important Position of the Bearing Spring

5HPRYH WKH FRQWDFW HOHPHQWV E\ RQH WKH FKDQJH RI 9RQ 0LVHV VWUHVV RI /DPHOOD EHDPV DUH DQDO\]HG WR ILQG RXW WKH PRVW LPSRUWDQW ORFDWLRQ RI VSULQJ EHDULQJ ZKLFK WKH DIIHFWV /DPHOOD EHDP PRVW

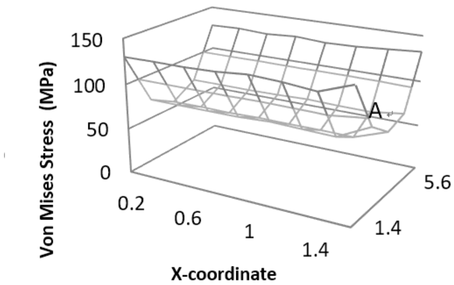

Fig. 14. Maximum Von Mises stress of lamella when delete the contact element one by one

)LJ VKRZV 9RQ 0LVHV VWUHVV RI /DPHOOD EHDPV ZKHQ WKH FRQWDFW HOHPHQW UHPRYHG :KHQ EHLQJ WKH FRQWDFW element QHDU WKH ERWWRP RI WKH ODPHOOD UHPRYHG L H VLPXODWLQJ WKH IDLOXUH RI WKH EHDULQJ 0LVHV VWUHVV RI /DPHOOD EHDP LV PD[LPXP 7KH EHDULQJ VSULQJ ZKLFK KDV WKH PD[LPXP 9RQ 0LVHV VWUHVV RI /DPHOOD EHDPV ORFDWHG QHDU SRLQW $)LJ VKRZV WKH)1 VSULQJ EHDULQJ 6OLGLQJ EHDULQJ VSULQJ ZKLFK VXEMHFWHG WR WKH YHUWLFDO ORDG RI WKH FORVH WR WKH VOLGLQJ VSULQJ)6 RI WKH EHDULQJ 7KH VKHDU GLVWULEXWLRQ RI /DPHOOD LV EDVLFDOO\ FRQVLVWHQW ZLWK WKH /DPHOOD 7KH EHDULQJ XQGHU WKH PD[LPXP YHUWLFDO ORDG Ground XQGHU WKH PD[LPXP YHUWLFDO IRUFH WKH EHDULQJ VSULQJ LV WKH PRVW LPSRUWDQW SRVLWLRQ RI WKH EHDULQJ VSULQJ ZKLFK ZLOO FDXVH WKH PD[LPXP 9RQ 0LVHV VWUHVV

/DPHOOD EHDPV QRW WKH VDPH SRVLWLRQ VSULQJ WKDW WKH VWUHVV LV EXW ERWK DUH FORVH WR WKH VOLGLQJ HQG

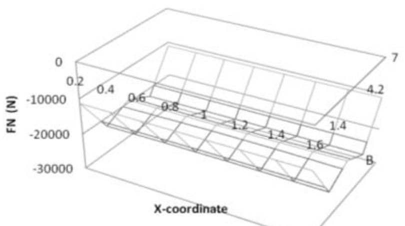

Fig. 15. FN of sliding spring

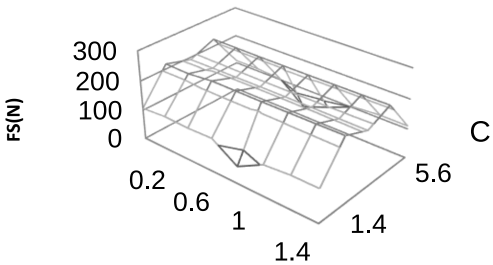

Fig. 16. FS of sliding spring

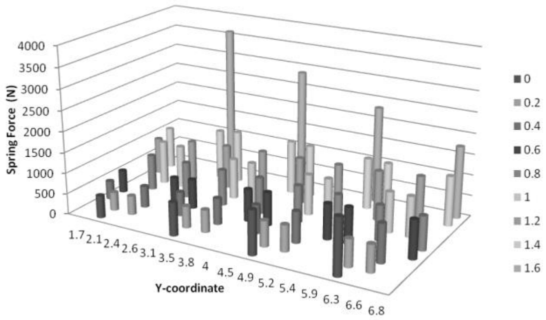

Fig. 17. Spring force of control spring

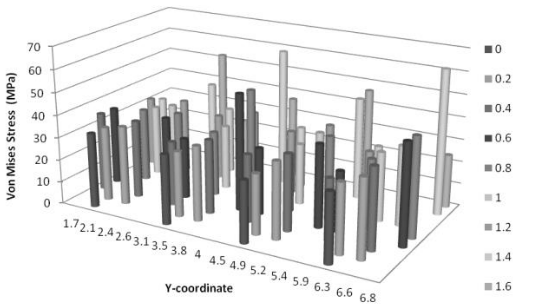

Fig. 18. Maximal von mises stress of lamella when remove the control spring one by one

G. Analysis of the Most Important Position of the Control Spring

$V VKRZQ LQ)LJ WKH VSULQJ IRUFH RI WKH FRQWURO VSULQJ LV WKH ODUJHVW the FORVHVW WR WKH VOLGLQJ HQG

)LJ VKRZV WKH springs WKH FRQWURO VSULQJ LV UHPRYHG /DPHOOD EHDP

FRQWURO VSULQJ LV UHPRYHG WKH VWUHVV RI ODPHOOD EHDPV LQ WKH VDPH SRVLWLRQ VSULQJ VWUHVV LV ORFDWHG DW WKH H[SDQVLRQ GHYLFH 0LVHV VWUHVV RI ODPHOOD EHDP WKH H[SDQVLRQ GHYLFH

IV. Conclusion

,Q WKLV SDSHU possible FDXVHV RI WKH GLVHDVH RI WKH GHYLFH DUH VWXGLHG E\ SDUDPHWULF ILQLWH 7KH PDLQ FRQFOXVLRQV DUH DV IROORZ

7KH KRUL]RQWDO GLVSODFHPHQW VHQVLWLYH WR WKH VWLIIQHVV VSULQJ LV VHQVLWLYH WR IULFWLRQ SUHWLJKWHQLQJ IRUFH VOLGLQJ VSULQJ force VR LW DOVR KDV DQ LQIOXHQFH GLVSODFHPHQW RI D EHDP

7KH VWLIIQHVV RI FRQWURO VSULQJ H[SDQVLRQ GHYLFH VWUHVV WKH /DPHOOD EHDP KLJKHU WKH VSULQJ VWLIIQHVV WKH VSULQJ LV QRW HYHQO\ DUUDQJHG GLVSODFHPHQW RI WKH EHDP

7KH smaller WKH IULFWLRQ SUHPDWXUH IDLOXUH RI WKH VOLGLQJ VSULQJ DOVR EH FRQWURO IURP VOLSSLQJ DZD\

7KH PRVW LPSRUWDQW VSULQJ WKH PRGXODU H[SDQVLRQ GHYLFH VOLGLQJ HQG 7KDW LV VSULQJ VSULQJV QHDU WKH VOLGLQJ HQG DUH PRUH OLNHO\ DQG WKH GDPDJH KDV D JUHDW LPSDFW

Acknowledgment

7KLV VWXG\ ZDV IXQGHG E\ 1DWLRQDO 3URJUDP RI &KLQD <DQG 7UDQVSRUW UHVHDUFK SURMHFW DW -LDQJVX 7

References

[1] *Control Systems of Modular Expansion Joints* 7HFKQLFDO UHSRUW 0DJHED /WG

[2] *Mageba Modular Expansion Joints - The Benchmark for Large Movements* 7HFKQLFDO UHSRUW RI 0DJHED /WG

[3] 7KRPDV 6SXOHU *Proc. 34th IABSE Symposium,* 9HQLFH ,WDO\

[4] < +XDQJ 6WXG\ RQ SHUIRUPDQFH HYDOXDWLRQ

[5] = /L 6WXG\ RQ WKH GLVHDVH PHFKDQLVP RI PRGXODU *Urban Roads Bridges and Flood Control* SS -XO\

[6] =)6XQ + :DQJ *Highway Engineering* YRO QR SS

[7] = 2 + :HL < &KHQ $QDO\VLV RI IDWLJXH *Journal of South China University of Technology* YRO QR SS

[8] % Coelho $ + - 0 9HUY XUW 3HHDQ6 /HHQGHUQDW]PLFV RI PRGXODU H[SDQVLRQ 1LMKRII G-JH *Engineering Structures* S

[9] *JTG B01-2014* Technical *Standards for Highway Engineering* 3HRSOH V WUDQVSRUWDWLRQ SUHVV

[10] '% 7 ² 2016 *Maintenance and Replacement of Highway Bridge Expansion Equipment* 3HRSOH V 7UDQVSRUWDWLRQ

[11] *DPH FUHDWLRQ *Parametric Finite Element Analysis Technique and Its Application Examples* %HLMLQJ :DWHU &KLQD &RQVHFU YDQG 3RZHU 3UHVV

[12] - .2XVWHUKRXW DQG <= DQJ *Tdl / Tk Portal Classic* 6HFRQG (GLWLRQ 7VLQJKXD 8QLYHUVLW\ 3UHVV

[13] = D. Chang ' ;XHDQG 4:DQJ 'LVHDVH DQG SUHYHQWLRQ PHDVXUHV RI PRGXODU H[SDQVLRQ MRLQW *Shanxi Architecture* QR SS-

[14] - %DQJ $ EULHI GLVFXVVLRQ RQ WKH GDPDJH DQDO\VLV DQG PDLQWHQDQFH WHFKQRORJ\ RI H[SDQVLRQ MRLQWV RI EULGJH *Science and Technology Horizon* QR SS-

[15] ; 0LQ. <XHSLQJ' +HDQG +=KRX ([SHULPHQW UHVHDUFK RQ SHUIRUPDQFH RI GLVSODFHPHQW PRGXODU H[SDQVLRQ *Highway Traffic Technology (Application Technology Version)* YRO QR SS-

[16] ; 0LQ 3 Huang ' ' +HDQG +=KRX ([SHULPHQW VWXG\ RQ SHUIRUPDQFH RI FRQQHFWLRQ RI PRGXODU H[SDQVLRQ *Modern Transportation Technology* YRO QR SS-

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